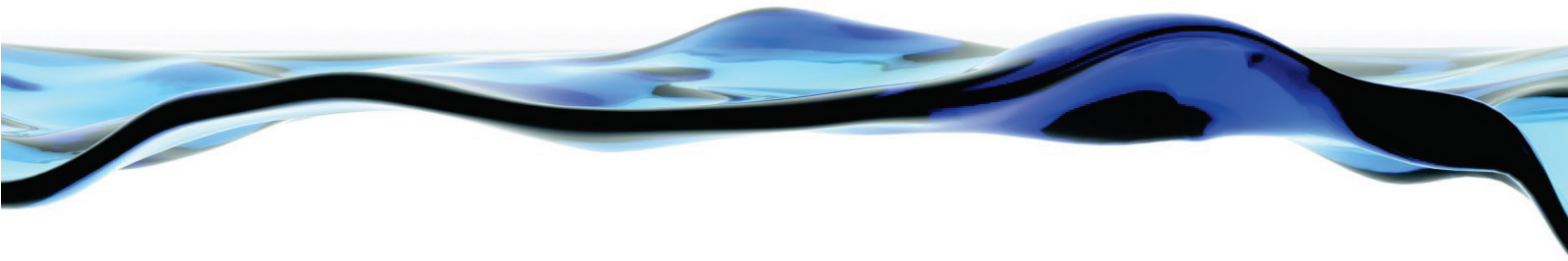
Analysis of South Australia’s environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan

Pollino CA, Lester RE, Podger GM, Black D and Overton IC



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Preface

The *Water Act (2007)* requires the Murray–Darling Basin Authority (MDBA) 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 was a first step in this process and a major milestone for water management in Australia.

Within the Guide, the MDBA described scenarios that could meet the environmental water requirements for the Basin. 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, 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. The science review was undertaken by CSIRO as a member of the Goyder Institute.

This report is one of several prepared as a part of the science review. Key findings from this and other related reports have been synthesized and released in 'A science review of the implications for South Australia of the Guide to the proposed Basin Plan: synthesis' (CSIRO, 2011).

Terms of reference

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 Expert Reference Groups as agreed with the South Australian Government's 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.

Assessment region

The review has been confined to the South Australian portion of the Murray-Darling Basin. The EWR assessment is made against two key environmental assets, Riverland-Chowilla and the Coorong, Lower Lakes, and Murray Mouth (CLLMM); and three key ecosystem function sites (SA Border, Morgan and Wellington). The water quality and salinity assessments consider several sites down the River Murray and the assessment of environmental water delivery considers sources upstream of the South Australian border.

The operation of regulators or locks in manipulating water levels of Riverland–Chowilla has not been considered in this review. As this asset is a hydrologic indicator site, the provision of flows is intended to meet the South Australian environmental water requirements in their entirety, not just localised requirements.

Scenarios

Five scenarios were provided by the MDBA – without development, baseline, and three Guide (3000GL, 3500GL and 4000GL) scenarios. These are described on the Terms and abbreviations page.

Models and model data from the Murray–Darling Basin Authority

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.

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 22 January 2011 and are the basis for the analysis of daily flows as required for the assessment of EWRs and water quality. Only the model that represents the South Australian River Murray, i.e. MDBA's MSM-BigMod model, for the five scenarios listed above, was made available. This restricted the analyses 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.

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.

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 incongruent, i.e. annual and mean 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.

Companion reports

This report is one of five reports from the project, the others are:

- A science review of the implications for South Australia of the Guide to the proposed Basin Plan: synthesis (CSIRO, 2011)
- Synthesis review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth (Maltby E and Black D, 2011)
- Socioeconomic implications of the Guide to the proposed Basin Plan – methods and results overview (Connor JD, Bannerjee O, Kandulu J, Bark RH and King D (2011)
- A compilation of reports informing a socioeconomic assessment of the Guide to the proposed Basin Plan. (Connor J (ed.), 2011)

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
spells	a time-series analysis of flows, used to determine the frequency of occurrence of an event in a daily flow series such as the frequency of event requirements in environmental water requirements
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, 2010a; 2010b)
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.

Structure of this report

This report contains much of the background review and analyses conducted to underpin the environmental and water quality and delivery components of the science review and meet the terms of reference. The content and scope of the parts reflects the project structure and are based on the information and data available at the time of their writing (October to December 2010). The reports have been peer-reviewed and are:

- Part I – Environmental water requirements
- Part II – Water quality and salinity
- Part III – Delivery of a flow regime to meet South Australia's environmental water requirements.

Parts I and III – 'Environmental water requirements' and 'Delivery of environmental water requirements' – focus on the two key South Australian environmental assets, namely Riverland–Chowilla and the Coorong, Lower Lakes and Murray Mouth (CLLMM). 'Environmental water requirements' describes the determination of the most suitable environmental water requirements (EWRs) for South Australia, for comparison with those determined by the Murray–Darling Basin Authority (MDBA) as published in the Guide; and the consistency criteria on which to base that comparison for South Australia. It contains a review of the MDBA approach to determining EWRs, a review of relevant literature to establish the EWRs for analysis, and then an assessment of how those EWRs are met under the scenarios described in the Guide (for descriptions of those scenarios see Terms and abbreviations).

While the major component of the project focussed on the implications of the Guide on meeting South Australia's environmental water requirements, water quality and salinity were also considered. A review of targets and assessment of impact is reported in Part II 'Water quality and salinity'.

In addition to reviewing the Guide, the project team undertook additional modelling to determine the volume and pattern of delivery of flow to meet SA's EWRs. For this purpose optimised daily flows were developed (two each for the Riverland-Chowilla and CLLMM). This work is described in Part III 'Delivery of a flow regime to meet South Australia's environmental water requirements'.

Acknowledgements

The authors would like to acknowledge the significant role of other members of the project team in providing the material for this report:

- Linda Merrin for data analysis and reporting in Part I
- Donna Hughes for model execution, analysis and reporting in Part III.

Contents

Part I – Environmental water requirements

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1 Introduction

The content of this Part is drawn from a series of papers which were written to fulfil the progressive reporting requirements of the environmental components of the science review and covers:

- key messages from the assessment, taken from the Synthesis Report
- a description of the treatment of environmental water requirements (EWRs) in the Guide (Chapter 2)
- a review of EWRs that have been defined for key environmental asset sites in South Australia, and assessment of these against modelled without-development and baseline data (from the CSIRO Murray-Darling Basin Sustainable Yields Project) (Chapter 3)
- an assessment of EWRs against the Guide modelled data (Chapter 4).

1.1 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 1.1 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 under the different models

	MDBA EWRs			SA EWRs		
Data source	Scenario					
	3000	3500	4000	3000	3500	4000
Riverland–Chowilla						
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*						
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 .

- Key ecosystem function metrics
    - Metrics are rated as poor for low-flow season baseflow requirements for all sites and a loss of cease-to-flow requirements at Morgan. The remaining metrics show an improvement of ≥60% from the baseline. This outcome is the result of regulation of flows.

Table 1.2 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 The MDBA approach: environmental water requirements in the Guide to the proposed Basin Plan

The Guide to the proposed Basin Plan (MDBA, 2010a; 2010b) has been developed to address a history of overallocation in many regions of the Murray-Darling Basin. Consistent with the objectives of the *Water Act 2007*, a major component of the Guide is to determine environmentally sustainable levels of take (ESLT). The ESLT is defined in Section 4 of the *Water Act 2007* as:

> the level at which water can be taken from that water resource which, if exceeded, would compromise:
>
> (a) key environmental assets of the water resource; or
> (b) key ecosystem functions of the water resource; or
> (c) the productive base of the water resource; or
> (d) key environmental outcomes for the water resource.

As guided by the *Water Act 2007*, a subset of MDBA activities was to determine:

- the amount of water needed for the environment, known as the environmental water requirement (EWR), to protect, restore and provide for the ecological values and ecosystem services of the Basin and
- long-term average sustainable diversion limits (SDLs), which must not compromise key environmental assets (including water dependent ecosystems, ecosystem services and sites with ecological significance), key ecosystem functions, the productive base and key environmental outcomes for the water resource (MDBA, 2010b).

To determine EWRs, the MDBA went through a process of identifying water regime (volume, duration and timing) requirements for 106 hydrologic indicator sites, comprising of 18 key environmental assets and 88 key environmental functions in the Basin. The 18 asset sites were considered to be key hydrologic indicator sites for the 2442 assets identified in the Basin. Together, the function and asset sites are believed to be sufficiently representative to guide the determination of SDLs (MDBA, 2010b). The justification for this was the hydrologic connectivity and independence between key ecosystem functions and key environmental assets, as stated in the Guide (MDBA, 2010b, p. 90):

> … if sufficient water is provided for key ecosystem functions at one location it will be sufficient for those functions at many locations, both upstream and downstream. This same water will also provide for floodplain and wetland ecosystem functions associated with environmental assets, as well as contributing to the ecosystem functions associated with the rivers connecting the assets together. Moreover, this water will provide for the broader environmental water requirements of ecosystem services, the productive base, and the key environmental outcomes for the water resource.

In addressing the needs of inland water requirements, the MDBA suggest that the flow regimes required to sustain key ecosystem functions are typically the base and freshes flow components, while the overbank flows typically sustain key environmental assets (Figure 2.1).

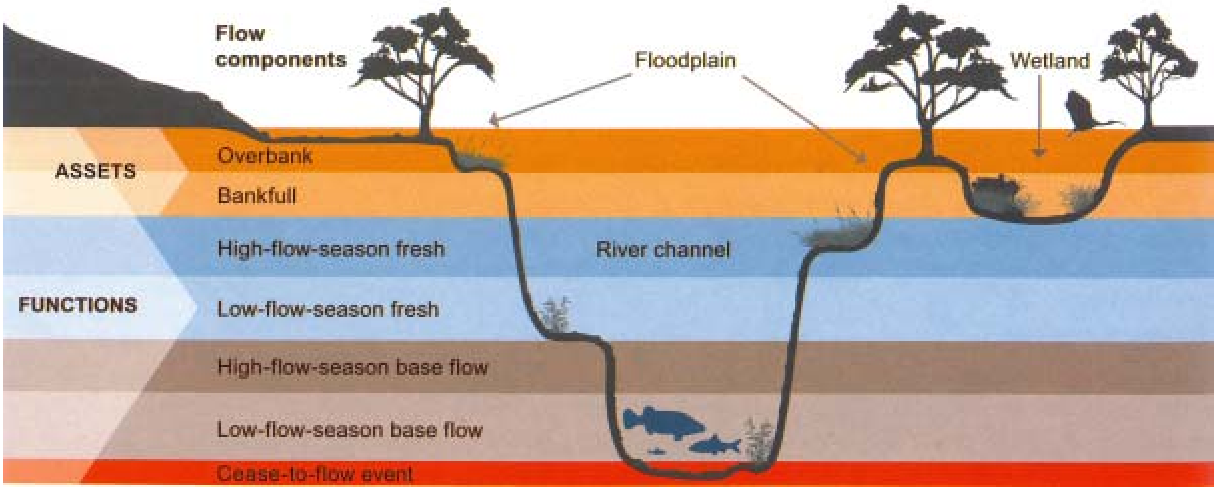

Figure 2.1 Range of flows relevant to asset and function requirements (sourced from MDBA, 2010b, p. 104)

The South Australian sites included by the MDBA in establishing SDLs are shown in Figure 2.2. Hydrologic indicator sites are:

- Asset sites
    - the Riverland–Chowilla
    - Coorong, Lower Lakes, and Murray Mouth (CLLMM).
- Ecosystem function sites (flow gauge stations)
    - Murray River upstream of the border (F59) (although this gauge site is not in SA, it is the most relevant gauge for the Riverland–Chowilla site)
    - Murray River downstream of Lock 3 (F60)
    - Murray River at Morgan (F61)
    - Murray River at Wellington (F62).

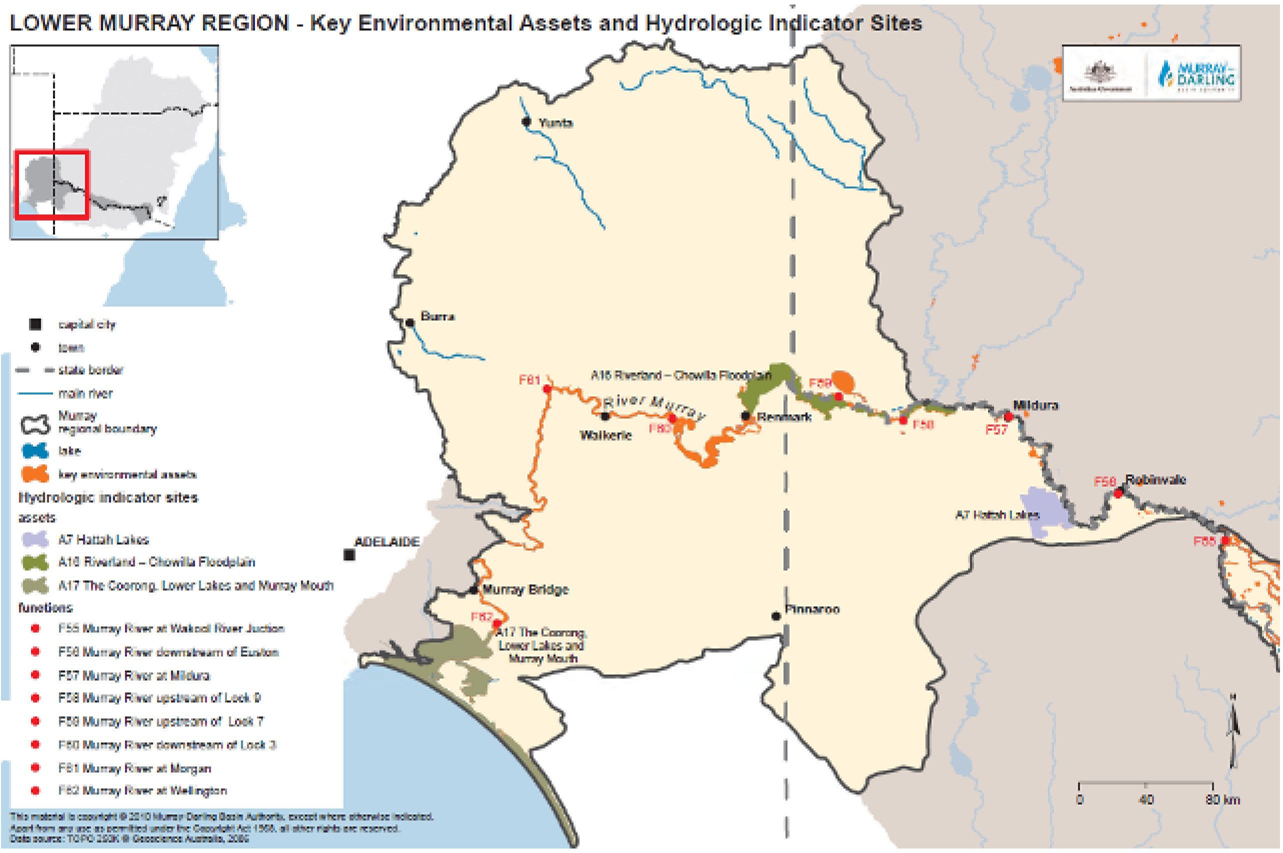

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Figure 2.2 Location of environmental indicator sites in the Lower Murray, including South Australia (MDBA, 2010c)

2.1 Hydrologic indicator sites: key environmental assets

The MDBA went through a process of identifying assets throughout the Basin, based on 5 criteria:

- Criterion 1: the water-dependent ecosystem is formally recognised in and/or is capable of supporting species listed in relevant international agreements.
- Criterion 2: the water-dependent ecosystem is natural, near natural, rare or unique.
- Criterion 3: the water-dependent ecosystem provides vital habitat.
- Criterion 4: the water-dependent ecosystem supports Commonwealth, state-, or territory-listed threatened species and/or ecological communities.
- Criterion 5: the water-dependent ecosystem supports or is capable of supporting significant biodiversity.

As previously stated, a total of 2442 assets were identified across the Basin from this process. From this, 18 hydrologic indicator sites were selected based on their representation of extent and nature of the floodplains and wetlands (MDBA, 2010b). For each hydrologic indicator site, a set of ecological targets were derived using a sequence of activities (Figure 2.3), which were aimed at delivering water to achieve maintenance of structure and function of environmental attributes for that site. The Guide states that meeting the targets will require a combination of flows, providing a range of depth and duration as part of a long-term flow regime.

Flow regime requirements were specified in terms of:

- a flow threshold or total flow volume
- the required duration for that flow threshold, or duration over which the volume should be delivered
- the required timing (seasonality) of the event (if important)
- the required frequency of events, given low and high uncertainty
- the level of groundwater dependency.

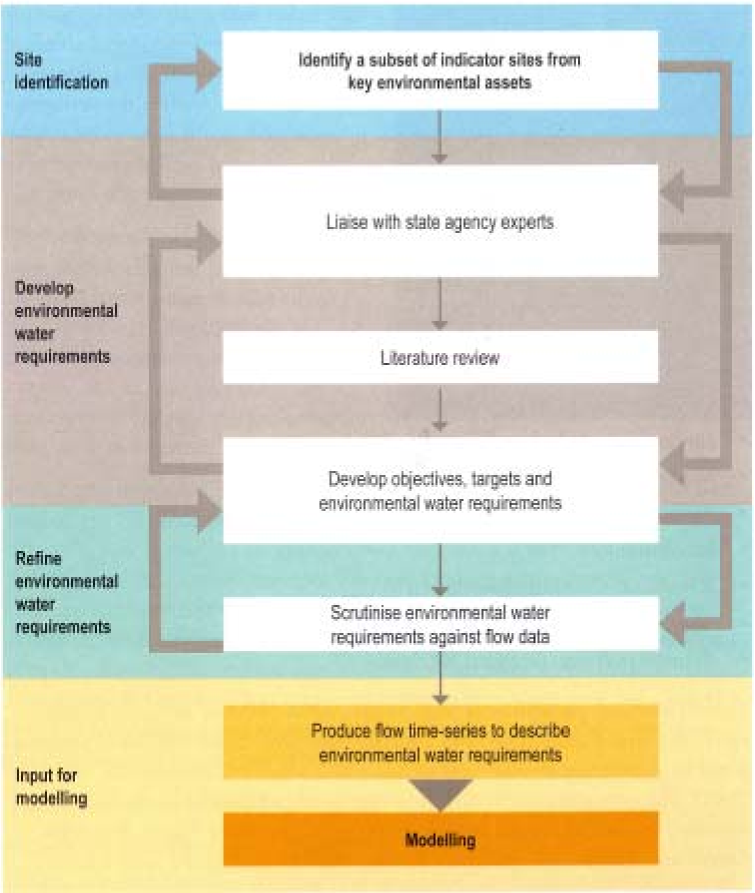

Figure 2.3 Sequence of activities for deriving EWRs, and the inputs to the first phase of modelling (from MDBA, 2010b, p. 95)

Using modelled current arrangement (baseline) flows, volumes of additional environmental water to meet flow requirements were quantified (MDBA, 2010b). eFlow Predictor (eWater Cooperative Research Centre) was used to quantify additional volumes, where the augmented flow was constrained to volumes that are without-development modelled flow, ensuring the augmented flows are physically achievable (MDBA, 2010b). A hypothetical example from the Guide is in Figure 2.4. 'Current arrangements' flows, or without-development flows are 'augmented' such that the event characteristics in EWRs are expressed. The part of the hydrograph where flows are augmented is done in reference to the without-development flow series.

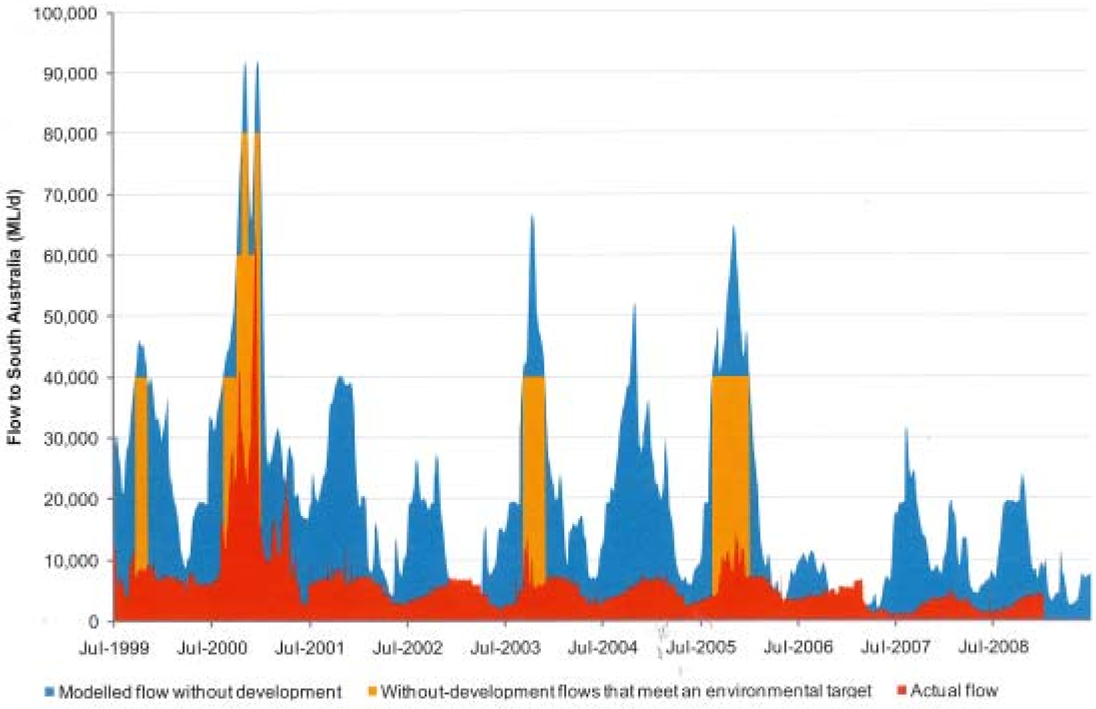

Figure 2.4 Potential environmental flow events for Riverland-Chowilla, which have been augmented using EWRS for this asset. Actual flow refers to observed flows (MDBA, 2010b, p. 494)

2.2 Hydrologic indicator sites: key ecosystem function

To establish regime requirements for ecosystem function, the MDBA specified four key ecosystem functions, which were assessed at 88 sites across the Basin:

- the creation and maintenance of habitats for use by plants and animals (including fish)
- the transportation and dilution of nutrients, organic matter and sediment (the building blocks for habitats)
- providing connections along rivers for migration and recolonisation by plants and animals (including fish)
- providing connections across floodplains, adjacent wetlands and billabongs for foraging, migration and recolonisation by plants and animals (including fish).

The flow components and metrics that were to be used in assessing key ecosystem functions are shown in Table 2.1. These sought to provide greater coverage of low-flow EWRs in the Basin, whilst supporting the high-flow EWRs of environmental assets. The relative change in metrics between without-development and current scenarios were being assessed at each of the sites. For the 88 indicator sites, a rating was given depending upon how different it was from the without-development (long-term average) flow regime used. The ratings are:

- 'good' – 80–100% of without-development flow
- 'moderate' – 60–80% of without-development flow
- 'poor'– less than 60% of without-development flow.

The basis for these ratings is that they were applied in the MDBA Sustainable Rivers Audit reporting (Davies et al., 2008), but no further justification of these are given. Arguably, the choice of categories can be regarded as arbitrary. For gauges rated as less than moderate, targets were to be established to achieve a 'moderate' rating.

Table 2.1 Seasonal metrics used for assessing ecosystem function (Alluvium, 2010)

Flow component	Flow metric	Measurement unit
Low flow season		
Base flow	flow rate equivalent to XB percentile flow based on non zero flows in season of interest	ML/day
Cease-to-flow	no. of years with at least one cease-to-flow spell	number (of years)
	average number of cease-to-flow spells per year	number (per year)
	average duration of cease-to-flow spells	number (of days)
Fresh Where a fresh is a flow that exceeds XF percentile flow based on non cease-to-flows in the season of interest	no. of years with at least one fresh	number (of years)
	average number freshes per season	nnmber (per season)
	average duration of freshes	number (of days)
High flow season		
Base flow	flow rate equivalent to XB percentile flow based on non zero flows in season of interest	ML/day
Cease-to-flow	no. of years with at least one cease-to-flow spell	number (of years)
	average number of cease-to-flow spells per year	Number (per year)
	average duration of cease-to-flow spells	Number (of days)
Fresh Where a fresh is a flow that exceeds XF percentile flow	no. of years with at least one fresh	Number (of years)
	average number freshes per season	Number (per season)
	Average duration of freshes	Number (of days)
Any season		
Bankfull	1.5 year ARI flow rate (based on a partial series analysis)	ML/day
Overbank	5 year ARI (based on partial series analysis)	ML/day
	SRA Seasonal Period Index	SP (seasonal period)

XB – 80th percentile and XF – 20th percentile

Other than documentation in the Guide and in a supporting report (Alluvium, 2010) the technical methods and outcomes for assessing key ecosystem functions have not been published by the MDBA.

2.3 Analysis methods used in the Guide

To determine SDLs, hydrological demands for hydrological indicators were to be specified using the Basin hydrological framework (Figure 2.5). This analysis gave an initial indication of the volume of additional water required by the environment. However, as stated in MDBA (2010b, p. 108):

> it became clear that these complex models are not well suited to exploring the range of environmental water requirements and various policy scenarios for setting SDLs in a timely way. An analytical tool that allowed this exploration was required.

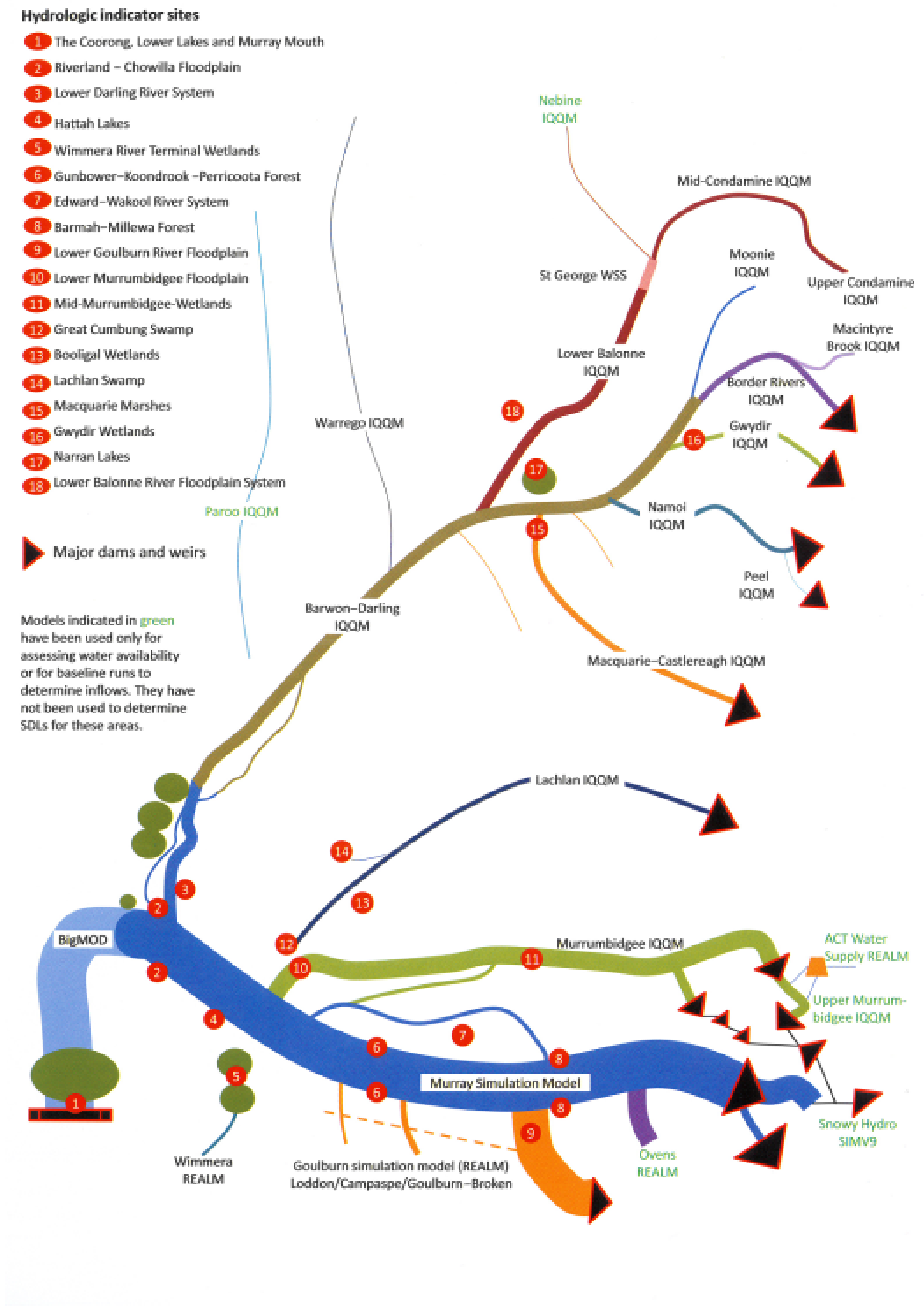

Figure 2.5 Hydrologic modelling framework, showing hydrologic indicator sites (MDBA, 2010b, p. 184)

The analytical tool used flow duration curves, and considered the end-of-system locations in each region, with an example shown here (Figure 2.6). For key ecosystem functions, targets were derived for achieving a minimum of a moderate rating and an upper limit for a good rating for each flow regime component (achieve at least 60% of the without-development value for minimum and 80% for upper limit). The logic for selection of 60 to 80% is not given.

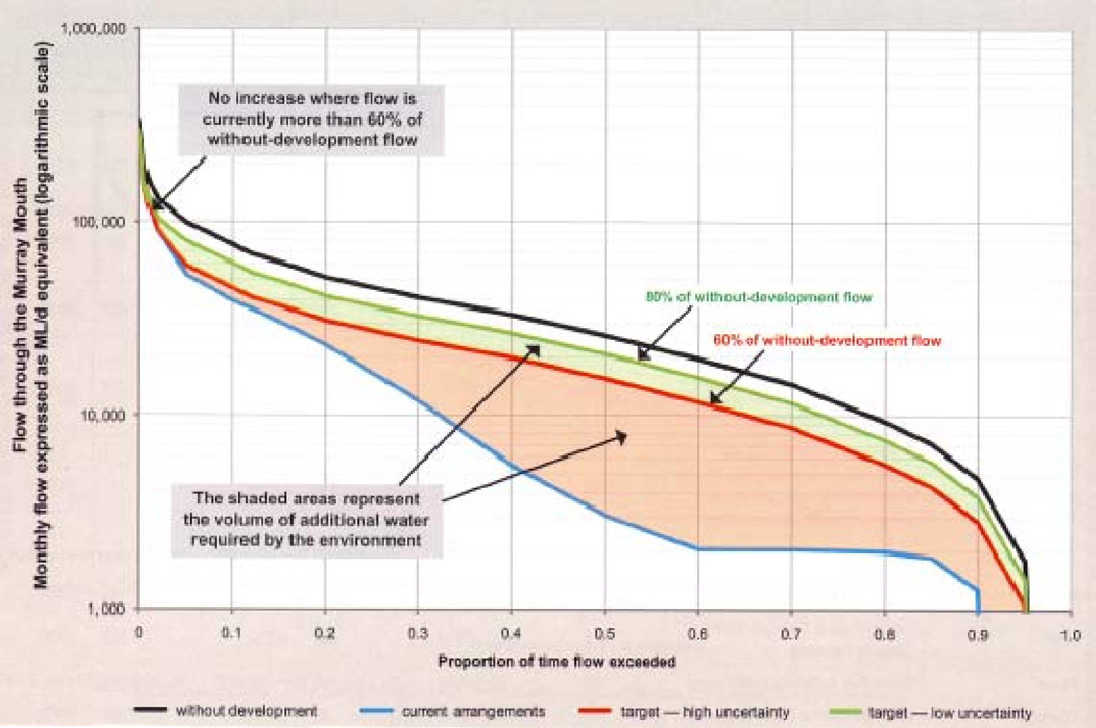

Figure 2.6 Flow duration curve for the River Murray at the barrages showing target range (MDBA, 2010b, p. 111)

Analyses showed that the range of surface water required to meet the requirements of the *Water Act 2007* was between 22,100 GL/year and 26,700 GL/year (long-term average), which is between 67% and 81% of the total available surface water under the historical climate scenario. To meet this range would require an additional volume of between 3658 GL/year and 6900 GL/year (long-term average) from the current diversion limits. In doing this, the Guide (MDBA, 2010b, p. 113) states:

> the approach outlined above is appropriate to determine the aggregate environmental water share; however, it should not be inferred that the Guide to the proposed Basin Plan recommends simply providing a fixed percentage of the without-development flow to the environment. Implementation of environmental watering requires adaptive management to accommodate priorities and opportunities, operational constraints, and mitigation of potential negative impacts (e.g. flooding of urban areas).

The assessment of meeting EWRs was made using the analytical tool, considering increase in water available to the environment of 3000 GL/year, 3500 GL/year and 4000 GL/year. These scenarios would meet the EWRs for the Basin, but with different levels of confidence and assumes a return to a wetter climate. It is later stated in the Guide (MDBA, 2010a, p. 125) that:

> modelling and other analysis undertaken to date indicates that it will not be possible to achieve these targets for all key environmental assets and key ecosystem functions, and consequently there will need to be some trade-offs in many regions.

A long-term average reduction of 7600 GL/year in diversions has a lower dependence on a return to wetter climatic conditions, and will provide greater resilience to the Basin's water-dependent ecosystems, including a full range of forecasts of reductions in surface-water availability due to climate change. The MDBA considers that the low-uncertainty end of the range would not optimise economic, social and environmental outcomes, and has therefore not invested as many resources in assessing confidence limits at this end of the range. However, the MDBA has indicated that the EWRs for key environmental assets and key ecosystem functions can be achieved with a low level of uncertainty with a Basin-wide reduction in diversions of about 7600 GL/year. This represents a confidence limit in the end-of-system flow analysis of about ±10% (how this was estimated is not described).

It is stated in the Guide that the EWRs for key environmental assets and key ecosystem functions can be achieved with a high level of uncertainty with a Basin-wide reduction in diversions of 3000 GL/year. The Guide also states that their best estimate for the end-of-system flow analysis represents the EWRs of the key environmental assets and key ecosystem functions with a confidence limit of about ±20% for the high-uncertainty target (how this was estimated is not described). It is concluded in the Guide (MDBA, 2010b, p. 113) that:

> Actual environmental watering will involve variable provision of water to the environment. In some years environmental watering priorities and opportunities (e.g. unregulated flow conditions, volumes in storage, availability of planned environmental water and allocations to held environmental water entitlements) may mean that provision of a high proportion of available water to the environment will be appropriate. In other years, owing to different priorities and water availability, the proportion provided to the environment will be less.

The use of the analytical tool for determining a percentage of without-development flow that will meet environmental targets is an assumption that has not been tested by the MDBA. Despite the scientific input into specific flow requirements for hydrologic indicator sites, the SDL has been based on a percentage of without-development flow driven by the assumptions of 60% achieving moderate and 80% achieving good conditions (Figure 2.6). The second assumption is that the accumulation of flow metrics for the assets can be simplified to a goal of 60% for high risk and 80% for low risk of achieving the without-development flows. Section 4 (Assessment of meeting environmental water requirements in South Australia) tests the validity of this assumption, assessing whether flow requirements of South Australian assets can are met under the Guide scenarios.

3 Environmental water requirements for South Australian asset sites

This chapter contains a review of environmental water requirements (EWRs) that have been defined for key environmental asset sites in South Australia, and assessment of these against modelled without-development and baseline data. When this chapter was written, the MDBA modelled Guide data had not been released. Consequently, the assessment component used the model data from CSIRO Murray-Darling Basin Sustainable Yields Project (CSIRO, 2008).

3.1 Riverland–Chowilla

In this section, the various EWRs for target communities are assessed in terms of their representativeness against without-development and baseline modelled flows. In this report, EWRs included in the assessment are those published in the Guide (MDBA, 2010a; 2010b), by the SA Government (DWLBC, 2010), and plans which have flow requirements specifically for this asset. These include reports by MDBC (2006a), Department of Environment and Heritage (2010), DWLBC (2010) and Ecological Associates (2010). The EWRs can be found in Appendix A to this Part. Whilst it is recognised that water levels are also an important aspect of management of this asset, particularly through the manipulation of locks, they are not dealt within this Part.

The ecological character of the Riverland–Chowilla asset is dominated by communities of black box, red gum, lignum, waterbirds and fish. The EWRs that have been established for the asset predominantly target these community types, and include targets for wetland inundation. In comparing EWRs, it is important to recognise that there are some slight differences in the representation of scale. The asset boundaries used in the Guide (MDBA, 2010b, p. 657) are shown below (Figure 3.1).

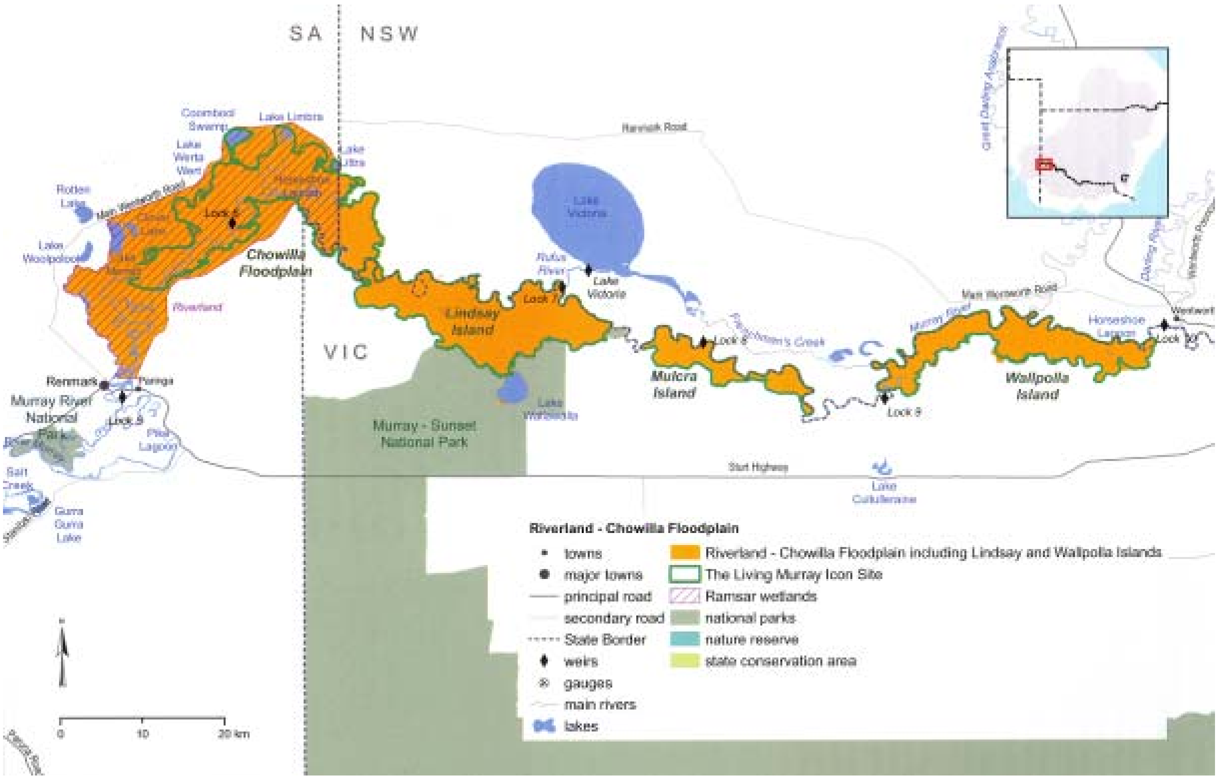

Figure 3.1 Map of the Riverland–Chowilla site (MDBA, 2010b, p. 657)

The Department of Environment and Heritage (2010) plan has a focus on maintaining character of Ramsar areas, and the boundary is limited to the Ramsar wetlands. The MDBC (2006a) icon site description focuses predominantly on Chowilla (Figure 3.1) and the Ecological Associates (2010) draft report considers the stretch of the River Murray from the SA border to Wellington. The DWLBC (2010) report focuses on the Chowilla/Riverland Ramsar site, which includes the reach from the South Australian border to Renmark, which is consistent with the focal area defined in the Guide.

The SA report (DWLBC, 2010) states that: ‘the preferred approach to setting EWRs is to use a functional, rather than site-based approach’, and draws upon the Ecological Associates (2010) draft report. Nonetheless, many of the targets and objectives are set at an asset scale. However, targets specific for provision of mosaic habitats are included. The Guide (MDBA, 2010a; 2010b) draws upon the Newall Ramsar Ecological Character Description prepared for the Ramsar site (Newall et al., 2009), with these targets being published in Department of Environment and Heritage (2010). Other inputs to the Guide are the icon site Environmental Management Plan (MDBC, 2006a), the Chowilla Creek Environmental regulator investment proposal (SAMDBNRMB, 2008) and an unpublished report by Cale (2009).

Comparing across planning documents, there are some variations in the selection of targets used for defining EWRs (Table 3.1) (that is, targets that have explicitly defined and quantified flow objectives). Vegetation indicators are common across all documents, with EWRs being defined for red gum forest and woodland and black box woodlands. Lignum maintenance targets were defined in all documents other than MDBA (2010b). EWRs for waterbirds are only defined in two of the documents. The MDBA (2010b) specify targets for maintenance of existing vegetation communities, rather than for reproductive and regenerative processes. Maintenance targets were adopted, as restoring or increasing the extent of communities would typically require land use change, which is outside the scope of the Basin Plan (*Water Act 2007,* s. 22(10)).

Table 3.1 List of target types specified in each planning document, with shading of box indicating target by source document

Target	MDBA[1]	SA[2]	EA[3]	EMP[4]	MDBC[5]
Wetland – holistic	■	■	■		
Red gum: maintenance	■	■	■	■	■
Red gum: regeneration, reproduction		■	■	■	
Black box: maintenance	■	■	■	■	■
Black box: regeneration, reproduction		■	■	■	
Lignum: maintenance		■	■	■	■
Lignum: regeneration, reproduction				■	
Chenopod / Samphire			■	■	
Aquatic veg: maintenance			■	■	
Aquatic veg:regeneration, reproduction			■		
Other vegetation				■	■
Waterbirds		■	■		
Fish		■	■		
Biofilms, organic matter			■		
Physical processes		■	■		

[1] MDBA, 2010b
[2] DWLBC, 2010
[3] Ecological Associates, 2010
[4] Department of Environment and Heritage, 2010
[5] MDBC, 2006a

The SA and Environmental Management Plan (EMP) EWRs are the most holistic in their representation. In the EMP, EWRs are specified for chenopods. These are a terrestrial species, and local rainfall is considered to be sufficient to meet water requirements, consequently their exclusion from the SA EWRs is understandable. The aquatic vegetation EWRs specified in the EMP are met by EWRs specified for other communities. This is also the case for fish communities in EMP and SA documents, in that the requirements are the same as those expressed for vegetation and wetland-scale water requirements.

The MDBA EWRs specified in the Guide are the most restrictive in scope and the least representative of the asset. In not defining lignum and waterbird water requirements, the Guide (MDBA, 2010b, p. 663) states the assumption that ‘flows specified for other targets will satisfy the water requirements for lignum and waterbird breeding’. Little evidence is presented in the Guide to support this statement. Although waterbirds and lignum are important ecological characteristics of the site, and are a criterion for listing of this asset under the 1971 Ramsar Convention, they are omitted. As assessed in the later parts of this Part, the duration of wetting for lignum and waterbirds are longer than that for red gum and black box communities (e.g. Roberts and Marston, 2000; Rogers and Ralph, 2010), and whilst flood volumes for inundation of vegetation communities overlap, duration requirements do not. All documents reference the RIM-FIM (River Murray Floodplain Inundation Model) study for defining flood volumes to inundate different vegetation communities (Overton et al., 2006) (Figure 3.2). The MDBA notes the modelling inconsistencies in the Guide (MDBA, 2010b, p. 661):

> further analysis and investigation as preliminary work undertaken by South Australian departmental staff indicates that flows specified to meet targets at the Riverland – Chowilla Floodplain hydrologic indicator site may not be sufficient to meet all downstream requirements based on interrogation of the River Murray Floodplain Inundation Model. However, this analysis also revealed inconsistencies between modelled floodplain inundation and modelled flows that are unresolved. Subsequently, where a discrepancy exists between the literature and floodplain inundation and hydrologic modelling, analysis of modelled without-development flows has been used to help determine environmental water requirements, particularly to ensure the recommended flows are achievable and not greater than without-development flows.

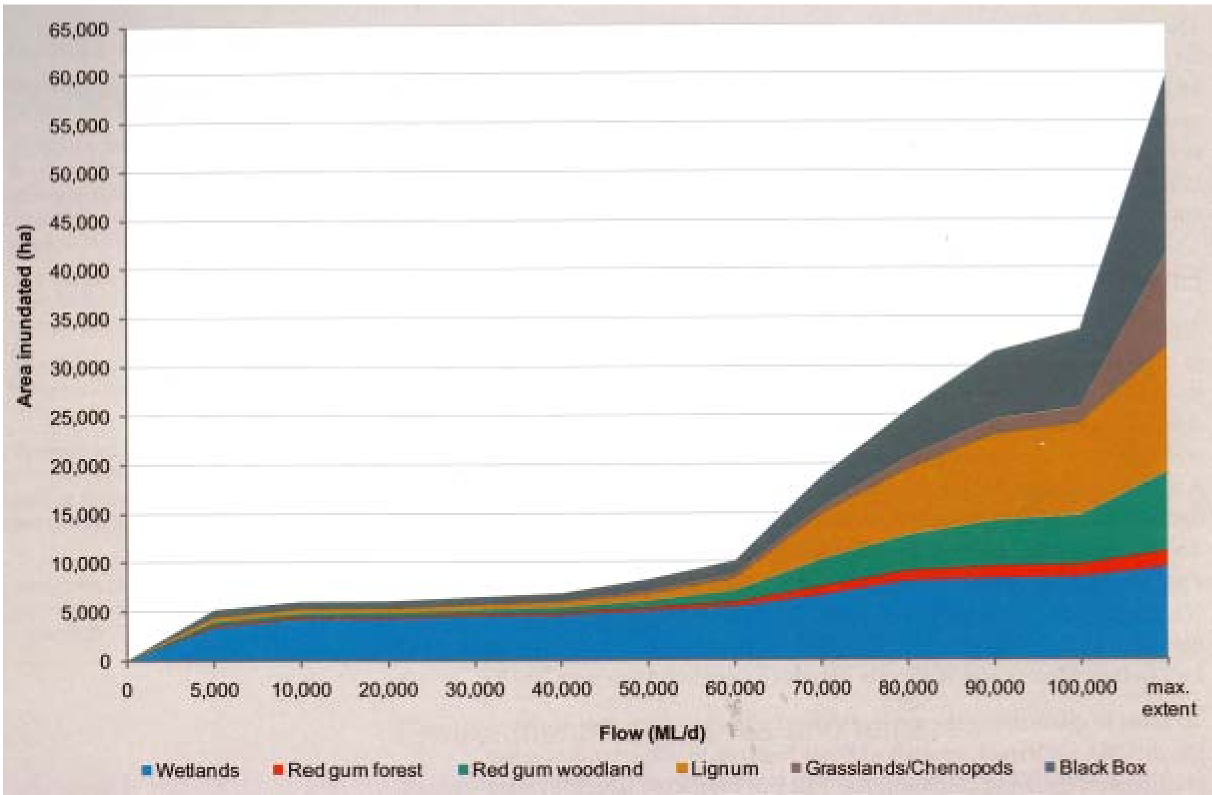

Figure 3.2 Flows required to inundate selected vegetation types between locks 6 and 9 (MDBA, 2010a modified from Overton et al., 2006)

In determining targets for vegetation communities, lignum make a substantial area of the Chowilla wetlands (Figure 3.3).

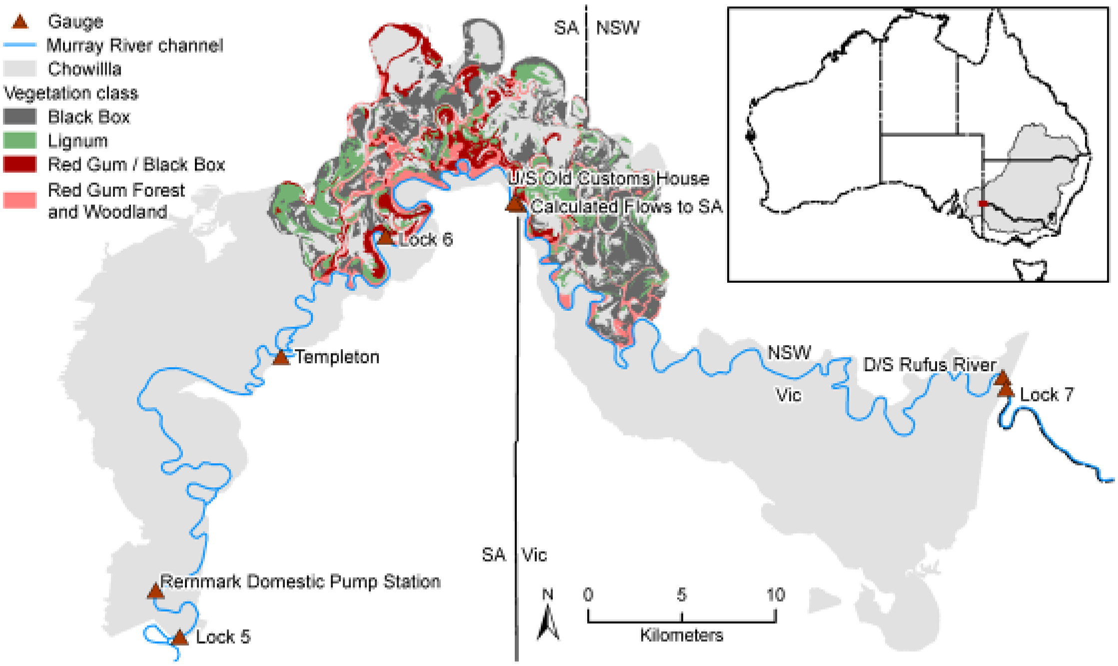

Figure 3.3 Spatial distribution of vegetation in Chowilla

3.1.1 Comparative analysis of published environmental watering requirements

To compare targets in the Guide to other plans using a technically consistent approach, two styles of comparisons are used: flow vs. duration and flow vs. frequency. EWR recommendations by target are documented in Tables in Appendix A.

The purpose of this chapter is to review EWRs and determine if these are reasonable for the Riverland–Chowilla. In doing so, specific information on the water requirements of Riverland–Chowilla communities to meet planning purposes is not provided beyond that reviewed below. The EWRs (specifically duration and frequency) for different communities are drawn from data that are not necessarily specific to that community in Riverland–Chowilla, as very little of these data exist within the literature. This assumption adds some uncertainty to EWRs, and the recommendations herein. However, this uncertainty is likely to be minimal alongside errors in flow and inundation modelling, as communities across the Basin occur on common zones of the floodplain, and therefore are likely to have broadly similar wetting requirements (Overton et al., 2011).

Environmental water requirements – magnitude and duration

In this section, EWR flow magnitudes are plotted against flow durations for the different target communities. A brief overview is presented for each plot, and the text after the plots discusses the implications of these for each target community in more detail.

The duration and magnitude of flows to SA to meet MDBA EWRs resemble a decay curve, where the floodplain is inundated at decreasing durations for increasing flows (Figure 3.4). EWRs would be met as a successive process of flow delivery, at the frequencies specified.

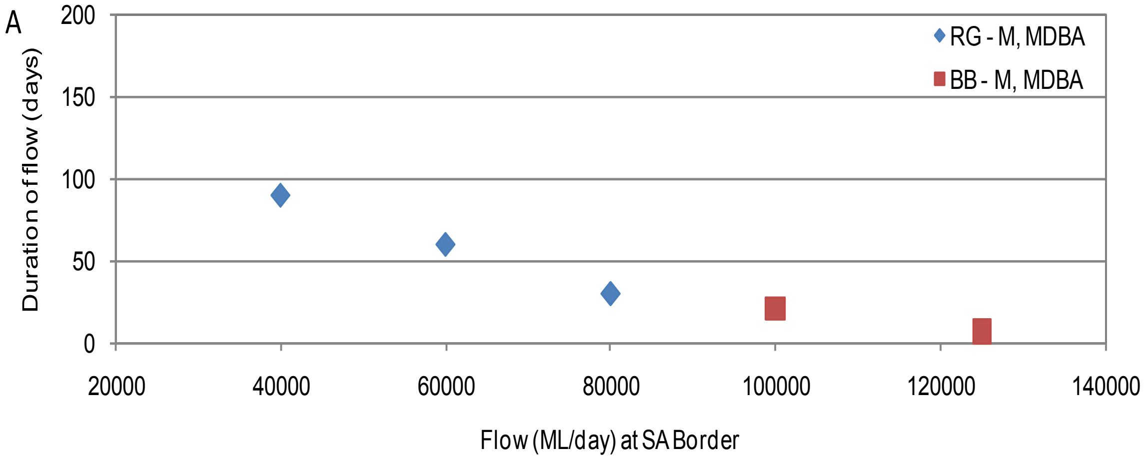

Figure 3.4 Flow versus duration for MDBA (2010b) targets for red gum (RG) and black box (BB). M = maintenance. Data used to generate plots are in Table A.2 and Table A.4 in Appendix A

When the MDBA targets are overlain with other published EWRs, variability in recommendations, and in particular flow duration requirements, emerge (Figure 3.5 and Figure 3.6). A recommendation in the EMP (Department of Environment and Heritage, 2010) of 70,000 ML/day for black box sits outside the inundation zone for this vegetation type. The MDBA (2010b) recommendation of 40,000 ML/day would only inundate a very small proportion of the red gum forest, with flows of up to 80,000 ML/day being required to inundate 80% of the red gum forest and woodland community.

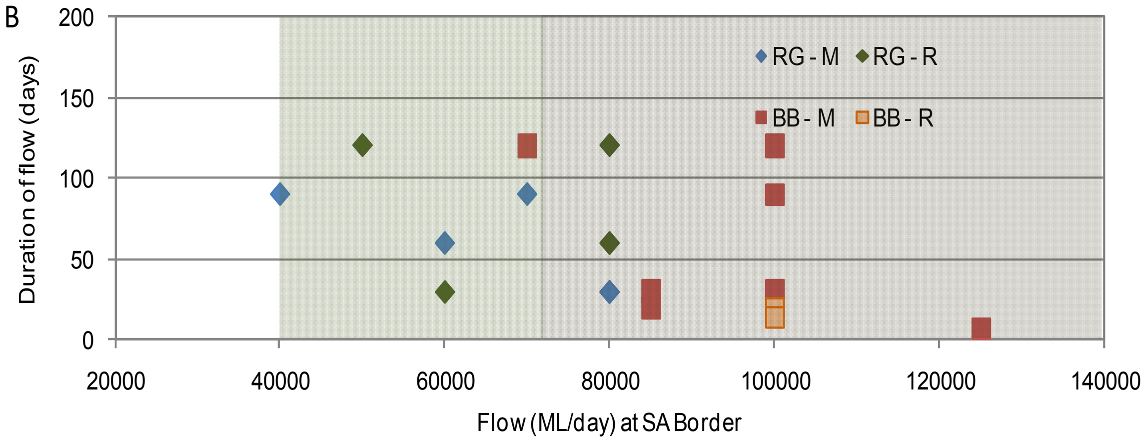

Figure 3.5 Flow versus duration for all published targets for red gum (RG) and black box (BB). Green and grey shaded boxes indicate areas inundated by red gum and black box, respectively, using RIM-FIM findings as a guide. M = maintenance, R= recruitment and regeneration. Data used to generate plots are in Table A.1 and Table A.4 in Appendix A

When the waterbird and lignum targets are overlain with the black box and red gum targets, whilst the flow requirements are met by the MDBA EWRs (Figure 3.6), duration requirements are not.

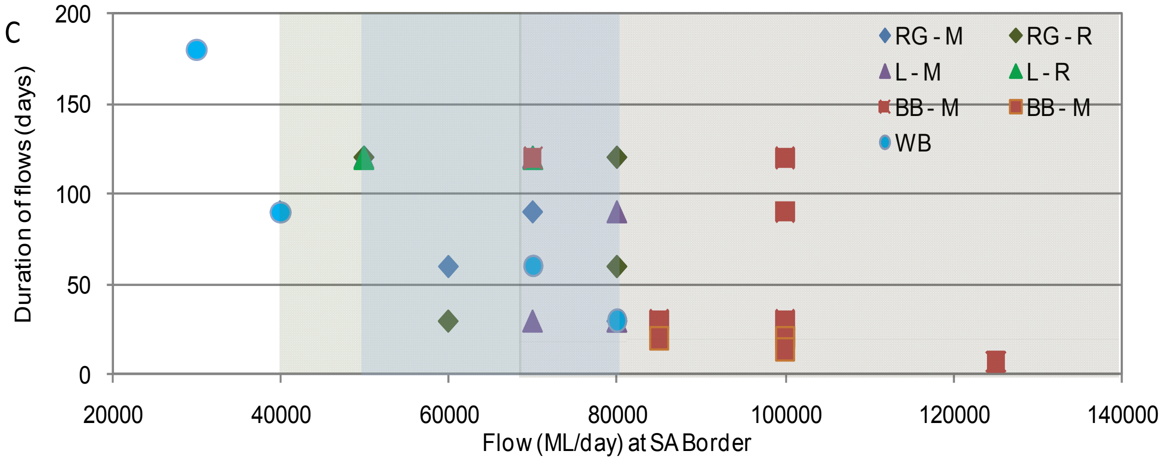

Figure 3.6 Flow versus duration for all published targets for red gum (RG), black box (BB), lignum (L) and waterbirds (WB). Green, blue and grey shaded boxes indicate areas inundated by red gum, lignum and black box, respectively, using RIM-FIM findings as a guide. M = maintenance, R= recruitment and regeneration. Data used to generate plots are in Table A.2, Table A.3 and Table A.4

The general disparity between required flow magnitudes and durations reflects the quality of knowledge in inundation behaviour associated with the asset. Whilst daily flow volumes have been defined in the River Murray Flood Inundation Model (RIM-FIM), the representation of dynamics of inundation has not been modelled. Therefore the duration of wetting in different parts of the asset, including depression areas, given a flow of a particular duration at a gauge, is not represented in RIM-FIM, leading to uncertainty in their representation within EWRs. The MDBA durations are not likely to be representative of the requirements for lignum and waterbirds, particularly when compared with EWRs published in other reports.

Specific comments on EWRs by target community are provided below.

Red gum

Although separate targets are often specified for red gum forest and woodlands, the water requirements specified for each are the same. Forest and woodland communities will be treated as a single community in this review.

Red gum communities typically occur in areas inundated at between 40,000 and 80,000 ML/day. The water requirements specified for red gum generally vary in duration, but flow requirements are consistent. The MDBA target of only 40,000 ML/day is likely to only wet riparian zones, and flows up to 80,000 ML/day are required to inundate significant amount of existing (~80%) red gum stands. Reproduction and regeneration targets for red gum are particularly variable across documents. Generally, inundation of between 2 and 8 weeks is considered to meet regeneration and reproduction requirements (Roberts et al., 2000; Rogers and Ralph 2010).

Black box

Black box communities typically occur in areas inundated above 70,000 ML/day. There is some variability in black box targets specified. The lower end target specified by Department of Environment and Heritage (2010) is unlikely to inundate significant areas of black box communities. Some variability is specified in duration. Typically, black box requires an inundation period of 2 to 4 months (Roberts and Marston, 2000; Rogers and Ralph, 2010). Durations in the Guide are comparatively short (21 and 7 days), but if such targets are successive, the duration specified is reasonable.

Lignum and waterbirds

As stated above, the EWRs in the Guide assume that the targets specified will implicitly meet lignum and waterbird water requirements. To review this assumption, targets from other planning documents have been included in Figure 3.6.

Lignum occur in areas inundated between 50,000 and 70,000 ML/day, given this, their volumetric targets are met by the MDBA EWRs. However duration of inundation required to achieve maintenance requirements can vary between 1 and months (Rogers and Ralph, 2010), to 6 and 12 months (Roberts and Marston, 2000). For this site, the MDBC (2006a) Icon Site Management Plan recommends a 3-month inundation period, whereas the Department of Environment and Heritage (2010) specify periods of between 3 and 6 months. There is little evidence to suggest that the stated MDBA (2010b) targets or the lignum target specified by the DWLBC (2010) of 30 days will meet lignum requirements. Generally, other EWRs specified in the Guide (MDBA, 2010b) specify longer inundation periods for lignum. Healthy lignum provides important breeding habitat for many colonial nesting waterbirds, as found in many other parts of the Murray-Darling Basin (Kingsford, 2002) and it is assumed that this is also the case in South Australia.

In Ecological Associates (2010), volumes of 30,000 and 40,000 ML/day were set as targets for waterbirds. There is little evidence that these targets would achieve their stated aims, and are not considered any further here. Flows of this magnitude result in minimal flooding of waterbird habitats. Other published targets (Appendix A, Table A.6) for waterbirds are of the similar volume magnitudes to those in MDBA (2010b). However, as for lignum, specified durations are too short. For example, minimum flood duration for glossy ibis fledgling success is 5 months, with an ideal duration of 5 to 8 months (Rogers and Ralph, 2010). Minimum flood duration for straw necked ibis fledgling success is 6 months, with an ideal duration of 9 to 12 months (Rogers and Ralph, 2010).

Unless the Riverland–Chowilla floodplain is considered marginal habitat for waterbirds, targets for both lignum and waterbirds should be explicitly included in the Basin Plan. At a minimum, targets could be specified which are enacted if a breeding event is initiated. Targets could be specified as a contingency, which aim to prolong the event to ensure the success of fledgling, given that an event is triggered.

Flow and frequency

EWR recommendations by target are documented in Appendix A.

As with flow and duration, the recurrence interval for flows determined by the MDBA to meet targets set for red gum and black box resemble a decay function (Figure 3.7), where the floodplain is inundated at flows greater than 40,000 ML/day. As the MDBA targets are not to be read in isolation, it is assumed the EWRs would be met as a successive process of flow delivery, at the frequencies specified.

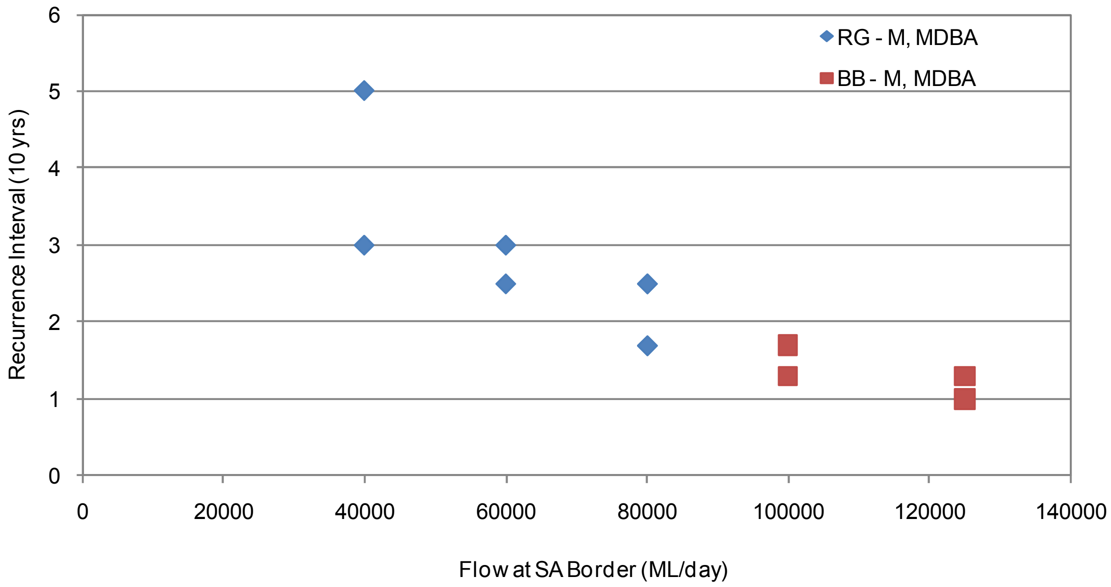

Figure 3.7 Flow versus recurrence intervals of red gum (RG) and black box (BB) EWRs published in the Guide

To assess the feasibility of published recommendations, flow spells analyses (using the eWater CRC River Analysis Package) were conducted on modelled without-development and modelled baseline flows. An example of spells analyses for increasing flow volumes for 30-day periods are plotted at different recurrence intervals (Figure 3.8). Post-1976 and post-2000 were selected as representative recent climate and extreme dry periods.

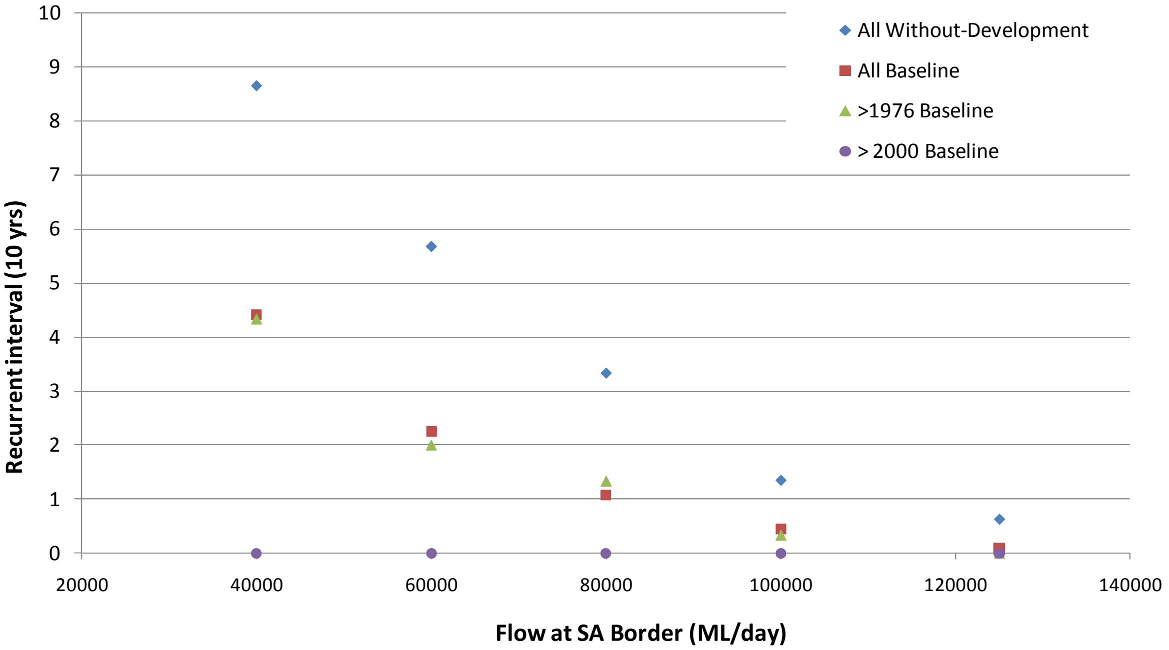

Figure 3.8 Spells analysis of flows at the SA border (all with a duration of 30 days), showing historical (modelled without-development), modelled baseline, >1976 (modelled dry) and >2000 (modelled recent drought) sequences

Spells analysis was used to determine the frequency of the recommended EWRs in modelled flows sequences to determine whether those EWRs are reasonable. Modelled flows are bounded by without-development and baseline flows, along with post-1976 (a relatively dry period) and post-2000 flows (the recent drought). Figure 3.9 shows the recurrence of flow spells of different duration and flows plotted with the black box and red gum EWRs. Boxes are overlayed on Figure 3.10 to represent windows of suitability for red gum (green), lignum (grey), waterbirds (blue) and black box (brown). Windows represent the published flooding frequency wetting requirements for these communities (Roberts and Marston, 2000; Rogers and Ralph, 2010), and the inundation volume in which this community is found (vegetation only). To assist interpretation, whether the EWR is bounded within modelled flows is reported in Table 3.2 and Table 3.3.

The majority of EWRs are consistent with their modelled recurrence intervals over the duration of the flow sequences. They also occur within the boxes, which represent the requirements for a target community. Consistent with the Guide, certain EWRs, such as the requirement from Newall et al. (2009) (300,000 ML/day recommendation), represent extreme rare events, only being observed once in modelled flows, so are not recommended for inclusion as a target.

The Riverland–Chowilla EWRs published by the MDBA (2010b) are also adequate in meeting their stated targets. However, additional floodplain targets should be explicitly included to consider lignum and colonial nesting waterbird water requirements.

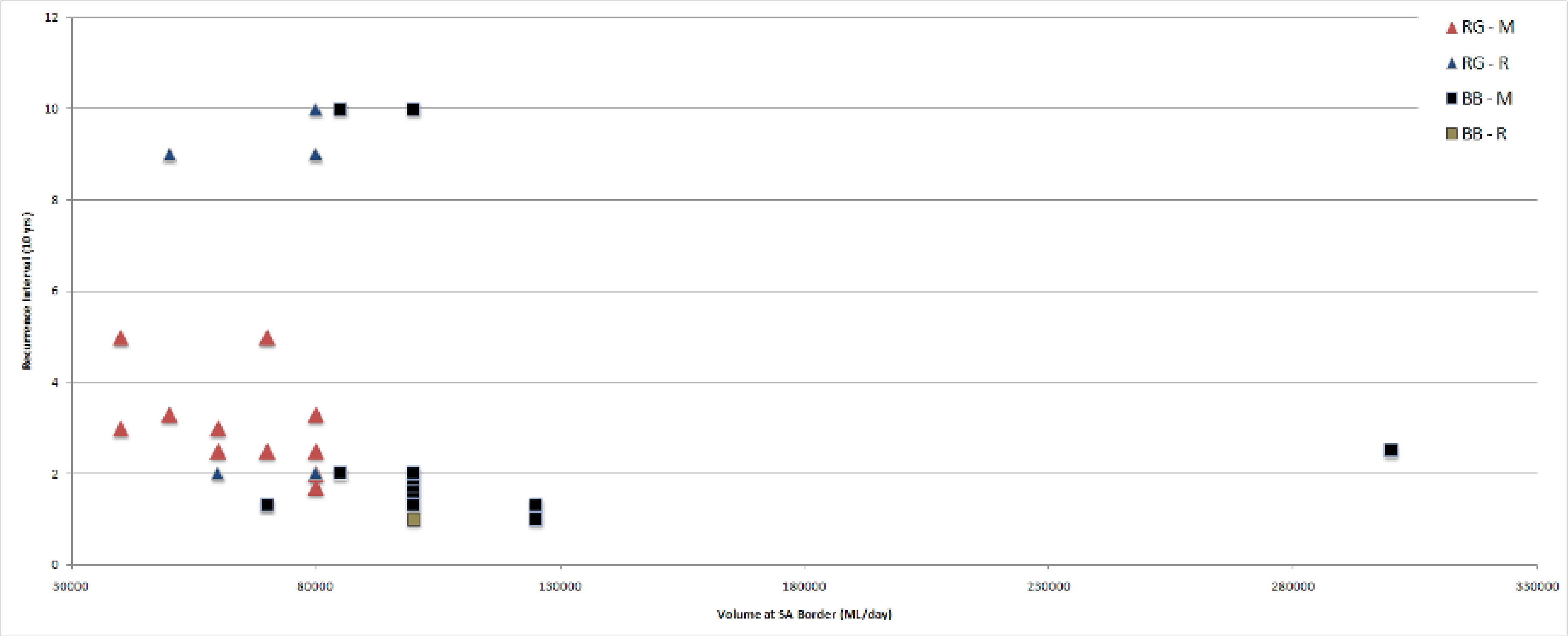

Figure 3.9 Flow versus recurrence intervals of red gum (RG) and black box (BB) published EWRs, as listed in Appendix A. M = maintenance, R= recruitment and regeneration

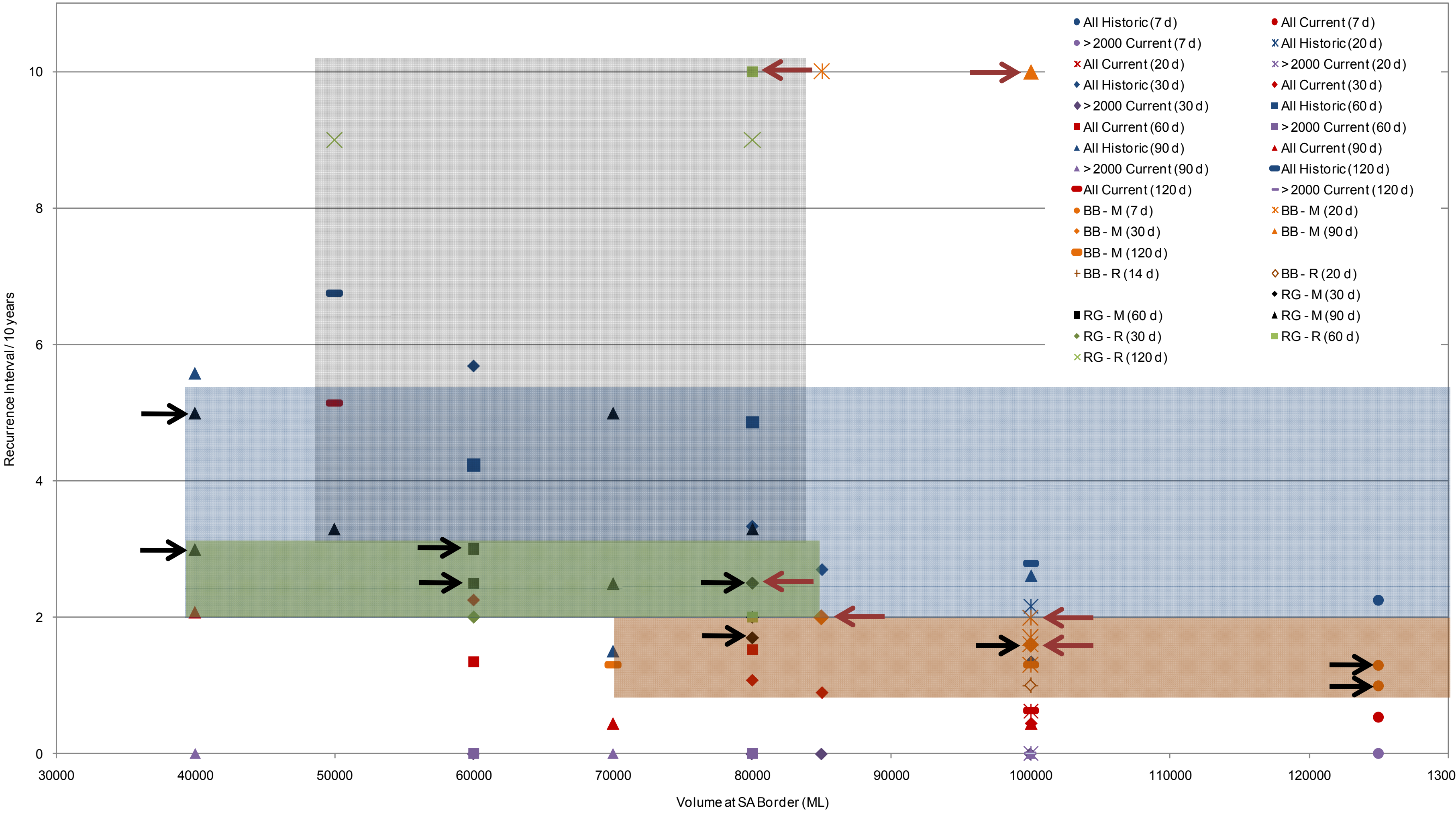

Figure 3.10 Flow volume versus recurrence interval at different time intervals for without-development (blue symbols), baseline (red symbols) and >2000 (modelled recent drought – purple symbols) flow scenarios, overlayed with EWR recommendations for red gum (RG) and black box (BB). M = maintenance, R= recruitment and regeneration. Boxes overlayed on the plot show frequency versus occurrence windows for red gum (green), lignum (grey), waterbirds (blue) and black box (brown), using information from Roberts and Marston (2000); Rogers and Ralph (2010). Black arrows show MDBA targets, and red arrows show SA government targets

Table 3.2 Published EWRs for red gum. The last column indicates whether the EWR frequency is within the recurrence intervals of without development vs. current (Figure 3.10)

Source	Target	Flow requirement (flow to SA)	Duration	Frequency	Bounding within modelled flows
		ML/day		Year (y)	
Maintenance					
MDBA (2010b)	Maintain 80% of the current extent of red gum forest in good condition	40,000	90 d total (7 d min.)	3 to 5 y in 10	Yes
MDBA (2010b)	Maintain 80% of the current extent of red gum forest in good condition	60,000	60 d total (7 d min.)	2.5 to 3 y in 10	Yes
MDBA (2010b)	Maintain 80% of the current extent of red gum forest in good condition	80,000	30 d total (7 d min.)	1.7 to 2.5 y in 10	Yes
MDBA (2010b)	Maintain 80% of the current extent of red gum woodland in good condition	80,000	30 d total (7 d min.)	1.7 to 2.5 y in 10	Yes
DWLBC (2010)	Maintain and improve the health of 80% of the river red gum woodlands and forests (adult tree survival)	80,000 to 90,000	>30 days	1 y in 4	Yes
Ecological Associates (2010)	Red gum forest and woodland: adult tree survival	80,000	1 month	2 y in 10	Yes
Department of Environment and Heritage (2010)	Red gum forest and woodland: Maintenance	50,000 (1/3 of community maintained) to 80,000 (2/3 of community maintained)	4 to 7 months	1 y in 3	No
MDBC (2006a)	Maintain or improve tree health within 70% of the mixed river red gum woodland areas	5000-70,000	3 months	1 in 2 y to 1 in 4 y	70,000 ML – No
Regeneration					
DWLBC (2010)	Successful recruitment of cohorts of river red gums, ie recruitment must equal or exceed river red gum mortality	80,000	2 months	Successive years (at least 2 consecutive)	Yes
Ecological Associates (2010)	Red gum forest and woodland: germination and recruitment	60,000	1 month	2 yrs in 10	Yes
Ecological Associates (2010)	Red gum forest and woodland: germination and recruitment	80,000	2 months	2 yrs in 10	Yes
Department of Environment and Heritage (2010)	Red gum forest and woodland: recruitment	50,000 (1/3 of community maintained) to 80,000 (2/3 of community maintained)	4 months	7 to 9 yrs in 10	No

Table 3.3 Published EWRs for black box. The last column indicates if the EWR frequency is within the recurrence intervals of the without development vs. baseline scenarios (Figure 3.8)

Source	Target	Flow requirement (flow to SA)	Duration	Frequency	Bounded within modelled flows
		ML/day		years	
Maintenance					
MDBA (2010b)	Maintain 80% of the current extent of black box woodland in good condition	100,000	21 d total (1 d min)	1.3–1.7-in-10	Yes
MDBA (2010b)	Maintain 80% of the current extent of black box woodland in good condition	125,000	7 d total (1 d min)	1–1.3-in-10	Yes
DWLBC (2010b)	Maintain and improve the health of ~50% of the Black Box woodlands	85,000	30 days	1-in-5	Yes
DWLBC (2010b)	Maintain and improve the health of ~60% of the Black Box woodlands	100,000	20 days	1-in-5	Yes
DWLBC (2010b)	Maintain and improve the health of 80% of the Black Box woodlands	>100,000	20 days	1-in-6	Yes
	Black Box Woodland; Floodplain Chenopod Shrubland: Adult tree survival	100,000	1 month	1-in-15	Yes
	Black box woodland: Survival	70,000 (20 %) to 100,000 (40%) to 300,000 (majority)	2 to 4 months	1-in-30	Yes (70, 000 and 100) No (300,000)
	Maintain or improve tree health within 45% of the mixed Black box woodland areas.	50,000–100,000	3 months	1-in-4	Yes
Regeneration					
DWLBC (2010)	Successful recruitment of cohorts of Black Box at lower elevations, , ie recruitment must equal or exceed River Red Gum mortality	85,000	20 days	Consecutive years	Unclear specification. If every year – No
DWLBC (2010)	Successful recruitment of cohorts of Black Box at higher elevations, , ie recruitment must equal or exceed River Red Gum mortality	>100,000	20 days	Consecutive years	Unclear specification. If every year – No
	Black Box Woodland; Floodplain Chenopod Shrubland: Germination and Recruitment	100,000	2 weeks	1 year in 10	Yes
	Black box woodland: Recruitment	70,000 (20 %) to 100,000 (40%) to 300,000 (majority)	Long enough to saturate surface soil, with slow recession	1-in-10 (23 years in succession every 30)	Yes

3.1.2 Concluding comments

To be holistic in meeting the Riverland–Chowilla ecological character requirements, the Guide should include EWRs to meet the requirements of lignum and waterbird communities. Given that the SA EWRs specified for Riverland–Chowilla are reasonable in scope and definition, the SA EWRs are most appropriate for meeting the asset requirements. SA government EWRs are more holistic in their representation of the ecological character of the asset. As stated previously, 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 government and MDBA were broadly consistent and representative of species requirements.

A broad review of asset plans demonstrated that asset objectives, target communities and associated EWRs are broadly consistent across planning documents. The ecological character of the asset is defined by SA government and MDBA as including black box, red gum, lignum, waterbirds and fish. The definition of the spatial extent of the asset, downstream of the SA border, are consistent between SA government (DWLBC, 2010) and the MDBA; however, the Guide includes the Lindsay and Wallpolla Islands which are upstream of the SA border.

Specific comments on MDBA's EWRs are:

- MDBA (2010b) targets are biased towards maintenance of individual vegetation types. Although targets are specified according to the *Water Act 2007*, which precludes restoring or increasing the extent of communities, regenerative and reproductive targets should still be specified to meet requirements of existing communities.
- Although the relationships between flow volumes and inundation areas have been established using RIM-FIM, the relationships between flows and delivery regime, and flows and duration of inundation on the floodplain, are less clear.
- The MDBA note discrepancies between RIM-FIM volume and inundation area. This should be resolved given the fundamental role of this model in establishing EWRs.
- Time between events as a measure of resilience should be specified more clearly by the MDBA as an environmental water requirement. Even though the EWRs are not obligations that need to be met under the Basin Plan or State Water Resource Plans, it is likely they will be applied in determining annual priorities of Basin watering.
- Lignum and waterbirds
    - Explicit statement of requirements for these targets should be made by the MDBA, consistent with other MDBA EWRs published in the Guide. This will assist in prioritisation of water deliveries and in establishing monitoring and evaluation processes for the Riverland–Chowilla site.
    - The vegetation targets specified in MDBA (2010b) are too short to fulfil bird breeding requirements.
    - Lignum shrubland is an important breeding habitat for colonial nesting waterbirds. Targets specified by the MDBA are too short to fulfil wetting requirements of this vegetation type.

In determining ecological outcomes in Riverland–Chowilla in response to flow, it is worth noting that unlike the CLLMM, there is no ecological response model specific for this site. To reduce uncertainties in how the Riverland–Chowilla asset is likely to respond to alternative flow regimes, we highly recommend an investment in dedicated ecological response modelling at this site, so that we can move beyond generic understanding of water requirements for its communities.

3.2 Coorong, Lower Lakes, and Murray Mouth

The Coorong, Lower Lakes, and Murray Mouth (CLLMM) is the second hydrologic indicator site nominated for South Australia by in the Guide (MDBA, 2010b). This section of the Part compares the EWRs in the Guide for that site (MDBA, 2010b) with other published EWR recommendations (e.g. DWLBC, 2010; Lester et al., 2010).

The area of focus for the MDBA was defined to be consistent with the area listed on the Ramsar Wetlands of Australia dataset (Figure 15; MDBA, 2010b, p. 672) and Figure 3.11 (this chapter). This was consistent with other studies undertaken that specify EWRs for the site (Phillips and Muller, 2006; MDBC 2006b; DWLBC, 2010; Lester et al., 2010).

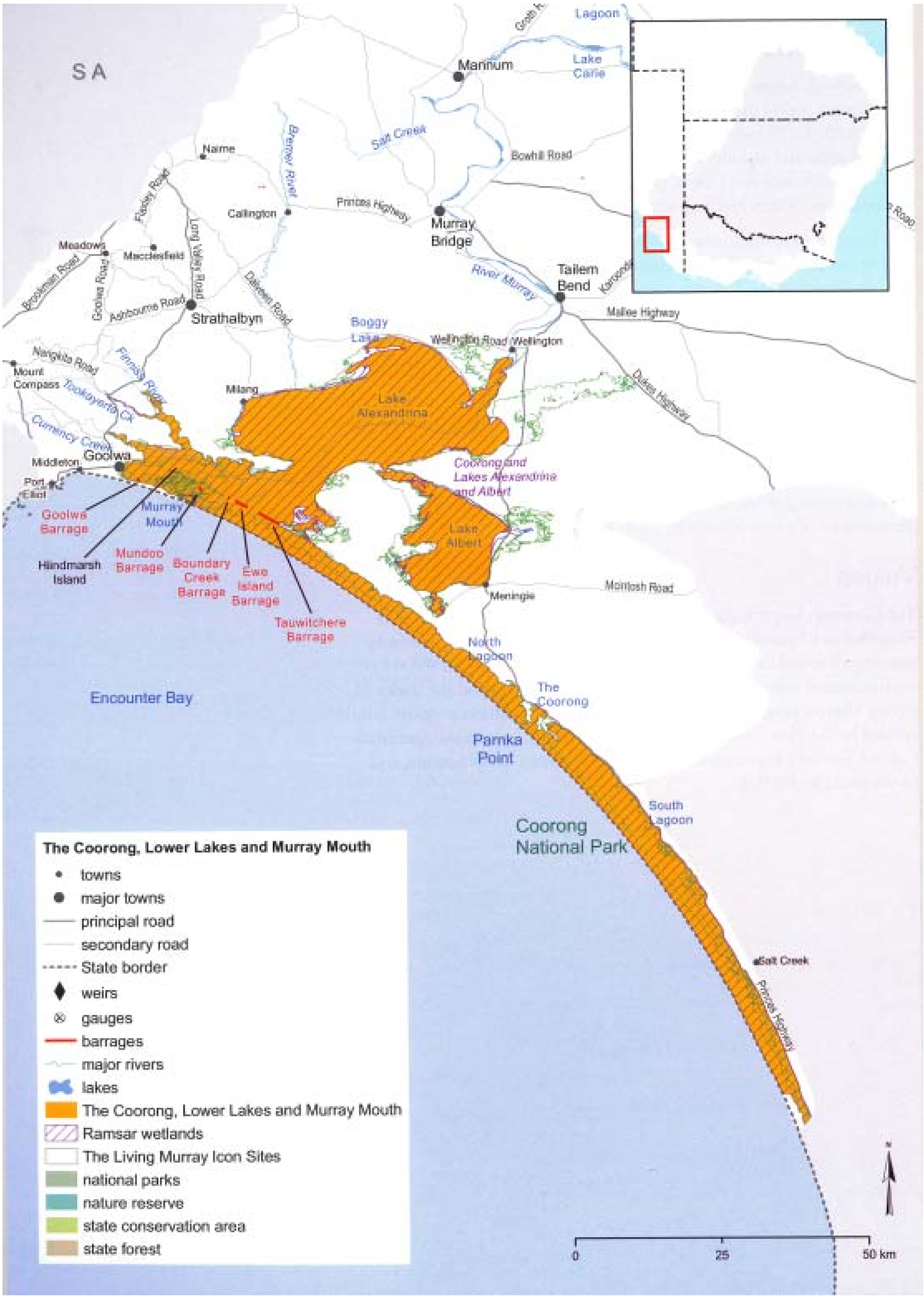

Figure 3.11 Location and extent of the Coorong, Lower Lakes (Alexandrina and Albert), and Murray Mouth considered by the Guide to the proposed Basin Plan (Source: MDBA 2010b, p. 672)

MDBA (2010b) divided the site into four parts in recognition of differences in ecological character, in order to set EWR targets. These were the Coorong South Lagoons, the Coorong North Lagoon, Lakes Alexandrina and Albert and the Murray Mouth. Most of the other reports also divided the site into sections and while the individual components varied (e.g. tributaries included in Phillips and Muller 2006), they were broadly comparable.

There was a wide variety of selected targets which explicitly defined EWRs for the CLLMM across the range of reports (Table 3.4). The reports reviewed here include a response from the South Australian Government (DWLBC, 2010) to an earlier version of the relevant section of MDBA (2010b)[1], the completed work upon which that response was drawn (Lester et al. 2010), the Ramsar Ecological Character Description for the site (Phillips and Muller, 2006) and the Icon Site Management Plan (MDBC, 2006b). Precise targets specified are documented in Table 3.5.

Three targets were included for the CLLMM by MDBA (2010b):

- maintenance of a range of healthy estuarine, marine and hypersaline conditions to support keystone species in the North and South Lagoons of the Coorong
- provision of sufficient flows to allow for salt and nutrient export
- provision of a variable lake level regime to support riparian vegetation communities and prevent the exposure of acidic soils.

A response to an earlier draft of MDBA (2010b) by DWLBC (2010) highlighted the importance of a water quality (salinity) target for Lake Alexandrina. This was identified as a primary determinant of ecological function in the site. Lester et al. (2010) (a later version of the work described by DWLBC (2010) but one that was not available to the MDBA in a timeframe suitable for inclusion in the Guide to the proposed Basin Plan) identified the same targets. Both DWLBC (2010) and Lester et al. (2010) also set targets based on the existing ecological response model for the Coorong, the ecosystem states model (Lester and Fairweather, 2009) for both avoiding degraded ecosystem states and encouraging the healthiest ecosystem states.

Phillips and Muller (2006) set limits of acceptable change (as opposed to targets for EWRs) for several parameters that they identified as primary determinants of ecological character. These included salinity in the Lakes and tributary wetlands, salinity in the Coorong, turbidity in the Lakes and Coorong, the areal extent of riparian and submerged aquatic vegetation in the Lakes and *Ruppia* spp. in the Coorong, water levels in the Lakes and Coorong, an open Murray Mouth, habitat availability (including connectivity), water regimes and described the need for a limit of acceptable change for inflows from the Murray River (but recognised that setting one was beyond the scope of the report).

A target for mouth openness was also set by MDBC (2006b), as were targets for more frequent estuarine fish spawning and recruitment and enhanced migratory wader bird habitat in the Lakes and Coorong. A large number of more-specific targets are also set, but this report was not written for the purpose of setting an EWR for the site, so many of them are not relevant to the task addressed here (as was the case for Phillips and Muller, 2006).

Table 3.4 List of target types used in each EWR document

Target	MDBA (2010b)	DWLBC (2010)	Lester et al. (2010)	Phillips and Muller (2006)	MDBC (2006)†
Aquatic macrophyte *Ruppia megacarpa* (NL)	🟩			🟩	‡
Aquatic macrophyte *Ruppia tuberosa* (SL)	🟩			🟩	‡
Healthy ecosystem states	(SL only)	🟩	🟩		
Salt export (MM)	🟩		***		
Riparian vegetation communities (LAA)	🟩			🟩	‡
Prevent acidification (LAA)	🟩				
Ramsar ecological character	*	🟩	🟩	🟩	
Salinity (LAA)		🟩	🟩	🟩 and tributaries	
Turbidity (NL, SL, LAA)				🟩	
Water levels (SL, LAA)	🟩	🟩 LAA only	🟩 LAA only	🟩 and NL	
Open Murray Mouth	**	**	**	🟩	🟩
Estuarine fish spawning and recruitment			**		🟩
Migratory wader bird habitat			**		🟩

† MDBC (2006) refer to the listed targets as objectives and define targets within each. The objectives were seen as the most similar construct, so have been included here despite the difference in terminology.
* Ramsar ecological character is mentioned by MDBA (2010b) but the other targets are intended to encompass this, so no specific target is set.
** Other targets were designed to achieve the objective described, so this target is effectively covered.
*** Salt export was not a specific target, but maintenance of salinity in the LAA was a mechanism used to meet other targets so this is likely to be covered.
‡ More-specific targets for these types were included (amongst others) but were encompassed by the overall targets shown.
Abbreviations: NL – Coorong North Lagoon, SL – Coorong South Lagoon, MM – Murray Mouth, LAA – Lakes Alexandrina and Albert.

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[1] Note that comments that are no longer applicable to the final version of MDBA (2010) have been excluded from this assessment.

3.2.1 MDBA Coorong, Lower Lakes, and Murray Mouth targets

The Guide sets targets based on ‘keystone’ species in the Coorong, using two species of the aquatic macrophyte *Ruppia* (*R. megacarpa* and *R. tuberosa*) and assert that providing appropriate conditions for these two species will cater for the broader Coorong ecosystem. The choice follows Phillips and Muller (2006) which provides no justification for this assertion. The choice of these two species does need to be supported as there are other choices of surrogate species, some of which may be better justified than the two selected here. The specific target relating to these species is to

> maintain a diverse range of healthy estuarine, marine and hypersaline conditions in the Coorong, in particular healthy populations of ‘keystone’ species such as *R. tuberosa* in the South Lagoon and *R. megacarpa* in the North Lagoon (MDBA, 2010b, p. 676).

While the species may have been an important component of the system at the time of Ramsar-listing in 1985, *R. megacarpa* has not been recorded in the North Lagoon of the Coorong for more than 20 years (Phillips and Muller, 2006), and a better target would be to reinstate a healthy population, rather than maintain one that is not there.

The salinity requirements identified for *R. tuberosa* were that average annual South Lagoon salinities not exceed 60 g/L, and that maximum salinities not exceed 100 g/L in 95% of years, or 130 g/L in 100% of years. Water level requirements of average annual water levels not falling below –0.09 m AHD, being at least 0.27 m AHD and exceeding 0.37 m AHD (at the same frequency as currently occurs) were also identified. The use of the target of 130 g/L has been questioned by others (DWLBC, 2010) as being untested and likely to be above the tolerances of many species in the CLLMM. A range of scientific sources are cited in support of these requirements (MDBA, 2010b).

Salinity targets to support Ramsar-listed ecological character (including *Ruppia* spp.) in the Coorong were described by Phillips and Muller (2006). These include targets of no more than 58,000 µS/cm EC with areas below 39,000 µS/cm EC in the Murray Mouth, a range of 5,000 to 60,000 µS/cm EC in the North Lagoon not exceeding 50,000 µS/cm EC at Long Point to the north and 100,000 µS/cm EC at McGrath Flat to the south. In the South Lagoon, targets were set for salinities around 30,000 µS/cm EC in winter/spring, not exceeding 100,000 µS/cm EC at Villa dei Yumpa to the north of that lagoon and 130,000 µS/cm EC at Sand Spit Point to the south of that lagoon. Further, Phillips and Muller (2006) also set a target of 0% loss of areal habitat for both species of *Ruppia* in the Coorong.

A second target described by MDBA (2010b) is to provide sufficient flow to enable the export of salt and nutrients from the Basin through an open Murray Mouth. Recognising that there are difficulties associated with defining an open Murray Mouth, as there is no one volume that is sufficient to keep the Mouth ‘open’, as such, and an additional definition is required, the target was based on salt export from the Basin, at a level of a ten-year rolling average of 2 million tonnes/year. Phillips and Muller (2006) also set a target of an open Murray Mouth 100% of the time.

The final target specified by MDBA (2010b) for defining the EWRs for the CLLMM focused on variability in water levels in Lakes Alexandrina and Albert to support fringing and submerged vegetation, as well as to mitigate the risks associated with acid-sulphate soils in the CLLMM. Investigations into the location of acid-sulphate soils and likely buffering within the system identified trigger levels of –0.75 m AHD in Lake Albert and –1.75 m AHD for Lake Alexandrina (Department of Environment and Heritage (2010) cited in MDBA (2010b)), but precise targets for a water level regime were not set. Instead, an indicative average lake level was produced, and the details left to the state and local planning processes. A similar figure showing indicative water levels is provided by Phillips and Muller (2006), DWLBC (2010) and Lester et al. (2010) for the Lakes. No precise EWRs were set by any author relating to water level variability, and the assumption that other EWRs are sufficient to maintain water levels in the specified envelopes should be tested.

Most other reports also specified a salinity target for some or all of the freshwater components of the CLLMM. Phillips and Muller (2006) set a limit of acceptable change of salinity maintained below 700 µS/cm EC based on a five-year average for Lake Alexandrina, with a corresponding target of 1400 µS/cm EC for Lake Albert and a variety of targets for the most significant tributary wetlands (not included here as they are not addressed by any other report). Both DWLBC (2010) and Lester et al. (2010) specified a salinity target for Lake Alexandrina of between 700 and 1000 µS/cm EC in 95% of years and less than 1500 µS/cm EC in 100% of years in order to maintain the Ramsar-listed ecological character of the CLLMM; and suggested that this target encompassed the needs of the individual indicator species, assemblages and processes that they reviewed across all parts of the CLLMM, including supporting healthy ecosystem states, as salinity in Lake Alexandrina was identified as the most flow-intensive parameter in the system (Lester et al. 2010). DWLBC (2010) and the more-detailed Lester et al. (2010) also set targets relating to the prevalence of degraded ecosystem states in the Coorong and the frequency of occurrence of the Healthy Hypersaline ecosystem state (thought to be related to high flow events).

Only Phillips and Muller (2006) specified targets for turbidity, and these were not set specifically for the purposes of setting an EWR, so are not outlined in detail here. Water regime targets relating to off-takes in the Mount Lofty Ranges and for flow requirements from the Upper South East drainage scheme were also specified.

MDBC (2006b) set lake height and discharge volume envelopes to quantify their three targets (i.e. mouth openness, increased estuarine fish spawning and recruitment, and enhanced habitat for migratory waders). In addition, they included a very large number of specific targets, including specifying water levels, flow timing and salinity ranges for a variety of parts of the CLLMM and for numerous taxonomic groups. We have not included these targets here as they were not linked to EWRs for the CLLMM.

The broad range of specific targets specified by different authors presents a challenge for the operationalisation of the EWR, particularly at small spatial and temporal scales. It is beyond the scope of this study to recommend which targets should be used, and how, in the delivery of environmental water to the CLLMM.

Overview of Coorong, Lower Lakes, and Murray Mouth EWRs

Despite the variability in the targets used as the basis for setting an EWR for the CLLMM in various reports, there was surprisingly little difference in the overall flow requirements specified.

The EWR set by MDBA (2010b) to meet the needs of the aquatic macrophyte, *Ruppia tuberosa*, was based on the salinity and water level requirements identified for that species. Given the relatively poor relationship between water levels and barrage flows (particularly during dry periods), EWRs were set based on salinities, and then checked for consistency with flow requirements to support the desired water levels. EWRs to support these targets were specified as:

- a long-term average barrage flow of at least 5100 GL/year
- a three-year rolling average barrage flow of greater than 2000 GL/year in 95% of years
- a three-year rolling average barrage flow of greater than 1000 GL/year in 100% of years.

The need for flows higher than 5100 GL/year was also identified, although insufficient evidence prevented the definition of a frequency, other than to suggest these flows recur at least as often as currently occurs.

For the second ‘keystone’ species, *Ruppia megacarpa*, targets were set based on salinity requirements. Targets of a maximum North Lagoon salinity of 42 g/L and average salinities of less than 19 g/L were identified. The flow requirements specified above to meet South Lagoon targets were determined to be sufficient to also meet these North Lagoon targets.

EWRs sufficient to allow for the export of 2 million tonnes of salt per year as a ten-year rolling average were identified as 3200 GL/year. No supporting evidence was provided for this figure and no reference given. A volume of 1000 GL/year as a minimum, at a rate of 2,000 ML/day was specified by Phillips and Muller (2006) to keep the Murray Mouth open.

No EWRs were specifically associated with the target to provide variable water levels in Lakes Alexandrina and Albert by any report reviewed.

DWLBC (2010) and Lester et al. (2010) specified EWRs to meet their salinity targets in Lake Alexandrina. To meet the target of a maximum average annual salinity across Lake Alexandrina of 1000 µS/cm EC, a three-year regime was specified. In any given year, the minimum flow over the barrages should be the maximum of:

- 650 GL
- 4000 GL minus flows in the previous year
- 6000 GL minus flows in the previous two years (adjusted for the maximum effect of flows two years ago) (Heneker, 2010; Lester et al., 2010).

Similar sets of rules were also defined to meet the 700 and 1500 µS/cm EC targets (Heneker, 2010; Lester et al., 2010). A high flow requirement was also specified with flows of 6000 and 10,000 GL required at their current frequency of every 3 and 7 years in the Coorong (Lester et al. 2010) as flows of this order and frequency were associated with the occurrence of one of the healthy ecosystem states.

Phillips and Muller (2006) were not specifically tasked with determining an EWR for the CLLMM, so did not have specific flow volumes associated with most of their targets. While they identified setting a limit of acceptable change on inflows from the River Murray as beyond the scope of their report, they did indicate that flows of 20,000 to 80,000 ML/day were needed at least every 5 years to recover ecological character and that flows of 100,000 ML/day were needed at least every 10 years to 'reset' the system (Phillips and Muller, 2006; p. 210). Phillips and Muller (2006) also recognised the detrimental impact of no-flow periods in the system and specified that these extend no longer than 100 days between March and August and no longer than 30 days between August and March each year. This would be provided for by their recommended fishway flow of at least 120 ML/day and an optimum of 900 ML/day all year.

The discharge volume envelope specified by MDBC (2006) ranged between 0 and 4 GL/month. This was much smaller than any of the other EWRs specified.

Consistency of EWRs with past events

In order to check the consistency of the EWRs recommended by MDBA (2010b) and others with our knowledge of the relative health of the ecosystem in the past, we calculated barrage flow and Coorong salinity statistics based on modelled without-development flows and current-development ('current') flows.

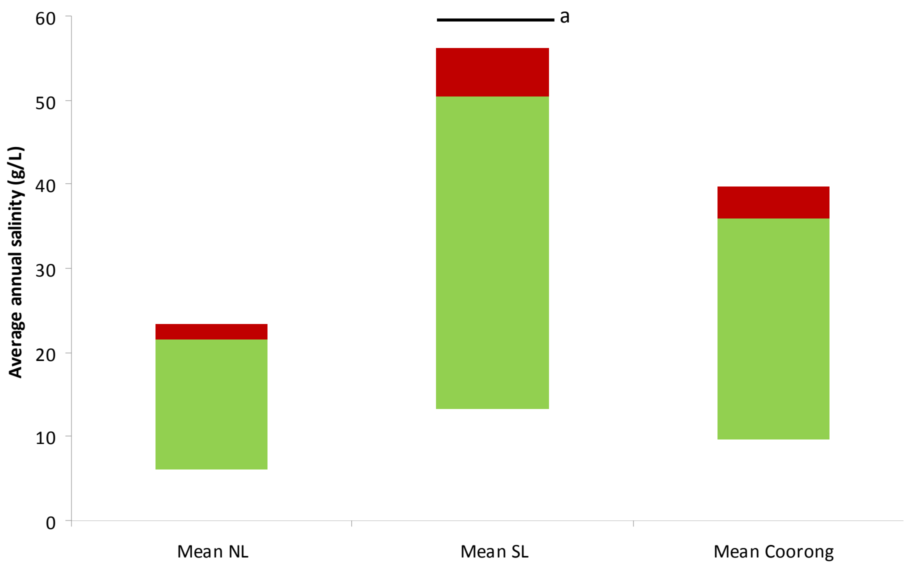
For the without-development flow sequence, we used the whole of the available sequence (1895–2006), while for the current flow sequence, we calculated statistics for the last ten years in the sequence (1996–2006; i.e. 'drought' conditions) and the last 30 years in the sequence (1976–2006; i.e. 'recent' conditions). The period from 1996 to 2006 (and subsequently) is widely acknowledged to be one of the worst droughts on record in the Murray-Darling Basin, and any flow targets used as EWRs should be greater than flows that have occurred during that time (and correspondingly, salinity targets should be lower than values that have occurred during that time). The recent period (1976–2006) was a period of slow decline in the ecological health of the system (Phillips and Muller, 2006) and so, again, EWRs should exceed flow conditions during that period and salinity targets should largely be lower than values that occurred during that time. The without-development modelled flow provides a reality check for the EWRs suggested.

Values that would not have occurred even without extractions and infrastructure in the Basin are clearly unrealistic to be used as targets. Flows were modelled using BigMod (Close and Sharma, 2005) and Coorong salinities were modelled using a hydrodynamic model described in Webster (2010).

Comparing average annual modelled salinities for the North Lagoon, the South Lagoon and the Coorong as a whole demonstrated that the North Lagoon typically has much lower and less variable salinities than the South Lagoon (Figure 3.12). MDBA (2010b) sets an average salinity target of less than 60 g/L in the South Lagoon of the Coorong (line 'a' in Figure 3.12) and a range of maximum salinity targets for both the North and South Lagoons as the basis of its EWR (lines 'b', 'c', 'f' and 'i' in Figure 3.12). All salinity targets set by MDBA (2010b) fell outside the modelled range of values for either the without-development or current flow sequences (Figure 3.12), including during recent and drought conditions, suggesting they are not appropriate for use in setting of EWRs for the CLLMM, with most being too high to ensure that degradation did not occur (with the exception of 'i' which was too low to be realistic on a regular basis).

Phillips and Muller (2006) was the only other report to set explicit salinity targets for the Coorong, and their suggested targets fall within the green zone (i.e. plausible conditions before degradation was recorded within the system; Figure 3.12), and so would be preferable as salinity targets for the Coorong over the MDBA targets. However, it should be noted that Lester et al. (2010) indicate that Coorong salinity alone is not well-correlated to either flow volumes or ecosystem health, so may not be the best variable for setting targets for EWRs.

i) Average annual salinities



ii) Maximum annual salinities

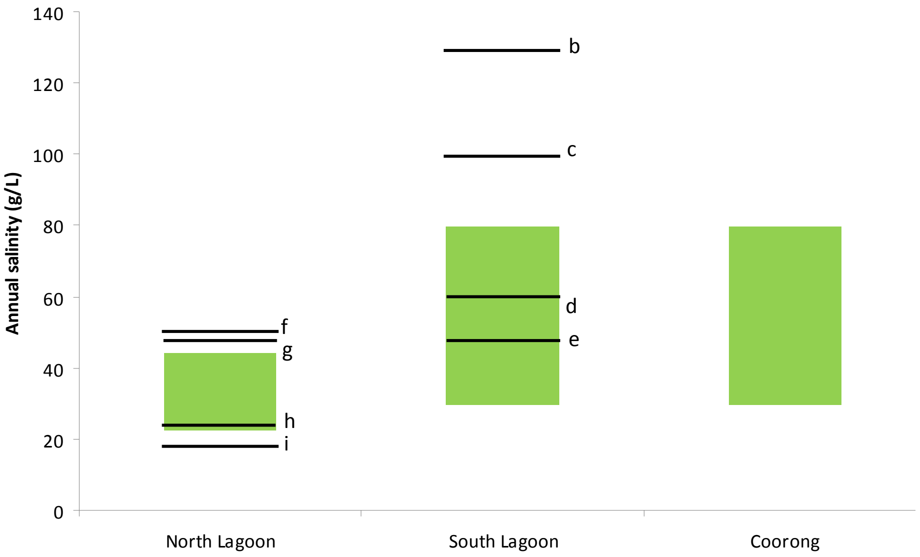


Figure 3.12 Comparison of modelled Coorong salinities and targets set by authors developing EWRs for the CLLMM for (i) average annual salinities; and (ii) maximum annual salinities. In (i) NL = North Lagoon and SL = South Lagoon

The base of the green zone shows the average annual salinity calculated from the without-development flow sequence. The division between the green and red zones is the average annual salinity calculated from the recent (1976–2006) flow sequence and the top of the red zone is the average annual salinity calculated during drought conditions. The green zone thus represents conditions that are plausible but before degradation was recorded in the system while the red zone records conditions that occurred in the recent past (while slow degradation was occurring) but before the severe drought conditions of the past 10 years. Targets are represented by lettered horizontal lines:

- a – average annual South Lagoon salinity proposed by MDBA (2010b)
- b – maximum annual South Lagoon salinity (100% of years) proposed by MDBA (2010b)
- c – maximum annual South Lagoon salinity (95% of years) proposed by MDBA (2010b)
- d – maximum South Lagoon salinity at Sand Spit Point proposed by Phillips and Muller (2006)
- e – maximum South Lagoon salinity at Villa dei Yumpa proposed by Phillips and Muller (2006)
- f – maximum annual North Lagoon salinity proposed by MDBA (2010b)
- g – maximum North Lagoon salinity at McGrath Flat proposed by Phillips and Muller (2006)
- h – maximum North Lagoon salinity at Long Point proposed by Phillips and Muller (2006)
- i – maximum annual North Lagoon salinity (unspecified proportion of years) proposed by MDBA (2010b).

Flow volume was the other variable for which targets were commonly set. Most targets were expressed either as average barrage flows (either as a long-term average or a three-year rolling average) or as the return interval of specified high flow events. Again, these were modelled using without-development, recent and drought conditions to assess the plausibility of the targets suggested.

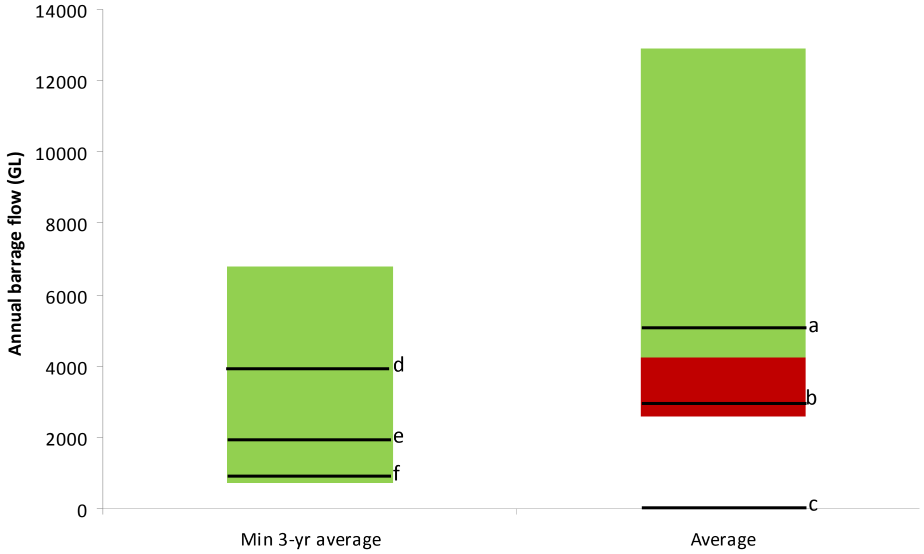
Here, unlike the salinity targets, flow targets set were mostly within the range of modelled values (Figure 3.13). The long-term average flow volume proposed by MDBA (2010b) fell within the green zone of plausible conditions before degradation was observed (line ‘a’ in Figure 3.13), although the target for salt export (while specified as a ten-year rolling average, not a long-term average) fell within the red zone (i.e. conditions occurring in the past 30 years while degradation has occurred within the CLLMM; line ‘b’ in Figure 3.13). This indicates that if met as a long-term average, it is likely that ecological degradation in the Coorong would occur as flows are comparable with those occurring over recent dry conditions. The target proposed by MDBC (2006b) is substantially lower than any modelled volume, or any other target, so should be disregarded (line ‘c’ in Figure 3.13).

For three-year rolling averages, there was remarkable consistency across the target set (lines ‘d’, ‘e’ and ‘f’ in Figure 3.13) with several reports setting the same targets, and all targets falling within the green zone of plausible conditions prior to degradation within the system. This suggests that these targets are well-founded (i.e. multiple methods to set EWRs by different authors identified similar volumes), and so are likely to be a sound basis upon which to set EWRs for the CLLMM.

High flow targets were set by both MDBA (2010) and Lester et al. (2010) (and thus also by DWLBC (2010)). Again, these targets were similar to one another (lines ‘g’, ‘h’ and ‘i’ in Figure 3.13), although Lester et al. (2010) and DWLBC (2010) had two different levels, with two different return intervals, compared to the one set by MDBA (2010b). Again, all targets fell within the green zone of plausible values before degradation (Figure 3.13), so are plausible as targets against which to set EWRs for the CLLMM that will prevent ecological degradation.

Based on this analysis, few salinity targets are consistent with past events in the Coorong (with the exception of those set by Phillips and Muller (2006)) and thus these are unlikely to be a good basis for setting EWRs for the CLLMM. Salinities at the suggested levels have only occurred in the recent drought conditions and are thus likely to be too high for many of the biota in the CLLMM (with the exception of one target that was not met on average under without-development conditions). However, barrage flow targets were consistent with past events in the CLLMM in times not considered to be typical of ecological degradation, so are plausible as EWRs. The target for the export of salt was the only one that fell within the range of conditions modelled for the previous 30 years where degradation was occurring within the system, so should not be used as the sole basis for setting an EWR, as it is unlikely to prevent ecological degradation.

i) Average barrage flows



ii) Number of events exceeding high flow volumes per 10 years

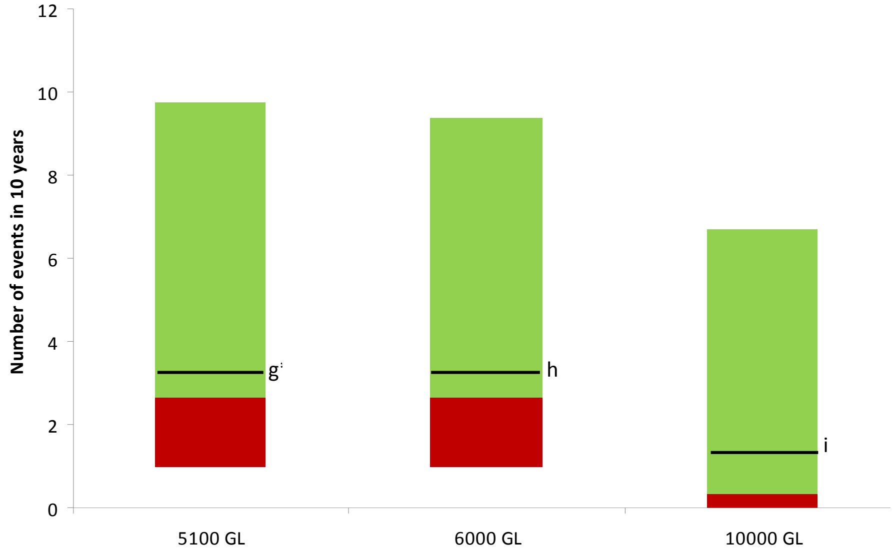


Figure 3.13 Comparison of modelled Coorong flow volumes and targets set by authors developing EWRs for the CLLMM for i) average barrage flows; and ii) number of events exceeding high flow volumes per 10 years

The base of the green zone shows the average flow volume (or number of events) calculated from the without-development flow sequence. The division between the green and red zones is that calculated from the recent (1976–2006) flow sequence and the top of the red zone is that calculated during drought conditions. The green zone thus represents conditions that are plausible but before degradation was recorded in the system while the red zone (and below) records conditions that occurred in the recent past (while slow degradation was occurring) but before the severe drought conditions of the past 10 years, and represent an unacceptable risk.Targets are represented by lettered horizontal lines:

- a – long-term average barrage flows proposed by MDBA (2010b)
- b – ten-year rolling average for salt export proposed by MDBA (2010b)
- c – average flow volume calculated from monthly flows proposed by MDBC (2006b)
- d – three-year rolling average barrage flows (95% of years) proposed as a maximum by Lester et al. (2010)
- e – three-year rolling average barrage flows (95% of years) proposed by MDBA (2010b), DWLBC (2010) and as a minimum by Lester et al. (2010)
- f – three-year rolling average barrage flows (100% of years) proposed by MDBA (2010b), DBLBC (2010) and Lester et al. (2010)
- g – high flow target set by MDBA (2010b)
- h – one of two high flow targets set by Lester et al. (2010)
- i – the second of two high flow targets set by Lester et al. (2010).

3.2.2 Conclusions on the review of EWRs

- Salinity targets specified by MDBA (2010b) are regularly outside the range of values plausible for periods without ecological degradation within the CLLMM.
- Despite this, the volumes specified by MDBA (2010b) are likely to be sufficient.
- Critical aspects of timing of flow delivery and the length of low- or no-flow periods are not addressed by MDBA (2010b) and these have the potential to significantly alter the effectiveness of the EWRs outlined by MDBA (2010b). This should be addressed to ensure the EWRs have the desired effect.

Table 3.5 Comparison of EWR metrics for the Coorong, Lower Lakes, and Murray Mouth

Source	Target	Basis of EWR	Barrage flow requirements	Frequency
South Lagoon				
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	<60 g/L as an average salinity for the SL	Long-term average of 5,100 GL/y	Long-term average
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	<100 g/L as a maximum salinity for the SL	three-year rolling average of 2,000 GL/y	In 95% of years
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	<130 g/L as a maximum salinity for the SL	three-year rolling average of 1,000 GL/y	In 100% of years
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	0.27 m AHD as an average annual water level for the SL*	Flows consistent with salinity-based requirements	Consistent with salinity-based requirements
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	>0.37 m AHD in the SL provide the healthiest ecosystem states	High flows (>5,100 GL/y)	At current frequencies
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia tuberosa* in the South Lagoon	<–0.09 m AHD in the SL trigger degraded ecosystem states	Flows consistent with salinity-based requirements	Consistent with salinity-based requirements
ECD	Maintain Ramsar-described ecological character		None specified	None specified
ECD	Maintain Ramsar-described ecological character	Maintain water levels within described envelope	None specified	None specified
ECD	Maintain Ramsar-described ecological character	No further reduction in habitat availability	None specified	None specified
DWLBC/ CLLMM EWR	Maintain current frequency of ecosystem states associated with high flows	No change in frequency of occurrence of the Healthy Hypersaline ecosystem state	Flows of at least 6,000 GL/y	At current frequencies (i.e. 1 in 3 years)
DWLBC/ CLLMM EWR	Maintain current frequency of ecosystem states associated with high flows	No change in frequency of occurrence of the Healthy Hypersaline ecosystem state	Flows of at least 10,000 GL/y	At current frequencies (i.e. 1 in 7 years)
North Lagoon				
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia megacarpa* in the North Lagoon	<50 g/L as a maximum salinity for the NL	Minimum flow of 1-2,000 GL/y	Consistent with SL requirements
MDBA	Maintain healthy populations of the ‘keystone’ species *Ruppia megacarpa* in the North Lagoon	<19 g/L as a maximum salinity for the NL in an unspecified proportion of years	Long-term average of 5,100 GL/y	Long-term average
ECD	Maintain Ramsar-described ecological character	Maintain water levels within described envelope	None specified	None specified
ECD	Maintain Ramsar-described ecological character	No further reduction in habitat availability	None specified	None specified
Murray Mouth				
MDBA	Provide sufficient flows to enable export of salt and nutrients from the Basin through an open Murray Mouth	Average of 2 million tonnes salt exported per year	ten-year rolling average of 3,200 GL/y	Ten-year average
MDBA	Provide sufficient flows to enable export of salt and nutrients from the Basin through an open Murray Mouth	Salinity <500 mg/L at Tailem Bend	ten-year rolling average of 3,200 GL/y	Ten-year average
ECD	Maintain Ramsar-described ecological character	Murray Mouth open	1,000 GL at a rate of 2,000 ML/day	100% of years
ECD	Maintain Ramsar-described ecological character	No further reduction in habitat availability	None specified	None specified

Source	Target	Basis of EWR	Barrage flow requirements	Frequency
Lakes Alexandrina and Albert				
MDBA	Provide a variable lake level regime to support riparian vegetation and avoid acidification	Trigger points of -0.75 and -1.75 m AHD for Lakes Albert and Alexandrina, respectively, to avoid acidification	None specified	None specified
MDBA	Provide a variable lake level regime to support riparian vegetation and avoid acidification	Maintain water levels within described envelope	None specified	None specified
ECD	Maintain Ramsar-described ecological character	0% change in areal extent of riparian and submerged aquatic vegetation	None specified	None specified
ECD	Maintain Ramsar-described ecological character	Maintain water levels within described envelope	None specified	None specified
ECD	Maintain Ramsar-described ecological character	No further reduction in habitat availability	None specified	None specified
DWLBC/ CLLMM EWR	Maintain Ramsar-described ecological character	Average annual salinity of 700-1000 µS/cm EC in Lake Alexandrina	three-year rolling average of at least 2,000 – 4,000 GL/y (never less than 650 GL)	95% of years
DWLBC/ CLLMM EWR	Maintain Ramsar-described ecological character	Average annual salinity of 700-1000 µS/cm EC in Lake Alexandrina	Long-term average of 5,100 GL/y	Long-term average
DWLBC/ CLLMM EWR	Maintain Ramsar-described ecological character	Maximum annual salinity of 1500 µS/cm EC in Lake Alexandrina	three-year rolling average of at least 1,000 GL/y	100% of years
DWLBC/ CLLMM EWR	Maintain Ramsar-described ecological character	Maintain water levels within described envelope	None specified	Every year
DWLBC/ CLLMM EWR	Maintain Ramsar-described ecological character	Maintain water levels within described envelope (to meet flooding requirements)	None specified	Every 3 years
MDBC	Open Murray Mouth, increased fish spawning and recruitment, and enhanced habitat for migratory waders	Maintain water levels within described envelope	None specified	None specified
Other				
ECD	Maintain Ramsar-described ecological character	Change in River Murray inflows	20,000 – 80,000 ML/day	At least every five years
ECD	Maintain Ramsar-described ecological character	Change in River Murray inflows	100,000 ML/day	At least every ten years
ECD	Maintain Ramsar-described ecological character	Low-flow periods	0 ML/day between March and August	<100 days
ECD	Maintain Ramsar-described ecological character	Low-flow periods	0 ML/day between August and March	<30 days
ECD	Maintain Ramsar-described ecological character	Fishway flows	>120 ML/day with an optimum of 900 ML/day at least between August and February	Annually
MDBC	Open Murray Mouth, increased fish spawning and recruitment, and enhanced habitat for migratory waders	Maintain discharge volumes within described envelope	Between 0 and 4 GL/month, varying seasonally	None specified

* Note that water levels were less closely-correlated with flows than salinity, so were not used as primary determinant of EWRs.
ECD is the ecological character description (Phillips and Muller 2006), DWLBC is DWLBC (2010), CLLMM EWR is Lester et al. (2010) and MDBC is MDBC (2006).

4 Assessment of meeting environmental water requirements in South Australia

This chapter:

- compares between annual and daily data provided by the MDBA (data sources described below)
- assesses the performance of environmental water requirements (EWRs) established by the MDBA in the Guide and those determined by the South Australian government against the scenarios presented in the Guide, using without development and baseline as a comparative.

The analysis of the flow data, and the different types of flow data (annual vs. daily) provided by the MDBA is important contextual information for the assessment of EWRs.

MDBA model data: flows to South Australia

Three data sources are used in this chapter for analysis of EWRs:

- annual volume data published by the MDBA in December 2010 (<http://www.mdba.gov.au/basin_plan/model-data>
- annual volume data calculated from the BigMod daily model flow data (model provided to CSIRO on 22 January 2011, BigMod model provided by MDBA for use by CSIRO)
- daily flow data from the BigMod daily model (as above).

The MDBA recommends using the first data type for assessment of EWRs. In the Guide, average annual volumes are published, which aim to meet the long-term average annual volume requirement for an asset. However, as Riverland–Chowilla EWRs are focussed on implementation of a flow regime, it is more appropriate to assess EWRs using daily data. The daily model data provided by the MDBA to CSIRO represents one possible scenario which meets asset volume requirements, and was derived post the release of the Guide. Subsequently, there are differences in the annual volumes reported in the Guide and calculated from the daily data.

Prior to assessment of EWRs against modelled data, a basic analysis comparing the annual and daily flow data (at the SA border) was undertaken, comparing all model scenarios (without development, baseline, 3000, 3500 and 4000). Across scenarios, we found that there are differences in results when using the annual and daily models, with average annual volumes being lower for the daily model as compared to the annual model (Table 4.1). However, the proportions relative to without-development flows were similar.

Table 4.1 Average annual volumes (GL) at SA border (Gauge 426200), showing percentage of without-development volumes and additional water under Guide scenarios. Results are shown for the Guide annual and BigMod daily models

Model scenario	Average annual volume	% of without development	Average annual volume	% of without development
	Guide annual model		BigMod daily model	
	GL	percent	GL	percent
without development	13,592	100%	12,968	100%
baseline	6,783	50%	6,603	51%
3000	8,661	64%	8,368	64%
3500	8,966	66%	8,644	66%
4000	9,290	68%	8,958	69%

Using the MDBA criteria for assessment of adequacy of environmental flows, under baseline, volumes at the gauge 426200 (gauge describing flows to SA) would be given a rating of poor, being < 60% of without-development flows (Table 4.1). Both model data sources return flows at this gauge to a moderate (≥60 – <80%) rating; however, the average annual volumes calculated using the daily model are lower than those calculated for the annual model.

A flow duration curve, comparing Guide scenarios with baseline and without development, shows that volumes of between 7000 ML/day and 100,000 ML/day are returned at a higher frequency than the baseline scenario. Outside these flow bounds, Guide scenarios return flows at a frequency similar to the baseline (Figure 4.1).

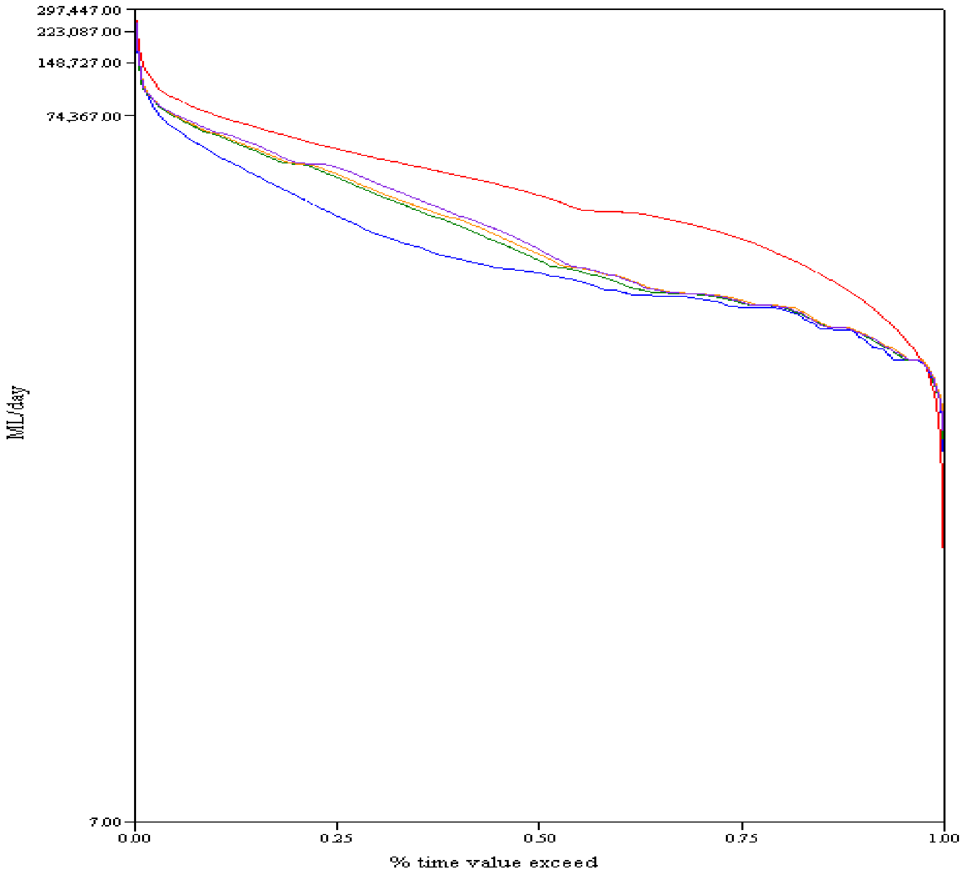


Figure 4.1 Flow duration curves (ML/day) at gauge 426200 for without-development (red), baseline (blue), 3000 (green), 3500 (orange) and 4000 (purple) scenarios

When plotting flows as recurrence intervals, high flows (~100,000 ML/day and above) are returned less frequently than that of the baseline (Figure 4.2).

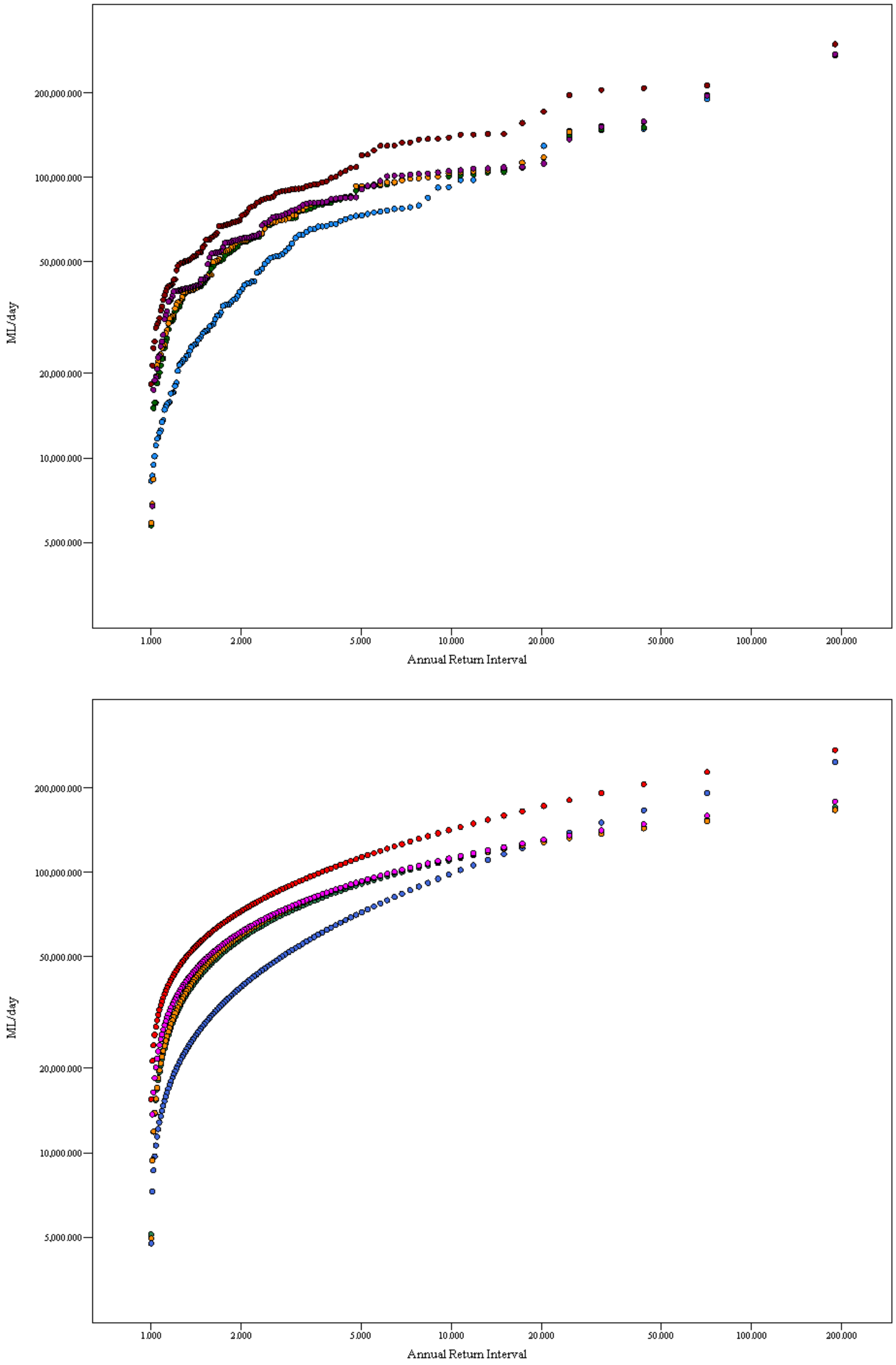


Figure 4.2 Flow recurrence intervals (ML/day) at gauge 426200 showing flood peaks (top) and Log Pearson 3 distributions (bottom) for without-development (red), baseline (blue), 3000 (green), 3500 (orange) and 4000 (purple) scenarios

4.1 Hydrologic indicator site: Riverland–Chowilla

The assessment of Riverland–Chowilla references volume and flow requirements at the SA border gauge (426200) and is based on the BigMod daily model data. As the MDBA and SA EWRs are specific to this gauge, and the purpose of this document is a review of the EWRs against the Guide, we have used this gauge for the analysis documented in this chapter.

Two forms of assessment are documented for the Riverland–Chowilla site. The first assessment quantifies the mean annual volume requirement (GL/year) to meet EWRs. This analysis is consistent with the approach used by the MDBA in quantifying volume requirements for meeting asset needs. The second form of analysis quantifies the ability of the Guide scenarios to meet EWRs as a flow regime. This analysis reflects that the flow requirements will vary inter-annually. This analysis has not been done by the MDBA.

4.1.1 Average annual volumes

Additional average annual flows at the SA border (gauge 426200) were calculated using eFlow Predictor Version 2.0.3 (eWater CRC). eFlow Predictor is designed to help environmental water managers predict the volumes that will meet an ecosystem's flow requirements in regulated rivers, and can assist in designing flow series and delivery of flows (see <http://www.ewater.com.au/products/ewater-toolkit/eco-tools/eflow-predictor/> for more information on this tool). Assessment was conducted against MDBA and SA EWRs. Volume requirements to meet EWRs are reported as having low and high risk ranges. These ranges relate to preferred and maximum recurrence intervals, specified in EWRs (see Appendix). The preferred volume represents a 'low risk' in meeting target requirements, and maximum flooding represents a 'high risk', where low risk is the wetting at the preferred interval, and high risk is wetting at the maximum tolerance interval.

Using eFlow Predictor, the average annual volumes required at the South Australian border to meet EWRs were quantified using different three rule types. These are:

- Force: where the event is forced to mimic the frequency and duration of the EWR as specified. Although this is an unrealistic scenario, it provides an upper limit of what volumes are required for meeting EWRs.
- Mimic frequency: where the event is set to mimic a return frequency of the without-development flows, and the duration of the event is forced to meet the EWR as specified. This option augments flows such that they mimic the frequencies of the without-development flow sequence.[2]
- Mimic event: where the event is set to mimic a return frequency and the duration of the event of the without-development flow. For a given year, additional water compared to what would have been there in the without-development sequence cannot be generated.

eFlow Predictor requires a reference and base flow series, and a set of flow rules, which are implemented within the base flow series, and can be unconstrained or constrained using the rule types described. The outputs are an alternative flow series, an assessment of the base, reference and 'alternative' or augmented flow series against flow rules, and a quantification of the average annual volumes required to meet flow rules.

For Riverland–Chowilla, in quantifying volumes, the baseline data is used as the base flow series, and the without-development data is used as the reference flow series. Consequently, additional volumes for the environment would be returned on top of the existing baseline arrangements. This assumes current operations in the Basin, which is likely to lead to a conservative estimate in quantifying additional flows. However, as the purpose of this section is to review the Guide, and this was the approach used in developing the Guide, it provides an insightful analysis of the Guide process. In replicating the process, it also allows us to test the sensitivity of assumptions used for each of the rule types, and the sensitivity of MDBA and SA EWRs used in development of the Guide.

Outcomes of analysis, shown in Table 4.2 and Table 4.3, suggest that MDBA EWRs are met under all Guide scenarios (consistent with the findings of the MDBA). This is regardless of the rule types used in the set up of eFlow Predictor. For

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[2] For each day of the reporting period, eFlow Predictor checks to see if the rule would have been met under the natural flow and current flow. If the rule is not met under the current flow, but would have been met under natural flow then eFlow Predictor augments the current flow to try and achieve the same frequency of rule success as would have been achieved naturally. This rule was used by the MDBA for flow augmentations.

SA EWRs, by forcing events, average annual volume requirements are higher than under all Guide scenarios (Table 4.2). Average annual volumes could be met under the 4000 scenario (low risk), using mimicking of event frequencies in the without-development scenarios, and extending durations and requirements could be met under Guide scenarios when event frequency and durations in without-development scenarios are mimicked.

Table 4.2. Average annual volumes required at the SA border to meet MDBA and SA Riverland–Chowilla EWRs under one forcing and two mimicking flow prediction rule types

Rule type	Rule type setting to meet requirements	MDBA EWRs		SA EWRs	
		Average annual volume requirement*			
		High risk	Low risk	High risk	Low risk
		GL		GL	
1	Force events – at the frequency and duration as stated	7922	8392	9208	9970
2	Mimic events without-development frequency, extend durations – frequencies of events are set to mimic without-development model frequencies and the event is extended to meet the EWR duration	7647	8030	8481	8703
3	Mimic events at without-development frequency and durations - targets mimic without-development model frequencies and the event durations mimic the without-development hydrograph	7563	7785	8095	8254

* Average annual volumes as calculated using the BigMod daily model

Table 4.3 Meeting average annual volumes required at the SA border to meet MDBA and SA Riverland–Chowilla EWRs under the Guide scenarios for each of the rule types described in Table 4.2

	MDBA EWRs						SA EWRs					
Rule type	3000		3500		4000		3000		3500		4000	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1 – force	◆	◆	◆	◆	◆	◆	●	●	●	●	●	●
2 – mimic	◆	◆	◆	◆	◆	◆	●	●	◆	●	◆	◆
3 – mimic	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

◆ indicates that the required average annual volumes are met; and ● indicates that they are not met

If selecting the appropriate for Riverland–Chowilla, there are going to be implications for operations in delivery of flows and in the ability to meet EWRs:

- Forcing of events represents the scenario with the greatest likelihood of meeting the objectives describing ecological character stated of the asset. However, the consequence of this rule set is that on average, events are met at a higher frequency than that of the without-development scenario. It would be difficult to meet these volume requirements operationally, especially during dry periods.
- The mimicking of without-development event frequencies represent EWRs being met on average over the modelling period, but with events being clustered, and occurring more frequently in wetter periods than in dry periods. This volume does not return the full character of the without-development flows, just the representative timing and peaks of events specified for the EWRs. The duration of these events are extended (where needed) to meet the EWR, often beyond the equivalent duration of flows in the without-development scenario. This ensures that the event is successful in meeting species lifecycle requirements. Extending durations prevents false starts, such as events that are too short to fulfil waterbird breeding through to successful fledging. An on average return of events represents the most realistic operational scenario taking climate variability into consideration. To extend the event durations beyond what would have occurred naturally, it is likely that water would need to be sourced from storages.
- The mimicking of specified EWRs at without-development frequencies with without-development durations is the volume least likely to meet ecological character objectives. This volume does not return the full character of the without-development flows, just the representative timing and peaks of events specified for the EWRs. Events are not extended to meet species requirements, but mimic the equivalent modelled without-development event. Subsequently, the duration aspect of the flow requirements for target communities may not be met.

To determine how the event frequencies change when events are forced versus mimicked, outcomes are shown against EWR specifications, in Table 4.4 and Table 4.5. These outcomes represent changed frequencies in event occurrence as an average over the 114-year model period. Where the frequencies are ‘mimicked’ against without-development flows, the average event occurrence is bounded within the maximum or high risk frequency between events. None of the EWRs fall outside the maximum (high risk) preferred wetting frequency. This indicates that EWRs are still likely to achieve the target, although sometimes with a higher degree of risk, relative to the EWR specification.

Table 4.4 Riverland–Chowilla EWRs from MDBA (2010b), showing total volumes for low and high risk scenarios. Frequencies of targets being met are given under without-development, augmented flow series, with force and mimic settings in eFlow Predictor

EWR	Flow	Duration	Frequency (low risk)	Frequency (high risk)	Without-development frequency	Force	Mimic
	ML/d	days	years				
Maintain 80% of the current extent of wetlands in good condition	40,000	30 d total	1-in-1	1-in-2	1-in-1	1-in-1	1-in-1
Maintain 80% of the current extent of red gum forest in good condition	40,000	90 d total	1-in-2	1-in-3	1-in-2	1-in-2	1-in-2
Maintain 80% of the current extent of red gum forest in good condition	60,000	60 d total	1-in-3	1-in-5	1-in-3	1-in-3	1-in-3
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 d total	1-in-5	1-in-7	1-in-3	1-in-3	1-in-5
Maintain 80% of the current extent of black box woodland in good condition	100,000	21 d total	1-in-7	1-in-9	1-in-5	1-in-5	1-in-7
Maintain 80% of the current extent of black box woodland in good condition	125,000	7 d total	1-in-9	1-in-11	1-in-6	1-in-6	1-in-10

Table 4.5 Riverland–Chowilla EWRs from DWLBC (2010), showing total volumes for Low and High risk scenarios. Frequencies of targets being met are given under without-development, augmented flow series, with force and mimic settings in eFlow Predictor

Objective	Flow required	Duration	Preferred timing	Preferred frequency (low risk)	Maximum time between events (high risk)	Without-development frequency	Force	Mimic
Temporary Wetlands								
Maintain and improve majority of the lower elevation temporary wetlands in healthy condition (20% of all temporary wetlands)	40,000 ML/day (flow required to inundate 20% of wetlands as per FIM III)	90 days	August to January	1-in-2	3 years	1-in-2	1-in-2	1-in-2
Maintain and improve 80% of temporary wetlands in healthy condition (includes lower and higher elevation temporary wetlands)	80,000 ML/day	>30 days	June to December	1-in-4	5 years	1-in-3	1-in-2	1-in-3
Inundation of lower elevation temporary wetlands (~ 20% of temporary wetlands) for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000 ML/day	90 days	Commencing in July to September	1-in-2	3 years	1-in-2	1-in-3	1-in-2
Inundation of temporary wetlands (~80% of temporary wetlands) for bird breeding events and frog breeding events	80,000 ML/day	>30 days	Commencing in August to September	1-in-4	5 years	1-in-3	1-in-3	1-in-4
Red gum								
Maintain and improve the health of 80% of the River Red Gum woodlands and forests (adult tree survival)	80,000 ML/day to 90,000 ML/day	>30 days	July to January	1-in-4	5 years	1-in-3	1-in-2	1-in-3
Successful recruitment of cohorts of River Red Gums, ie recruitment must equal or exceed River Red Gum mortality	80,000 ML/day	2 months	August to October	In successive years (at least 2 consec. for successful recruitment)	na	1-in-16	1-in-28	1-in-23
Waterbirds								
Provide habitat for waterbirds breeding events	70,000 ML/d	60 days	Starts August to October	1-in-4	6 years	1-in-3.5	1-in-3	1-in-4
Black box								
Maintain and improve the health of ~50% of the Black Box woodlands	85,000 ML/d	30 days	Spring or summer	1-in-5	8 years	1-in-4	1-in-4	1-in-5
Successful recruitment of cohorts of Black Box at lower elevations, , ie recruitment must equal or exceed River Red Gum mortality	85,000 ML/d	20 days	Spring or early summer	Consec. Years	na	1-in-3	1-in-4	1-in-4
Maintain and improve the health of ~60% of the Black Box woodlands	100,000 ML/d	20 days	Spring or summer	1-in-5	8 years	1-in-5	1-in-4	1-in-7
Maintain and improve the health of 80% of the Black Box woodlands	>100,000 ML/day	20 days	Spring or summer	1-in-6	8 years	1-in-5	1-in-4	1-in-7
Successful recruitment of cohorts of Black Box at higher elevations, ie recruitment must equal or exceed River Red Gum mortality	>100,000 ML/day	20 days	Spring or early summer	Consec. Years	na	1-in-5	1-in-16	1-in-7

Objective	Flow required	Duration	Preferred timing	Preferred frequency (low risk)	Maximum time between events (high risk)	Without-development frequency	Force	Mimic
Lignum								
Maintain and improve the health of ~50% of the Lignum Shrubland	70,000 ML/day	30 days	Spring or early summer	1-in-3	5 years	1-in-3	1-in-2	1-in-3
Maintain and improve the health of 80% of the Lignum Shrubland	80,000 ML/day	30 days	Spring or early summer	1-in-5	8 years	1-in-3	1-in-2	1-in-3.5
Maintain lignum inundation for Waterbird breeding events	70,000 ML/day	60 days	Starts August to October	1-in-4	6 years	1-in-4	1-in-3	1-in-4
Mosaic habitat								
Provide variability in flow regimes at lower flow levels	Variable flows from Pool to 40,000 ML/day	Variable	Annually	1-in-1	na	1-in-1	1-in-1	1-in-1
Provide mosaic of habitats, ie larger proportions of various habitat types are inundated	60,000 ML/day	60 days	Spring or early summer	1-in-3	4 years	1-in-3	1-in-2	1-in-3
	70,000 ML/day	60 days	Spring or early summer	1-in-4	6 years	1-in-4	1-in-3.5	1-in-6
	80,000 ML/day	>30 days	Spring or early summer	1-in-4	5 years	1-in-3	1-in-2	1-in-3.5
	90,000 ML/day	30 days	Spring or early summer	1-in-5	6 years	1-in-4	1-in-4	1-in-6
Bird breeding								
Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000 ML/day	90 days	Commencing in July to September	1-in-2	3 years	1-in-2	1-in-3	1-in-2
Maintain lignum inundation for Waterbird breeding events	70,000 ML/day	60 days	Starts August to October	1-in-4	6 years	1-in-3.5	1 in3.4	1-in-4
Provide habitat (River Red Gum communities) for waterbirds breeding events	70,000 ML/day	60 days	Starts August to October	1-in-4	6 years	1-in-3.5	1 in3.4	1-in-4
Inundation of temporary wetlands for larger scale bird breeding events	80,000 ML/day	>30 days *	Commencing in August to September	1-in-4	5 years	1-in-3	1-in-3	1-in-3.5
Fish								
Provide variability in flow regimes at lower flow levels (in channel)	Variable flows from Pool to 40,000 ML/day	Variable	Annually	1-in-1	na	1-in-3	1-in-1	1-in-1
Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000 ML/day	90 days	Commencing in July to September	1-in-2	3 years	1-in-2	1-in-3	1-in-2
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 ML/day	>30 days	Commencing in August to September	1-in-4	5 years	1-in-3	1-in-3	1-in-3.5

4.1.2 Conclusions: average annual volumes for Riverland–Chowilla

Given the sensitivity of setting rules for quantifying average annual volumes to the Riverland–Chowilla, we recommend that the mimicking of events and forcing of durations is the optimal strategy. This strategy is realistic in terms of operations, and will lead to fewer failed events. As the SA EWRs are the preferred (see Section 2), Riverland–Chowilla requirements are most likely to be achieved uner the 4000 scenario. Whether the flow regime requirements of Riverland–Chowilla are met under this scenario is the focus of the next section.

4.1.3 Flow regime requirements

Assessment of flow requirements for Riverland–Chowilla using average annual volumes is a sub-optimal approach. Given the changing frequencies, timing and durations of events required to meet EWRs, spells analysis (a time series analysis of flows) is a more appropriate assessment methodology. Spells analysis is used to determine the frequency of occurrence of an event in a daily flow series, such as the frequency of event requirements in EWRs in Guide scenarios. For this section, spells analysis was conducted using eFlow Predictor version 2.0.3 (eWater CRC). Performance measures used for comparisons are baseline and without-development flows, and against the flow requirements (timing, frequency, duration, seasonality) as expressed within the MDBA or SA EWRs. We found that regardless of the EWRs chosen, event requirements are not met for any of the Guide scenarios (Table 4.6).

Table 4.6 Number of times MDBA and SA Riverland–Chowilla EWRs are met under the Guide scenarios, relative to without-development and baseline flows, and relative to the frequency specified in the EWR

		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 4.4)									
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 4.5									
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 Table A.1 and Table A.2 in Appendix A for their full description.
** EWR frequency reset to match without-development targets

All EWRs are met at a lower frequency than without-development, although the majority represent an improvement from the baseline. For EWRs which require flows of 40,000 ML/day, EWRs are specified as a higher frequency relative to the event occurrence in the without-development flow series. This reflects a limitation in the set-up of eFlow Predictor, where events must be specified as a whole number, rather than a criticism of that specific requirement.

Incremental improvements are found for each of the Guide scenarios up to and including flow requirements of 80,000 GL/day. All these targets also represent an improvement from the baseline, but are not met at the target frequency specified. Flows of greater than ≥100,000 ML/day are met less frequently than the baseline. These flow requirements are aimed at meeting black box flow requirements, suggesting that black box communities are more likely to be vulnerable to decline under the Guide scenarios.

In the spells 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 always met under the without-development scenario. However, year-by-year analysis of the without-development model data shows that the events are stochastic, and are clustered according to climate variability. Consequently, there are periods that exceed frequency of returns specified in EWRs, particularly during dry periods (Table 4.7). Whilst the period between events do exceed the maximum time specified in EWRs (high risk frequency), the without-development model has shorter periods between events than the other modelling scenarios. Negative numbers in Table 4.7 indicate that the EWR is not exceeded, and is wetted under (less than) what is required by the given number of years.

Table 4.7 Maximum period (in years) between events (Between) and the number of years that exceed the maximum (high risk) period requirement (Exceed) for Riverland–Chowilla MDBA and SA EWRs under the without-development, baseline and Guide scenarios. EWRs are shown as independent (non-repeated) requirements

	Scenario									
	without development		baseline		3000		3500		4000	
	between	exceed	between	exceed	between	exceed	between	exceed	between	exceed
	years									
MDBA EWRs										
40 GL, 30 days, 1-in-1	3	1	12	10	4	2	4	2	4	2
40 GL, 90 days, 1-in-2	3	0	19	16	11	8	7	4	7	4
60 GL, 60 days, 1-in-3	6	2	19	15	18	14	18	14	18	14
80 GL, 30 days, 1-in-5	9	3	17	11	17	11	16	10	16	10
100 GL, 21 days, 1-in-7	4	–4	17	9	31	23	31	23	31	23
125 GL, 7 days, 1-in-9	4	–6	25	15	29	19	29	19	29	19
SA EWRs										
40 GL, 90 days, 1-in-2	4	1	20	17	6	3	6	3	6	3
40 GL, 60 days, 1-in-1	4	1	12	9	8	5	8	5	8	5
60 GL, 60 days, 1-in-3	6	2	30	26	28	24	28	24	26	22
70 GL, 60 days, 1-in-4	8	2	20	14	18	12	18	12	18	12
70 GL, 30 days, 1-in-3	5	0	20	15	12	7	12	7	12	7
80 GL, 30 days, 1-in-4	10	5	19	14	19	14	18	13	18	13
80 GL, 30 days, 1-in-4	8	3	19	14	19	14	18	13	18	13
85 GL, 30 days, 1-in-5	7	2	19	14	30	25	30	25	30	25
90 GL, 30 days, 1-in-5	8	2	19	13	30	24	30	24	30	24
100 GL, 20 days, 1-in-5	6	–2	31	23	31	23	31	23	31	23

Periods between events of 80,000 ML/day have the same periods between events under the Guide scenarios as the baseline, and generally represent no improvement, and for some EWRs, a deterioration from the baseline. These EWRs are aimed at meeting the requirements of red gum, lignum, black box and temporary wetland inundation requirements.

These analyses demonstrate that the Guide scenarios do not deliver flows in a regime that is suitable for satisfying EWRs, whereby none of the target requirements are met.[3] For flows of 80,000ML/day and above, the scenarios perform worse than the baseline.

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[3] Note: The MDBA does not recommend the use of model data at time scales other than annual totals or long term annual averages.

Without ecological response modelling, it is difficult to predict the likely ecological outcomes of the flow scenarios with any certainty.

4.1.4 Quantifying additional flow requirements

Considering the MDBA scenarios, additional average volumes can be specified to meet EWRs (using the approach described in Section 3.1). An example of additional volumes required at the border to meet EWRs, relative to without development and baseline models (Figure 4.3).

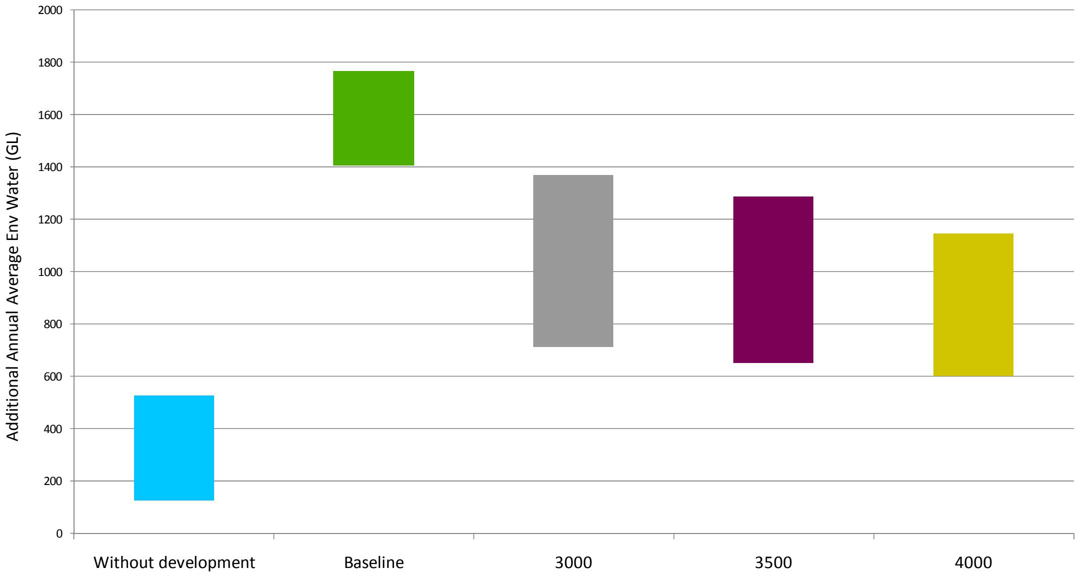


Figure 4.3 Additional average annual volumes required to meet MDBA Riverland–Chowilla EWRs (ranging from Force = 1 year to Mimic without-development frequencies), given Guide scenarios

The additional water to meet the without-development scenario represents the first MDBA EWR, which is specified in eFlow Predictor as being a higher frequency (1-in-1) than specified in the Guide. This is the nature of the software setup rather than a consequence of the EWR. Effectively, this volume could be subtracted from the other reported volumes in Figure 4.3.

Given that the Guide scenarios provide the required volumes to meet EWRs, an alternative strategy is to determine how the additional environmental water can be delivered in a regime that meets the Riverland–Chowilla water requirements (see Part III - 'Delivery of environmental water requirements').

4.1.5 Conclusions: flow regime requirements

A summary of findings for the Riverland–Chowilla EWRs are shown in Table 4.8.

Table 4.8 Assessment of meeting MDBA and SA Riverland–Chowilla EWRs under the Guide scenarios

	MDBA EWRs			SA EWRs		
Data source	Scenario					
	3000	3500	4000	3000	3500	4000
Riverland–Chowilla						
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

◆ 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.

Guide scenarios do not meet the flow regime requirements specified by the MDBA or SA EWRs. Whilst volume is sufficient under all scenarios to meet MDBA EWRs, SA EWRs are only met under the 4000 (daily flow) scenario. A redistribution of flows as per the flow regime requirements specified is required to meet EWRs.

Using the daily data, we found that event sizes of ≥100,000 ML/day, occur less frequently than the baseline. On average, these event requirements would be met by the without-development scenario. EWRs that are negatively influenced by this outcome are black box, and under Guide scenarios, this community is likely to become increasingly isolated on the floodplain.

Considering the analysis of year-to-year event frequencies for the without-development scenario, there are periods between events where maximum durations for event frequencies occur. These periods between events are noticeably greater under baseline and Guide scenarios. The periods between events are the same or greater for flows of ≥80,000 ML/day. These EWRs are aimed at meeting the requirements of red gum, lignum, black box and temporary wetland inundation requirements.

4.1.6 Sensitivity of Riverland–Chowilla targets: duration

In determining EWRs, the knowledge-base for determining the flows at the SA border to inundate target vegetation communities is strong. This was demonstrated in Section 2.1, where flow requirements in EWRs were consistent, being based on the River Murray Flood Inundation Model (RIM-FIM) (Overton et al., 2006). In contrast, the knowledge of duration of volumes required at the border to determine duration of inundation within Riverland–Chowilla is not well characterised. In this way, RIM-FIM is not a substitute of a hydrodynamic model.

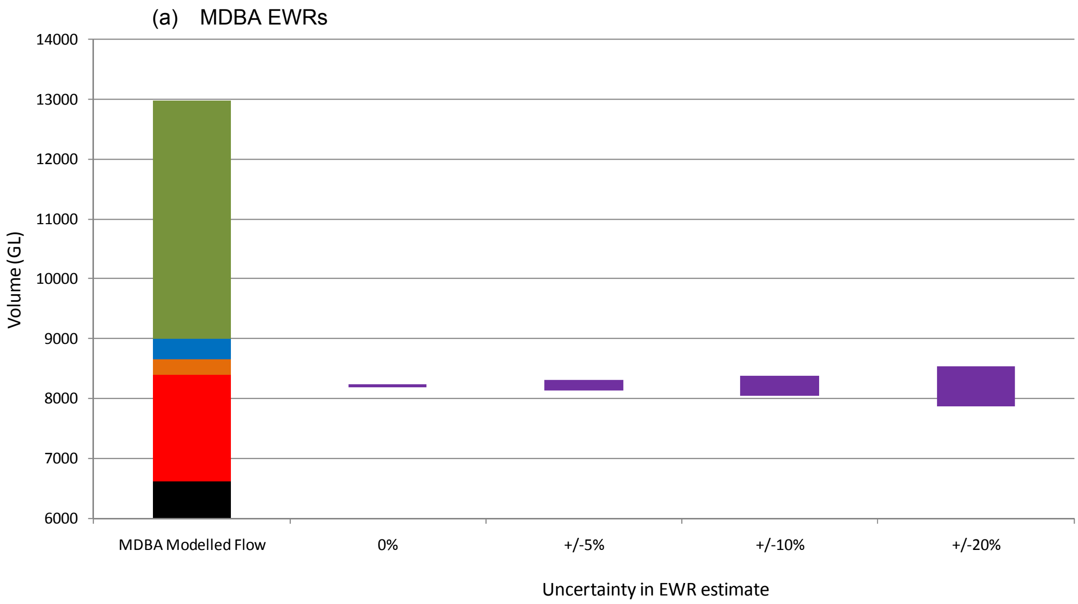
Consequently, to assess the sensitivity of the target to this knowledge uncertainty, analyses focussed on modifying the duration requirements of targets by ±20%, 10% and 5%. This sensitivity analysis can also act as a surrogate for uncertainties in the flow models.

The results of sensitivity analyses are presented as changes in volumes required at the SA border to meet EWRs, and the frequency at which EWRs are met under the Guide scenarios.

4.1.7 Average annual volumes

The average annual volume requirements to meet EWRs are quite insensitive to Guide scenarios. For MDBA EWRs, only when duration requirements are increased by 20% would the 3500 scenario be required to meet average annual volume requirements (Figure 4.4a).

For SA EWRs, an increase in durations by 10% no longer meets the 4000 scenario (Figure 4.4b). Reductions in 10% and 20% result in requirements being met under the 3500 and 4000 scenarios respectively.



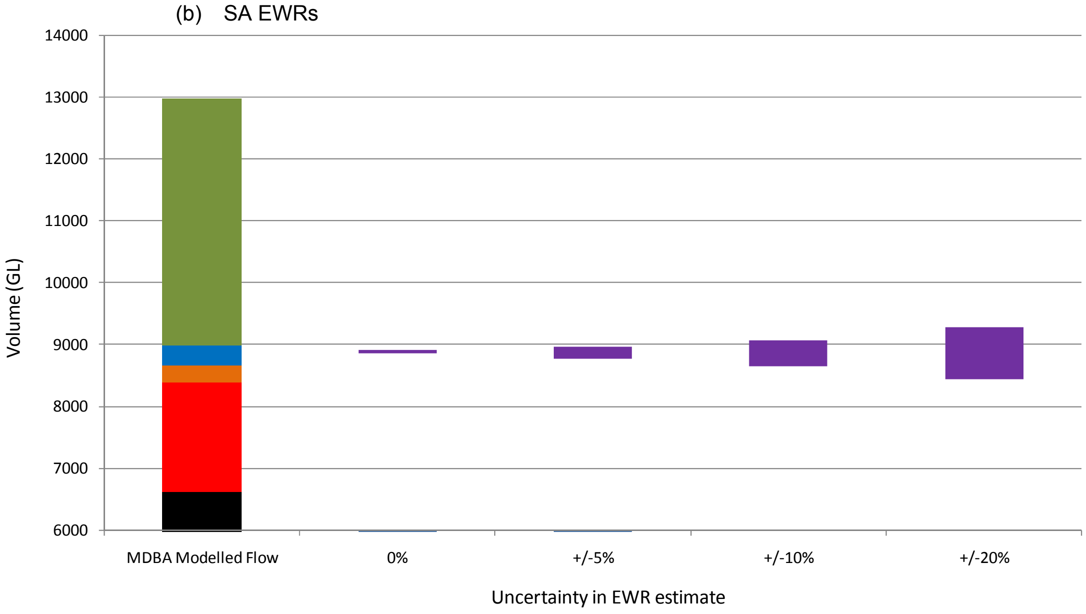


Figure 4.4 Volume requirements at the SA border to meet the (a) MDBA and (b) SA Riverland–Chowilla EWRs, considering changes in durations by ±5%, 10% and 20%, under the baseline (black), 3000 (red), 3500 (orange), 4000 (blue) and without-development (green) scenarios respectively. Events are modelled to mimic without-development frequencies, and events are extended in duration to meet flow requirement. Sensitivity volume outcomes are shown in purple

The performance of EWRs is only improved marginally when durations are decreased. For MDBA EWRs (Table 4.9), incremental improvements in performance against the requirement are seen under the 3500 scenario (80 GL) when duration requirements are decreased by 20%, and under the 4000 scenario (60 GL and 80 GL), and only when duration requirements are decreased by 10%. For SA EWRs (Table 4.10), no notable improvements are found.

Table 4.9 MDBA Riverland–Chowilla EWRs: the number of times event occurs, relative to the EWR frequency, considering changes in durations by ±5%, 10% and 20%, under the Guide scenarios

EWR	EWR frequency	–20%	–10%	–5%	0	5%	10%	20%
3000								
40 GL, 30 days, 1-in-1	113	71	67	65	65	63	62	62
40 GL, 90 days, 1-in-2	56	47	43	42	37	33	31	28
60 GL, 60 days, 1-in-3	37	25	22	22	22	22	21	16
80 GL, 30 days, 1-in-5	22	19	15	15	14	13	13	13
100 GL, 21 days, 1-in-7	16	6	6	6	6	6	6	5
125 GL, 7 days, 1-in-9	12	5	5	5	5	5	5	5
3500								
40 GL, 30 days, 1-in-2	113	71	70	67	67	66	66	64
40 GL, 90 days, 1-in-3	56	48	45	44	41	34	32	29
60 GL, 60 days, 1-in-4	37	26	24	23	22	22	20	16
80 GL, 30 days, 1-in-6	22	21	16	16	16	14	14	13
100 GL, 21 days, 1-in-8	16	7	7	7	7	7	6	6
125 GL, 7 days, 1-in-10	12	5	5	5	5	5	5	5
4000								
40 GL, 30 days, 1-in-3	113	72	72	70	70	70	70	68
40 GL, 90 days, 1-in-4	56	51	48	46	45	38	34	31
60 GL, 60 days, 1-in-5	37	33	31	28	26	23	22	20
80 GL, 30 days, 1-in-7	22	21	18	18	18	17	17	15
100 GL, 21 days, 1-in-9	16	6	6	6	6	6	6	6
125 GL, 7 days, 1-in-11	12	5	5	5	5	5	5	5

Table 4.10 SA Riverland–Chowilla EWRs: the number of time event occurs, relative to the EWR frequency, considering changes in durations by ±5%, 10% and 20%, under the Guide scenarios

EWR	EWR frequency	–20%	–5%	–10%	0	5%	10%	20%
3000								
40 GL 90 days	57	44	42	37	37	28	26	24
80 GL 30 days (Aug_Jan)	28	19	16	15	14	13	13	13
80 GL 30 days (Aug_Sept)	28	19	15	14	13	12	12	11
70 GL 60 days	28	17	15	13	12	11	10	7
85 GL 30 days	22	11	10	9	9	9	9	9
100 GL 20 days	22	6	7	6	6	6	6	6
70 GL 30 days (1-in-3)	38	28	27	25	23	22	20	20
40 GL 60 days	113	53	56	49	49	49	48	47
60 GL 60 days	38	23	18	17	16	16	14	12
90 GL 30 days (1-in-5)	22	9	9	9	9	9	7	6
3500								
40 GL 90 days	57	46	42	39	39	32	28	26
80 GL 30 days (Aug_Jan)	28	21	16	16	16	14	14	13
80 GL 30 days (Aug_Sept)	28	21	15	15	15	13	13	11
70 GL 60 days	28	18	15	15	13	11	10	8
85 GL 30 days	22	13	10	10	9	9	9	9
100 GL 20 days	22	7	7	7	7	7	7	6
70 GL 30 days (1-in-3)	38	29	27	26	24	23	23	20
40 GL 60 days	113	56	56	55	51	51	50	48
60 GL 60 days	38	23	18	17	16	16	15	12
90 GL 30 days (1-in-5)	22	9	9	9	9	9	7	7

EWR	EWR frequency	–20%	–5%	–10%	0	5%	10%	20%
4000								
40 GL 90 days	57	48	46	43	43	39	33	26
80 GL 30 days (Aug_Jan)	28	21	18	18	18	17	17	15
80 GL 30 days (Aug_Sept)	28	21	18	18	18	14	14	13
70 GL 60 days	28	18	16	15	15	12	11	10
85 GL 30 days	22	15	13	12	11	11	10	9
100 GL 20 days	22	6	6	6	6	6	6	6
70 GL 30 days (1-in-3)	38	33	30	28	27	23	22	21
40 GL 60 days	113	60	59	58	54	54	53	51
60 GL 60 days	38	29	25	23	19	17	17	14
90 GL 30 days (1-in-5)	22	11	10	9	9	9	9	7

4.1.8 Conclusions: sensitivity testing

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%.

4.2 Hydrologic indicator site: Coorong, Lower Lakes, and Murray Mouth

In order to assess whether the Guide scenarios met MDBA and SA Government EWRs for the CLLMM, output from the daily flow model was aggregated to provide a sequence of total annual barrage flows. For each scenario, these flows were compared to each of the MDBA and SA Government targets individually and instances where the flow volumes were insufficient to meet the target were identified. In cases where targets were specified to be met 95% of the time, the first 6 years (5.3%) in the sequences in which the target was not met were selected to represent the 5% of years in which the target could fail (and so were excluded from further analyses). For each year in which targets were not met (excluding the allowed failure rate of 5% where relevant), the number of interventions required and the average volume of each to redress the shortfall in barrage flows was calculated (see Appendix B). For example, the baseline scenario fails to meet the target of maintaining a three-year rolling average barrage flow of at least 2000 GL/year. So, the first 6 instances in which the three-year rolling average fell below 2000 GL/year were discounted (to give a 5% allowable failure rate). For remaining instances where the three-year rolling average was below 2000 GL/year, the difference between 2000 GL/year and the actual volume delivered was calculated. The number of instances in which additional water was required (18 for this example; Table B.1) and the average volume of additional water required to meet the shortfall (here, 700 GL/year require intervention; Table B.1) was calculated to provide an indication of how far from meeting the target each scenario was.

None of the Guide scenarios, as simulated, are predicted to meet all CLLMM-specific targets (Table 4.11). Furthermore, no Guide scenario is predicted to meet all MDBA targets either, with both the 3500 GL and 4000 GL scenario failing to achieve a three-year rolling average barrage flow of 1000 GL/year in 100% of years. All other MDBA targets are met under all Guide scenarios. Most of the SA Government targets are not met under any of the Guide scenarios. High-flow targets are met under all scenarios, but low-flow targets are not, even under the 4000 GL scenario. It should also be noted that all CLLMM-specific targets are met under the without-development scenario, while none are met under the baseline scenario. Thus, all Guide scenarios represented an improvement on baseline conditions, but do not replicate the effect of without-development flows. The higher the amount of additional environmental water, the closer the scenario came to meeting the specified targets.

Table 4.11 Assessment of meeting the MDBA and SA CLLMM EWRs under the without-development, baseline and Guide scenarios, simulated using the BigMod daily model

	Scenario				
Target	without-development	baseline	3000	3500	4000
MDBA targets					
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	✓	×	×	×	×
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	×	×	✓	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	×	✓	✓	✓
4000 GL – previous year in 95% of years	✓	×	×	✓	✓
6000 GL – 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	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	×	×	×	×
3000 GL – previous 2 years (adjusted) in 100% of years	✓	×	×	×	×
SA minimum flow (max of three previous targets) in 100% of years	✓	×	×	×	×
6000 GL/y 1-in-3 year frequency	✓	×	✓	✓	✓
10,000 GL/y 1-in-7 year frequency	✓	×	✓	✓	✓

'✓' indicates the target was met. '×' indicates where the target was not met. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Refer to Section 3.2.1 for a description of each MDBA and SA Government target.

The method of flow delivery, rather than the overall volume of water, is likely to be the primary driver for the Guide scenarios failing to meet many of the targets. The majority of targets, particularly under the 3500 and 4000 scenarios, are not met on only one or two occasions (See Table B.1 in Appendix B for the number of occasions on which each target is not met and the average volume of water required to meet that target). This suggests that, for the vast majority of flow conditions, the scenarios are able to meet the targets, but in very low-flow years, insufficient water is provided. This is further supported because increasing the volume in successive scenarios (i.e. from 3000 to 3500 to 4000) does not meet requirements, despite the volume of water required to meet the target being within the range identified to meet the shortfall. Thus, simply specifying an average flow volume is not necessarily sufficient to ensure that the targets are met. This applies both for MDBA and SA Government targets. In addition to an average annual volume, minimum flow volumes also need to be specified by the MDBA to ensure that environmental objectives are met. DWLBC (2010) specifies minimum flow volumes that could be applied by the MDBA.

By redistributing the environmental water allocated across years, it is possible that the additional volumes specified here (i.e. 3000, 3500 and 4000) would meet additional targets for the CLLMM. While it was not possible to investigate the effect of a redistribution of environmental flows as a part of this review (as we did not have the capacity to alter Guide scenarios in this manner), it is possible to estimate whether the additional flow volumes would be sufficient if optimally allocated. The highest additional volume is likely to be sufficient to meet the CLLMM-specific targets, if it was optimally allocated. In each instance where the 4000 scenario failed to meet targets, there were only one or two occasions where this was the case. Thus, it is likely that changing the pattern of flow delivery may mean that the targets can be achieved without additional water. This is also possible under the 3500 scenario, where targets were again not met in either one or two years (although volumes of water required to meet the shortfall were higher than those for the 4000 scenario). The scenario simulating an additional 3000 GL of environmental water fails to meet a higher number of the targets overall, and fails to meet them on more occasions (up to four), so is less likely to be able to be redistributed.

How might uncertainty in the models affect the ability of the Guide scenarios to meet targets for the CLLMM?

Within the Guide to the proposed Basin Plan, MDBA specified several ranges over which factors such as climate change or model uncertainty may affect water availability in the Basin. The nominated amount of uncertainty varied, depending on the source (e.g. 3% reduction in SDLs to account for climate change and up to 20% to account for model uncertainty). In order to assess the potential effect of uncertainty on the ability of the scenarios to meet targets for the CLLMM, we took a risk-based approach.

It is highly unlikely that any single source of uncertainty would be evenly distributed over the range of flow volumes. However, it is impossible to specify exactly how and when each element of uncertainty (e.g. climate change) may act. Therefore, in order to get a preliminary indication of how sensitive our assessment of the Guide scenarios was to uncertainty, we altered the targets by +5%, +10% and +20%, increasing the overall volume of water set as the environmental water requirement in each case. Because uncertainty may work in either direction, we also altered the targets by subtracting corresponding amounts. This created six sets of altered flow targets (±5%, 10% and 20%) against which each scenario was assessed. Targets were adjusted (as opposed to altering flow sequences, for example) because all targets were developed using the same models used by MDBA, so these would also be subject to the same sources of uncertainty (at least). This analysis provides crude bounds around the effect of changing target volumes on whether or not those targets are met under each scenario, so can be thought of as a semi-quantitative assessment of the risk associated with those scenarios. That is, where targets are met under all levels of uncertainty, there is a low risk of failing to meet that target. As the failure rates increase for the different levels of sensitivity, the relative risk of failing to meet that target under that scenario also increases.

The volume associated with each target was altered (i.e. instead of altering return frequencies, for example). Then, a similar assessment to that described above was applied to determine whether each altered set of targets was met, how often and how much additional water may be required for each scenario. Tables outlining each combination of scenario and altered target sequence are presented in Appendix B (Table B.1 to Table B.7), including the number of times each combination fails to meet the target and the average additional volume of water required to meet the shortfall, where relevant.

Each of the MDBA targets show a different level of risk for the different flow volumes (Figure 4.5). Under baseline flow conditions, no MDBA target is met under any level of uncertainty, except for the target for a long-term average of 5100 GL/year, which has a high level of risk associated with it (i.e. the target is not met when most levels of uncertainty are considered). That target (5100 GL/year long-term average) and the target of a three-year rolling average of 2000 GL/year are met under all other scenarios at all levels of uncertainty investigated, so can be considered low risk. The target of a three-year rolling average of 1000 GL/year in 100% of years is only met under the without-development scenario, and is then met for all levels of uncertainty. The salt export target (of a ten-year rolling average of 3200 GL/year) is more sensitive to the scenario, with decreasing levels of risk as the additional environmental water increases. There is a high level of risk associated with meeting this target under the 3000 scenario, a moderate level of risk under the 3500 scenario and a low level of risk of meeting that target under the 4000 scenario.

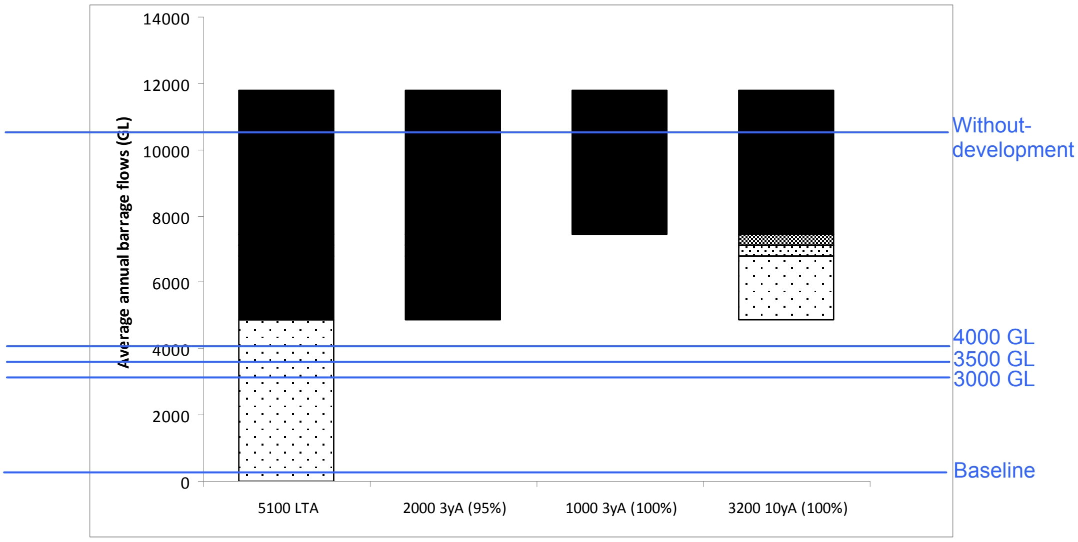


Figure 4.5 Relative risk levels for each MDBA CLLMM target over the range of total annual barrage flow volumes investigated under the without-development, baseline and Guide scenarios

Note: Pattern coding indicates the level of risk assocated with meeting each target. Solid black bars indicate that the target was met across all levels of uncertainty explored. Stippling shows intermediate levels of risk, with dark stippling indicating low risk (where the target was met for 76–99% of levels of uncertainty), moderate stippling indicating medium risk (51–75%) and light stippling indicating high risk (26–50%). An outline with no fill indicates a very high level of risk (1–25%). No bar indicates the target was not met for any level of uncertainty explored. Abbreviations are: 5100 LTA = a long-term average of 5100 GL/year, 2000 3ya (95%) = a three-year rolling average of 2000 GL/year in 95% of years, 1000 3yA (100%) = a three-year rolling average of 1000 GL/year in 100% of years, and 3200 10yA (100%) = a ten-year rolling average of 3200 GL/year in 100% of years.

As for the MDBA targets, there are varying levels of risk associated with different flow volumes for the different SA Government targets (Figure 4.6). The target of a minimum flow of 650 GL in 95% of years is not met under any level of uncertainty under the baseline scenario, but is always met under all other scenarios at all levels of uncertainty explored. The minimum flow targets set for 100% of years (of 2000 minus the previous year's flow, 3000 minus flow from the previous two years and the maximum of those two targets) are only met under the without-development scenario, but are then met for all levels of uncertainty explored. The high flow requirement of flows of 6000 GL/year with a return frequency of 1-in-3 years has a very high level of risk under the baseline scenario, but is always met under the Guide and without-development scenarios. The remaining targets show greater sensitivity to the level of uncertainty assessed. The remaining components of the minimum flow requirement for 95% of years (4000 GL minus flow from the previous year and 6000 GL minus flow from the previous two years adjusted for very high flows) are not met under any level of uncertainty under the baseline scenario, are at a high risk of failure under the 3000 scenario, a moderate risk of failure under the 3500 scenario, a low risk of failure under the 4000 scenario and no risk under the without-development scenario. The combined minimum flow volume target in 95% of years (the maximum of the two previous targets mentioned and the 650 GL/year minimum) is never met under the baseline or 3000 scenarios, has a very high risk of failure under the 3500 scenario and a high risk under the 4000 scenario. The final target, of high flows of at least 10,000 GL/year with a return frequency of 1-in-7 years, is at a high risk of failure under the baseline scenario, but a low risk under the 3000 and 3500 scenarios and no risk of failure under the 4000 and without-development scenarios.

In summary, the without-development scenario is the only one in which all target are met under all levels of uncertainty. Under the baseline scenario, all targets are either never met or only met with a high or very high level of risk. The 3000 scenario never meets some targets, but has either a high or a low level of risk associated with meeting other targets (depending on the target) or always meets a number of targets, thus representing an improvement on the baseline scenario. The 3500 scenario is a further improvement, failing to ever meet fewer targets, and with a range of levels of risk across the remaining targets (at least as high as the 3000 scenario). The 4000 scenario represents a further improvement, with lower levels of risk for several targets. Some targets are again never met, but one additional target is met under all levels of uncertainty and there are incremental improvements in the degree of risk associated with five targets. Thus, the more additional water is delivered to the CLLMM, the lower the level of risk of failing to meet the specified EWR targets.

This assessment of the level of risk associated with meeting each target under model uncertainty did not assess the potential impact of redistributing interannual barrage flows to provide optimal environmental flows to the CLLMM (as was suggested above). Thus, while some targets may never be met, except under without-development conditions, this does not imply that they could not be met by the volumes (and assoicated levels of uncertainty) explored here, should those volumes be delivered differently between years. Again, this highlights the inadequacy of specifying an average additional flow volume without additional conditions on how and when that volume is delivered.

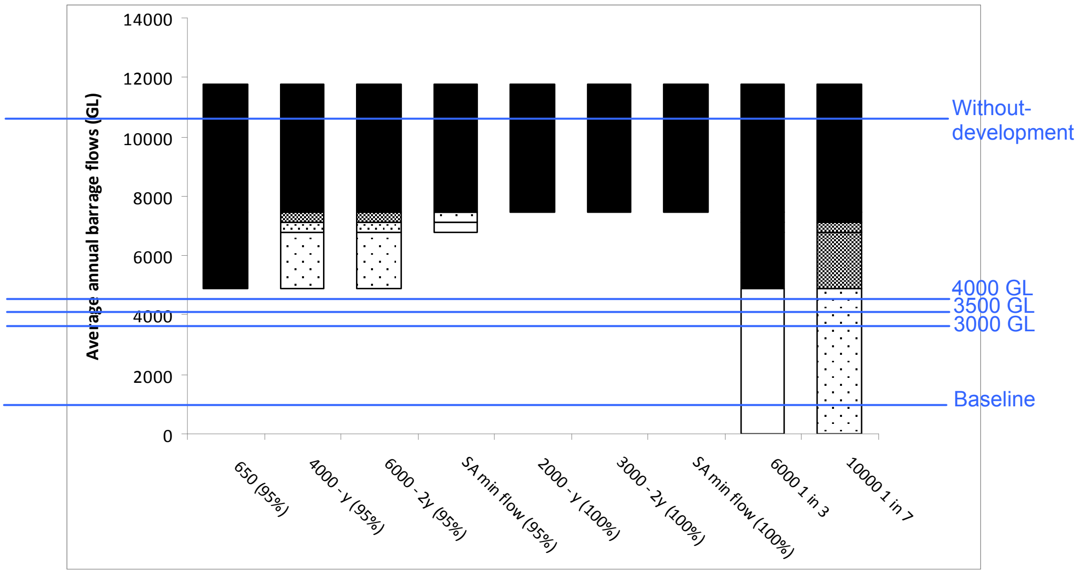


Figure 4.6 Relative risk levels for each SA Government CLLMM target over the range of total annual barrage flow volumes investigated under the without-development, baseline and Guide scenarios

Note: Pattern coding indicates the level of risk assocated with meeting each target. Solid black bars indicate that the target was met across all levels of uncertainty explored. Stippling shows intermediate levels of risk, with dark stippling indicating low risk (where the target was met for 76–99% of levels of uncertainty), moderate stippling indicating medium risk (51–75%) and light stippling indicating high risk (26–50%). An outline with no fill indicates a very high level of risk (1–25%). No bar indicates the target was not met for any level of uncertainty explored. Abbreviations are: 650 = 650 GL/year, 4000 – y (95%) = 4000 GL/year minus the previous year's flow in 95% of years, 6000 - 2y (95%) = 6000 GL/year minus the flow in the previous two years adjusted for very large flows for 95% of years, SA min flow (95%) = the maximum of the three previous targets in 95% of years, 2000 – y (100%) = 2000 GL/year minus the previous year's flow in 100% of years, 3000 – 2y (100%) = 3000 GL/year minus the flow in the previous 2 years adjusted for very large flows in 100% of years, SA min flow (100%) = the maximum of the previous two targets in 100% of years, 6000 1 in 3 = 6000 GL/year with a return frequency of 1 in 3 years, and 10,000 1 in 7 = 10,000 GL/year with a return frequency of 1 in 7 years.

Comparing results from the different models

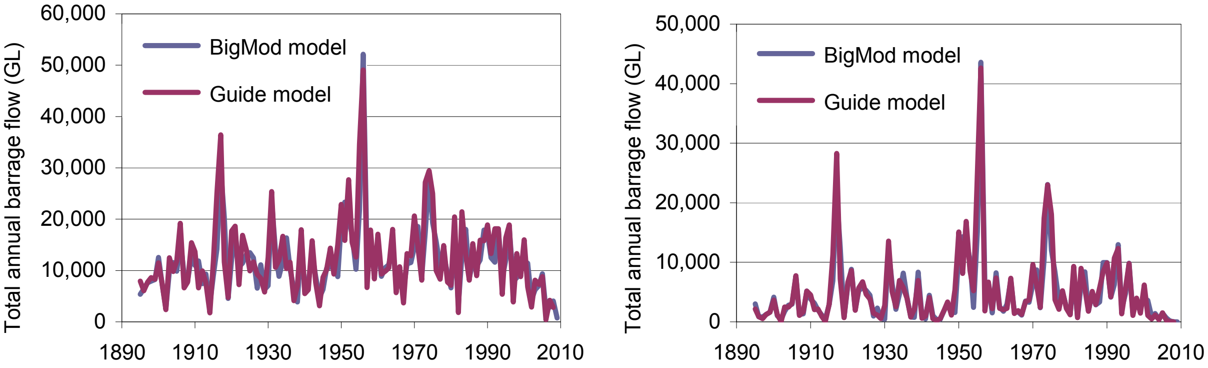
In exploring the likely impact of the Guide scenarios, MDBA used two separate models to estimate flows in the Basin. One model (the Guide annual model) used a monthly time-step and the results of simulations undertaken with this model were reported on the MDBA website. The other used a daily time-step (the BigMod daily model), and this has some differences in the simulated flows throughout the sequence. For example, flows at the barrages (Figure 4.7) tend to be slightly higher when simulated by the Guide annual model than by the BigMod daily model, with the exception of extremely large flows. Also, the 3000 scenario showed slightly different timing in high flows when results generated from each model were compared (Figure 4.7c).

These differences in flows are relatively small, when compared to the natural variability in flows among years. However, they do have the ability to influence the conclusions that are drawn based on simulations from one model versus the other. In assessing the ability of the Guide scenarios to meet the MDBA and SA targets for Chowilla, it was necessary to use output from the BigMod daily model, as the durations for the different flow events were specified in days. This is in contrast to the MDBA, who have used outputs from the Guide annual model for all assessment. For consistency, we have also used the BigMod daily model to assess CLLMM targets. However, for the CLLMM, it was also possible to assess the targets based on the Guide annual model, so we assessed the MDBA and SA targets based on monthly model simulations, in addition to the assessment based on the BigMod daily model. Thus, the same method used to assess whether targets were met or not, how often and by how much was repeated using outputs from the Guide annual model aggregated into total annual barrage flows.

When the targets were assessed using the Guide annual model, very similar results were obtained to those using the BigMod daily flow model, with respect to whether the target was met overall and how often targets were not met (Table 4.12). There were three differences in whether a target was assessed as being met or not. The baseline scenario was judged to meet the 5100 GL/year long-term average and the SA minimum flow target in 95% of years under the monthly model, where they did not under the daily model. Conversely, the volume of 3200 GL/year as a rolling ten-year average to achieve salt export was not judged to be met using the monthly model where it had been when using the daily model.

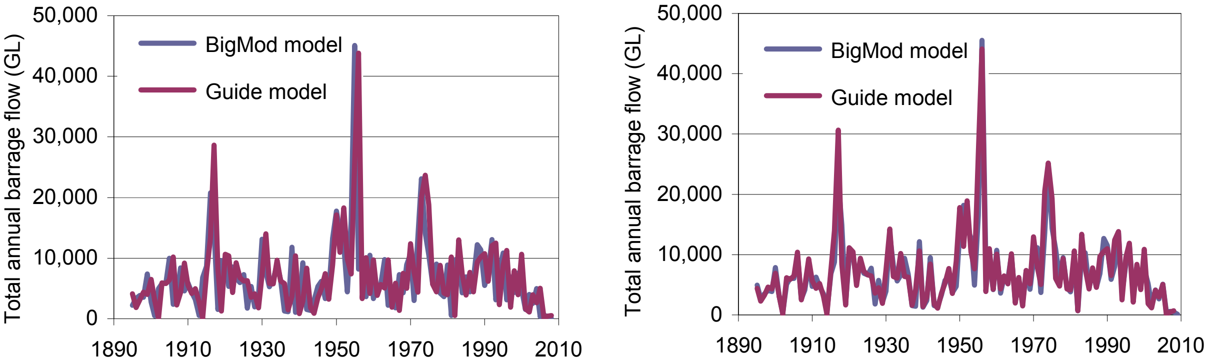
(a) without development

(b) baseline



(c) 3000

(d) 3500



(e) 4000

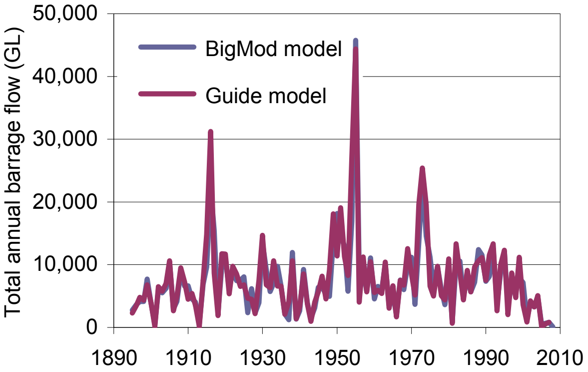


Figure 4.7 Comparison of total annual barrage flows under the BigMod daily model and the Guide model under the (a) without development, (b) baseline and (c-e) Guide scenarios

Further exploration into the volumes of additional water necessary where targets not assessed as met showed that the simulated shortfall under the Guide annual model was, for the most part, greater than that simulated under the BigMod daily model (Table C.1 in Appendix C). Of the 29 instances where neither model indicated that a target was met for a given scenario, only four had a smaller shortfall predicted by the Guide model. For all other cases, the volume required to meet the target was the same or greater. The greatest proportional increases occurred for the smaller shortfalls, so should not necessarily indicate large discrepancies between the two models.

The overall similarity between the results provides confidence that results generated using the BigMod daily model are broadly comparable to those from the Guide model. Thus, findings produced by the MDBA using the Guide model should be broadly similar to those reported here and for Chowilla. Discrepancies in the additional water required to meet shortfalls should be borne in mind, however, with there being no way to determine which the 'correct' volume is at this time. Thus, uncertainties in the modelling should be considered when a position is taken regarding a scenario that is likely to meet the environmental water requirements of SA assets.

Table 4.12 Assessment of meeting the MDBA and SA CLLMM EWRs under the without-development, baseline and Guide scenarios, simulated using the Guide model

	Scenario				
Target	without-development	baseline	3000	3500	4000
MDBA targets					
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	✓	×	×	×	×
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	×	×	×	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	×	✓	✓	✓
4000 GL – previous year in 95% of years	✓	×	×	✓	✓
6000 GL – 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	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	×	×	×	×
3000 GL – 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	✓	×	✓	✓	✓
10000 GL/year 1-in-7 year frequency	✓	×	✓	✓	✓

'✓' indicates the target was met by the Guide model. '×' indicates the target was not met by the monthly model. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Blue shading indicates targets that are met based on monthly flow model simulations that were not met based on daily flow model simulations and vice versa.

4.3 Ecosystem function targets

It is worth noting that the use of these metrics is solely based on the need to be consistent with the Guide for the purposes of this review. The metrics only link to function requirements by inference. The methodologies available to quantify flow requirements to assess ecosystem function are generally lacking.

On completion of this Technical Report, the method and outcomes of analyses undertaken for determining key ecosystem function requirements had not been published by the MDBA. To undertake the assessment of ecosystem function, the methods published in Alluvium (2010) were used as a guide. Consequently, the findings of this study may not be a direct comparison to the MDBA assessment.

Spells analysis was conducted using daily model data from MDBA (the BigMod daily model), and the software 'River Analysis Package' (RAP, eWater) The function assessment sites in the Guide are:

- Murray River upstream of the border (F59)
- Murray River downstream of Lock 3 (F60)
- Murray River at Morgan (F61)

- Murray River at Wellington (F62).

This report only assesses flow metrics at the SA border, Morgan and Wellington. The metrics used in the analysis were those documented in :

- base flows (Low and High season)
- cease-to-flow (Low and High season)
- freshes (Low and High season)
- bankfull (ARI = 1.5), overbank (ARI = 2.5 and 5).

At the time of writing this report, the MDBA was yet to publish the methods and results of the analysis of key ecosystem function sites.

The MDBA daily modelled flow scenarios were used for analysis. The reference flow was without-development, and the relative changes to this were calculated for the baseline and Guide scenarios. The assessment of change, relative to the without-development flows, used the MDBA approach, where low is <60% of without-development), moderate is 60–80% of without-development, and high is 80–100% of without-development. It is worth noting that whilst these classifications are used here, it is acknowledged that the choice to use them is solely to be consistent with the Guide for the purposes of this review. The classification process is untested and based on what appears to be a subjective choice.

The Guide scenarios show incremental improvements, where metrics show an incremental improvement between 3000 and 4000 scenarios (Table 4.13). The 4000 scenario represents the best improvement in returning flow metrics to an acceptable level of change, where the criteria for acceptable is moderate or better, and selected metrics are only met in the 4000 scenario.

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

Table 4.13 Ecosystem function metrics under the baseline and Guide scenarios relative to the without-development scenario (<60% red; 60–<80% blue; ≥80% green)

		Scenario relative to without development			
Flow component		baseline	3000	3500	4000
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./year	100%	100%	100%	100%
Cease-to-flow: High flow season	No. of years	100%	100%	100%	100%
	Average no./year	100%	100%	100%	100%
Cease-to-flow: All seasons	Average duration – CTF	100%	100%	100%	100%
Fresh: Low flow season	No. of years – Fresh	42%	54%	61%	69%
	Average no./year – 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./year – Fresh	40%	70%	73%	79%
	Average duration – Fresh	76%	67%	70%	68%
Bankfull	ARI 1.5	59%	82%	88%	91%
Overbank	ARI 2.5	58%	77%	79%	83%
Overbank	ARI 5	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./year	0%	0%	0%	0%
Cease-to-flow: High flow season	No. of years	0%	0%	0%	0%
	Average no./year	0%	0%	0%	0%
Cease-to-flow: All seasons	Average duration – CTF	0%	0%	0%	0%

		Scenario relative to without development			
Flow component		baseline	3000	3500	4000
Fresh: Low flow season	No. of years – Fresh	34%	57%	60%	67%
	Average no./year – 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./year – Fresh	38%	61%	65%	70%
	Average duration – Fresh	73%	63%	65%	64%
Bankfull	ARI 1.5	54%	79%	82%	49%
Overbank	ARI 2.5	55%	81%	83%	87%
Overbank	ARI 5	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./year	0%	59%	57%	90%
Cease-to-flow: High flow season	No. of years	33%	33%	0%	0%
	Average no./year	34%	8%	0%	0%
Cease-to-flow: All seasons	Average duration – CTF	28%	60%	55%	87%
Fresh: Low flow season	No. of years – Fresh	30%	49%	49%	53%
	Average no./year – 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./year – Fresh	39%	74%	77%	83%
	Average duration – Fresh	72%	64%	65%	65%
Bankfull	ARI 1.5	50%	71%	78%	89%
Overbank	ARI 2.5	54%	53%	55%	57%
Overbank	ARI 5	62%	70%	76%	80%

4.4 Risks

4.4.1 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 environmental water requirements. 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.

4.4.2 Residual risks beyond those addressed in the Guide

As applied in the Guide, an implicit assumption in deriving environmental water requirements for South Australia is that meeting these will minimise risks to assets and functions. Whilst there is sufficient evidence to demonstrate that flow is a fundamental driver of water dependent ecosystems, and their communities, other factors that can compromise objectives include:

- 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:

- illegal take of water
- poor coordination in the delivery of environmental water holdings between agencies
- 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
- inaccuracies in river system and other models
- limited representation of inundation dynamics in inundation models
- lack of consideration of 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.

References

Alluvium (2010) Key ecosystem functions and their environmental water requirements. Canberra, ACT, A Report for the Murray–Darling Basin Authority.

Cale B (2009) Literature review of the current and historic flooding regime and required hydrological regime of ecological assets on the Chowilla Floodplain. Report for the South Australian Murray-Darling Basin Natural Resources Management Board, Murray Bridge, South Australia.

Close A and Sharma P (2005) Hydrologic models used for water resource and salinity management in the River Murray system. In 28th International Hydrology and Water Resources Symposium (Ed: Institution of Engineers) Wollongong, NSW.

CSIRO (2008) Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Water for a Healthy Country Flagship, CSIRO, Canberra.

Davies PE, Harris JH, Hillman TJ and Walker KF (2008) SRA Report 1: a report on the ecological health of rivers in the Murray-Darling Basin 2004-2007. Report by the Independent Sustainable Rivers Audit Group for the Murray−Darling Basin Ministerial Council, Canberra.

Department of Environment and Heritage (2010) Management Plan for the Riverland Ramsar Site: A Plan for Wise Use 2010–2015. Adelaide, South Australian DEH.

DWLBC (2010) Preliminary Review of the Murray–Darling Basin Authority EWRs set for South Australian sites. South Australian Department of Water, Land and Biodiversity Conservation, Adelaide.

Ecological Associates (2010) The environmental water requirements of the South Australian River Murray (Draft). Adelaide, A Report for the South Australian Murray-Darling Basin Natural Resources Management Board by Ecological Associates.

Heneker TM (2010) Development of flow regimes to manage water quality in the Lower Lakes, South Australia. South Australian Department for Water Report. Adelaide, Government of South Australia.

Kingsford RT (2002) Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. Australian Ecology 25: 109-127.

Lester RE and Fairweather PG (2009) Ecosystem states of the Coorong: An ecosystem response model. Method development and sensitivity analyses. Water for a Healthy Country Flagship. CSIRO, Adelaide.

Lester RE, Fairweather PG, Heneker TM, Higham JS and Muller KL (2010) Specifying an environmental water requirement for the Coorong and lakes Alexandrina and Albert: A first iteration. Summary of methods and findings to date, A report prepared for the South Australian Department of Environment and Natural Resources.

MDBA (2010a) Guide to the proposed Basin Plan Volume 1: Overview. Murray–Darling Basin Authority, Canberra.

MDBA (2010b) Guide to the proposed Basin Plan Volume 2: Technical background. Murray–Darling Basin Authority, Canberra.

MDBA (2010c) Lower Murray Regaion – Key Environmental assets and hyrologic indicator sites. Murray–Darling Basin Authority, Canberra. Viewed 24 May 2011 <http://www.mdba.gov.au/files/cartographicmapping/aMurray_KEA_lower.pdf>.

MDBC (2006a) The Chowilla Floodplain and Lindsay−Wallpolla Islands Icon Site Environmental Management Plan 2006–2007. Murray-Darling Basin Commission Canberra.

MDBC (2006b) The Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan 2006–2007, Murray–Darling Basin Commission, Canberra.

Newall P, Lloyd L, Gell P and Walker K (2009) Riverland Ramsar Site ecological character description.South Australia Department of Environment and Heritage, Adelaide.

Overton IC, McEwan K and Sherrah JR (2006) The River Murray Floodplain Inundation Model (RiM-FIM): Hume Dam to Wellington, CSIRO Water for a Healthy Country Flagship Technical Report. CSIRO, Adelaide.

Overton IC, Pollino CA, Colloff MJ and Cuddy SM (2011) Defining hydro-ecological states and estimating water availability to inform environmental watering actions. Report to the Commonwealth Environmental Water Holder. Water for a Healthy CountryFlagship, CSIRO, Canberra.

Phillips B and Muller K (2006) Ecological character description: Coorong, lakes Alexandrina and Albert, Wetland of International Importance, South Australian Department for Environment and Heritage, South Australian Government, Adelaide.

Podger GM, Barma D, Neal B, Austin K and Murrihy E (2010) River system modelling for the Basin Plan: Assessment of fitness for purpose. Water for a Healthy Country Flagship, CSIRO, Canberra. Viewed 16 May 2011, <http://www.mdba.gov.au/files/bp-kid/1534-Final-Fitness-for-purpose.pdf >.

Roberts J and Marston FM (2000) Water regime of wetland and floodplain plants in the Murray-Darling Basin – a source book of ecological knowledge, Technical report 30/00, CSIRO Land and Water, Canberra.

Roberts J, Young WJ and Marston FM (2000) Estimating the water requirements for plants and floodplain wetlands: a guide. Occasional Paper 04/00. Canberra, Land and Water Resources Research and Development Corporation: 110.

Rogers K and Ralph T (2010) Floodplain wetland biota in the Murray-Darling Basin. Water and Habitat Requirements, CSIRO Publishing.

SAMDBNRMB (2008) Chowilla Creek environmental regulator investment proposal, South Australian Murray-Darling Basin Natural Resource Management Board, Murray Bridge, South Australia.

Webster IT (2010) The hydrodynamics and salinity regime of a coastal lagoon – The Coorong, Australia. Estuarine, Coastal and Shelf Science 90, 264–274.

Appendix A Comparison of EWR metrics

Table A.1 Comparison of EWR metrics for aquatic vegetation communities reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Objective	Flow requirement	Duration	Timing	Frequency	Maximum event separation
						years	
Maintenance							
EA*	Flowing water courses	Aquatic Macrophytes	Discharge should increase by 50% to 150% between August and October in 80% of years	Period of 2 to 4 months. Afterwards discharge should return to the minimum flow.	Seasonal exposure and inundation of riparian zone and backwaters to maintain a broad zone of aquatic vegetation		
EA	River channel and connected wetlands	Aquatic Macrophytes: Emergent reed bed plant communities extend across tens of metres in the littoral zone of wetlands and backwaters;			A seasonal water level fluctuation of 1 to 3 m;		
EA	River channel and connected wetlands	Aquatic Macrophytes*:* *Eucalyptus camaldulensis* colonises the intermittently flooded zone, forming a canopy to reed beds and other aquatic plant communities;			Peak water levels provided in late winter / early spring; and		
EA	River channel and connected wetlands	Aquatic Macrophytes: Mudflats are exposed over extensive areas over summer and provide habitat for herbland plant species			Water levels receding to an annual minimum in autumn		
EMP	Fringing aquatic reed and sedge	Semi-Permanent	25–30 GL/d (adj. to channel) 45–60 GL/d (low relict meander)	6	winter spring/early summer	1-in-2	1-2 years (if well established)
EMP	Aquatic	Permanent	3 GL/d Channels, >26GL/d Billabongs	Permanent	Permanent	1-in-2	0 for channels, 1 for billabongs
EMP	Aquatic	Semi-Permanent	40 GL/d	3-Jun	spring/summer	1-in-2	1 year
Recruitment							
EMP	Aquatic	Permanent	5 GL/d Channels, >40 GL/d Billabongs		Permanent	1-in-2	0 for channels, 1 for billabongs
EMP	Aquatic	Semi-Permanent	40 GL/d	Long duration, frequently not drying out at all	spring/summer	9-in-10	1 year
EMP	Fringing aquatic reed and sedge	Semi-Permanent	25-30 GL/d (adj. to channel) 45-60 GL/d (low relict meander)	6	winter spring/early summer	1-in-1-2	6–9 months

EA - Ecological Associates, 2010
EMP - Department of Environment and Heritage, 2010

Table A.2 Comparison of EWR metrics for red gum reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Flow requirement to SA	Duration	Timing	Frequency	Maximum event separation
		ML/day			years	
Maintenance						
MDBA	Maintain 80% of the current extent of red gum forest in good condition	40,000	90 day total (7 day min)	June to December	3 to 5-in-10	
MDBA	Maintain 80% of the current extent of red gum forest in good condition	60,000	60 day total (7 day min)	June to December	2.5 to 3-in-10	
MDBA	Maintain 80% of the current extent of red gum forest in good condition	80,000	30 day total (7 day min)	Preferably winter/spring but timing not constrained	1.7 to 2.5-in-10	
MDBA	Maintain 80% of the current extent of red gum woodland in good condition	80,000	30 day total (7 day min)	Preferably winter/spring but timing not constrained	1.7 to 2.5-in-10	
DWLBC	Maintain and improve the health of 80% of the river red gum woodlands and forests (adult tree survival)	80,000 to 90,000	>30 days	July to January	1-in-4	5 years
EA	Red gum forest and woodland: Adult tree survival	80,000	1 month	August to November	2-in-10	8 years
EMP	Red gum forest and woodland: Maintenance	50,000 (1/3 of community maintained) to 80,000 (2/3 of community maintained)	4 to 7 months	winter/spring	1-in-3	2 years
MDBC	Maintain or improve tree health within 70% of the mixed river red gum woodland areas.	5,000 to 70,000	3 months	Late winter/spring/ summer	1-in-2 to 1-in-4	
Recruitment						
DWLBC	Successful recruitment of cohorts of river red gums, ie recruitment must equal or exceed river red gum mortality	80,000	2 months	August to October	Successive years (at least 2 consecutive)	na
EA	Red gum forest and woodland: Germination and Recruitment	60,000	1 month	August to November	2-in-10	8 years
EA	Red gum forest and woodland: Germination and Recruitment	80,000	2 months	August to October	2-in-10	8 years
EMP	Red gum forest and Woodland: Recruitment	50,000 (1/3 of community maintained) to 80,000 (2/3 of community maintained)	4 months	spring	7 to 9-in-10	Serial inundation 2 to 3 years in succession
Service: habitat						
DWLBC	Provide habitat (river red gum communities) for waterbirds breeding events	70,000	60 days	Starts August to October	1-in-4	6 years
EA	Red gum forest and woodland: Productive community with high fauna habitat value	60,000	2 months	August to October	4-in-10	5 years
EA	Red gum forest and woodland: Productive community with high fauna habitat value	80,000	2 weeks	August to October	2-in-10	5 years
			AND			
			2 months	August to October	1-in-10	9 years

DWLBC, 2010
EA - Ecological Associates, 2010
EMP - Department of Environment and Heritage, 2010
MDBA, 2010b
MDBC, 2006a

Table A.3 Comparison of EWR metrics for lignum reported in relevant planning documents (ref Section 3.1.1)

Source	Objective	Flow requirement to SA	Duration	Preferred timing	Preferred frequency	Max time between events
		ML/day			years	
Maintenance						
DWLBC	Lignum: Maintain and improve the health of ~50% of the lignum shrubland	70,000	30 days	Spring or early summer	1-in-3	5 years
DWLBC	Lignum: Maintain and improve the health of 80% of the lignum shrubland	80,000	30 days	Spring or early summer	1-in-5	8 years
EA	Lignum shrublands: Productive community with high fauna habitat	80,000	1 month	Spring or Summer	2-in-10	8 years
EMP	Lignum shrubland: Maintenance	50,000 (1/3 of community maintained) to 70,000 (2/3 of community maintained)	3 to 6 months	1 in 3-10 (more freq wetting if soil is saline)	Unknown maybe critical?	Unknown reqs complete drying between floods
MDBC	Improve the health of 40% of the Lignum areas.	40,000 to 80,000	3 months	Late winter/spring/ summer	1-in-2 to 1-in-4	
Recruitment						
EMP	Lignum shrubland: Recruitment	50,000 (1/3 of community maintained) to 70,000 (2/3 of community maintained)	4 months	1 in 2 - 8 (more freq if soil is saline)	Unknown maybe critical?	Unknown reqs complete drying between floods
Service: Habitat						
DWLBC	Lignum: Maintain lignum inundation for Waterbird breeding events	70,000	60 days	Starts August to October	1-in-4	6 years

DWLBC, 2010
EA - Ecological Associates, 2010
EMP - Department of Environment and Heritage, 2010
MDBC, 2006a

Table A.4 Comparison of EWR metrics for black box reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Flow requirement (flow to SA)	Duration	Timing	Frequency	Maximum event separation
		ML/day			years	
Maintenance						
MDBA	Maintain 80% of the current extent of black box woodland in good condition	100,000	21 day total (1 day min)	Preferably winter/spring but timing not constrained	1.3 to 1.7-in-10	
MDBA	Maintain 80% of the current extent of black box woodland in good condition	125,000	7 day total (1 day min)	Preferably winter/spring but timing not constrained	1 to 1.3-in-10	
DWLBC	Maintain and improve the health of ~50% of the black box woodlands	85,000	30 days	Spring or summer	1-in-5	8 years
DWLBC	Maintain and improve the health of ~60% of the black box woodlands	100,000	20 days	Spring or summer	1-in-5	8 years
DWLBC	Maintain and improve the health of 80% of the black box woodlands	>100,000	20 days	Spring or summer	1-in-6	8 years
EA	Black box woodland; floodplain chenopod shrubland: Adult tree survival	100,000	1 month	Spring or Summer	1-in-15	14 years
EMP	Black box woodland: Survival	70,000 (20%) to 100,000 (40%) to 300,000 (majority)	2 to 4 months	Not critical?	1-in-30	30 years
MDBC	Maintain or improve tree health within 45% of the mixed black box woodland areas.	50,000 to 100,000	3 months	Late winter/spring/ summer	1-in-4	
Recruitment						
DWLBC	Successful recruitment of cohorts of black box at lower elevations, i.e. recruitment must equal or exceed river red gum mortality	85,000	20 days	Spring or early summer	Consecutive years	n/a
DWLBC	Successful recruitment of cohorts of black box at higher elevations, i.e. recruitment must equal or exceed river red gum mortality	>100,000	20 days	Spring or early summer	Consecutive years	n/a
EA	Black box woodland; floodplain chenopod shrubland: Gernmination and Recruitment	100,000	2 weeks	Spring or Summer	1-in-10	9 years
EMP	Black box woodland: Recruitment	70,000 (20%) to 100,000 (40%) to 300,000 (majority)	Long enough to saturate surface soil, with slow recession	Unknown	1j-in-10 (23 years in succession every 30 years)	Unknown

DWLBC, 2010
EA - Ecological Associates, 2010
EMP - Department of Environment and Heritage, 2010
MDBA, 2010b
MDBC, 2006a

Table A.5 Comparison of EWR metrics for floodplain vegetation reported in relevant planning documents (ref Section 3.1.1)

Source	Objective	Flow requirement (flow to SA)	Recurrence interval	Inundation length	Season	Max. time between events
		ML/day	years			
Maintenance						
EA	Black box woodland; floodplain chenopod shrubland: Adult tree survival	100,000	1-in-15	1 mo	Spring or Summer	14 years
EMP	River saltbush chenopod shrubland	60,000 (1/4 of community maintained) to 300000 (majority of community maintained)	1-in-30	2 to 4 mo	Not critical?	Unknown
EMP	Low chenopod shrubland	70,000 (1/2 of community maintained) to 300,000 (majority of community maintained)	1-in-30	2 to 4 mo	Not critical?	Unknown
EMP	Samphire low shrubland	50,000 to 60,000 (60 % of community maintained) to 80,000 (80 % of community maintained)	1-in-3 to 1-in-10 (more freq if soil is saline)	3 to 6 mo	Unknown maybe critical?	Unknown
MDBC	Maintain or improve tree health within 40% of the river coobah woodland areas.	40,000 to 70,000	1-in-2 to 1-in-3		Late winter/spring/ summer	
MDBC	Improve the area and diversity of grass and herblands	40,000 to 80,000	1-in-2 to 1-in-4	3 mo	Late winter/spring/ summer	
MDBC	Improve the area and diversity of flood-dependent understorey veg	40,000 to 80,000	1-in-2 to 1-in-4	3 mo	Late winter/spring/ summer	
Recruitment						
EA	Black Box Woodland; Floodplain Chenopod Shrubland: Gernmination and Recruitment	100,000	1 year in 10	2 weeks	Spring or Summer	9 years
EMP	River saltbush chenopod shrubland	60,000 (25% of community maintained) to 300,000 (majority of community maintained)	1-in-10 (23 years in succession every 30 years)	Long enough to saturate surface soil, with slow recession	Unknown	Unknown
EMP	Low chenopod shrubland	70,000 (50% of community maintained) to 300,000 (majority of community maintained)	1-in-10 (23 years in succession every 30 years)	Long enough to saturate surface soil, with slow recession	Unknown	Unknown
EMP	Samphire low shrubland	50,000 to 60,000 (60% of community maintained) to 80,000 (80% of community maintained)	1-in-2 to 1-in-8 (more freq if saline soils)	4 months	Unknown maybe critical?	Unknown

EA - Ecological Associates, 2010
EMP - Department of Environment and Heritage, 2010
MDBC, 2006a

Table A.6 Comparison of EWR metrics for waterbirds reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Flow requirement (flow to SA)	Duration	Timing	Frequency	Max time between events
		ML/day			years	years
River						
EA	Long waterbird breeding events provided one year in four; and short waterbird breeding events provided two years in four.		A seasonal fluctuation of 1 to 3 m to inundate wetland foraging habitat and inundate vegetation;			
EA	Long waterbird breeding events provided one year in four; and Short waterbird breeding events provided two years in four.		Inundation commences in mid spring and continues for 4 months (for rapid breeders such as Ibis) to 7 months (for long breeders such as Egret);			
EA	Long waterbird breeding events provided one year in four; and Short waterbird breeding events provided two years in four.		Water levels held stable during breeding periods;			
EA	Long waterbird breeding events provided one year in four; and Short waterbird breeding events provided two years in four.		Water is not introduced to high connecting wetlands for 2 periods of 2 yrs every 8 yrs			
Floodplain						
DWLBC	Provide habitat for waterbirds breeding events	70,000	60 days	Starts August to October	1-in-4	6
DWLBC	Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000	90 days	Commencing in July to September	1-in-2	3
DWLBC	Inundation of temporary wetlands for larger scale bird breeding events	80,000	> 30 days	Commencing in August to September	1-in-4	5
EA	Waterbird Breeding and Foraging: Support frequent small scale breeding events through wetland and fringing woodland inundation	30,000	3 to 6 months	August to September	5-in-10	3
EA	Waterbird Breeding and Foraging: Support occasional large scale breeding events through wetland and floodplain inundation	70,000	2 months	September to October	2-in-10	8
Service: Habitat						
DWLBC	Maintain lignum inundation for Waterbird breeding events	70,000	60 days	Starts August to October	1-in-4	6
DWLBC	Provide habitat (River Red Gum communities) for waterbirds breeding events	70,000	60 days	Starts August to October	1-in-4	6

DWLBC, 2010
EA - Ecological Associates, 2010

Table A.7 Comparison of EWR metrics for fish (water levels) reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Water regime recommendation
River		
EA	Murray cod and callop typically occur in watercourses that provide more than 1 m depth of water	Minimum flow should provide a depth of more than 1 m for more than 80% of the length of the watercourse.
EA	Inundation of linked wetland and floodplain habitat in spring and summer to provide habitat for juvenile fish growth	Provide inundation of connected wetland or floodplain habitat between September and December by elevated watercourse discharge or other water management measure.
EA	Seasonal increase in discharge initiates breeding in Australian smelt and callop	Discharge should increase by 50% to 150% between August and October in 80% of years for a period of 2 to 4 months. Afterwards discharge should return to the minimum flow.
EA	Provide fish nursery habitat in low-level wetlands only 1 year in four; AND	A seasonal fluctuation of 1 to 3 m to inundate wetlands and provide fish passage
EA	Provide fish nursery habitat in high-level wetlands 2 years in four.	Water levels rise to maximum level within the period from August and October;
EA		Wetlands remain connected by constant water levels for 3 months 1 yr in 3
EA		Wetlands remain connected by constant water levels for 6 months 2 yrs in 3
EA		Exit cues of a drop in water level of 0.2 m over 2 days is provided prior to drawdown
EA		Weir levels are drawn down over 2 months
EA	Maintain a collection of wetlands in each reach that are briefly connected on an annual basis	In a year with low weir raising, raise and hold the water level to the intermediate level for two weeks during spring
EA		In a year with an intermediate weir raising, raise and hold the water level at the maximum level for a further two weeks during spring.

EA - Ecological Associates, 2010

Table A.8 Comparison of EWR metrics for fish (flow requirements) reported in relevant planning documents (ref Section 3.1.1)

Floodplain						
Source	Target	Flow requirement (flow to SA)	Duration	Timing	Frequency	Max. time between events
		ML/day			years	years
DWLBC	Provide variability in flow regimes at lower flow levels (in channel)	Variable flows from pool level to 40,000	Variable	Annually	1-in-1	na
DWLBC	Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000	90 days	Commencing in July to September	1-in-2	3
DWLBC	Inundation of temporary wetlands for larger scale bird breeding events and frog breeding events	80,000	>30 days	Commencing in August to September	1-in-4	5
DWLBC	Stimulate spawning, provide access to the floodplain and provide nutrients and resources.					
EA	Stimulate spawning, provide access to the floodplain and provide nursery habitat	30,000	2 to 3 months	August to September	4-in-10	4
EA	Stimulate spawning, provide access to the floodplain and provide nursery habitat	70,000	2 months	August to September	2-in-10	8

DWLBC, 2010
EA - Ecological Associates, 2010

Table A.9 Comparison of EWR metrics for biofilms, food webs and processes reported in relevant planning documents (ref Section 3.1.1)

Source	Target	Water Regime Recommendation
River		
EA	Seasonal exposure and inundation of woody debris to support a variety of successional stages of biofilms	Discharge should increase by 50% to 150% between August and October in 80% of years for a period of 2 to 4 months. Afterwards discharge should return to the minimum flow.
EA		Afterwards discharge should return to the minimum flow.
EA	Flowing watercourses have a high proportion of detritvores, grazers and predators with little local primary production. The inundation of floodplains and wetlands is required to sustain food web.	
EA	Flooding of organic matter following exposure intervals of 6 months to 2 years.	A seasonal water level fluctuation of 1 to 3 m;
EA		Inundation of the upper limit of the weir range for 1 to 6 months, 1 year in 3, followed by exposure;
EA		Inundation of the middle limit of the weir range for 1 to 6 months, 2 years in 3, followed by exposure;
EA		Inundation of the lower limit of the weir range for 1 to 6 months 3 years in 3, separated by periods of exposure.
EA	Flooding of biofilm substrates following exposure intervals of 6 months to 2 years.	A seasonal water level fluctuation of 1 to 3 m;
EA		Inundation of the upper limit of the weir range for 1 to 6 months, 1 year in 3, followed by exposure;
EA		Inundation of the middle limit of the weir range for 1 to 6 months, 2 years in 3, followed by exposure;
EA		Inundation of the lower limit of the weir range for 1 to 6 months 3 years in 3, separated by periods of exposure.

Floodplain						
	Specific aims	Minimum threshold	Duration	Timing	Frequency	Max time between events
		ML/day			years	years
EA	Support food web of river and permanent wetlands	30,000	1 week	any time	10-in10	3
EA	Sediment mobilisation and transport in main river channel and low-level anabranches	30,000	1 month	any time	1-in-2	4
EA	Support food web of river and permanent wetlands	80,000	1 week	any time	5-in-10	5
EA	Support food web of river and permanent wetlands	100,000	1 week	any time	1-in-10	9

EA - Ecological Associates, 2010

Table A.10 Comparison of EWR metrics for broad habitats, physical form and processes eported in relevant planning documents (ref Section 3.1.1)

Source	Target	Flow requirement at SA border	Duration	Timing	Frequency	Max time bn events
		ML/day	days		years	years
MDBA	Maintain 80% of the current extent of wetlands in good condition	40,000	30 days total (7 day min)	June to December	5-in-10 to 7-in-10	
DWLBC	Temporary Wetlands: Maintain and improve majority of the lower elevation temporary wetlands in healthy condition (20% of all temporary wetlands)	40,000 (flow required to inundate 20% of wetlands as per FIM III)	90 days	August to January	1-in-2	3
DWLBC	Temporary Wetlands: Maintain and improve 80% of temporary wetlands in healthy condition (includes lower and higher elevation temporary wetlands)	80,000	>30days	June to December	1-in-4	5
DWLBC	Temporary Wetlands: Inundation of lower elevation temporary wetlands (~ 20% of temporary wetlands) for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000	90 days	Commencing in July to September	1-in-2	3
DWLBC	Temporary Wetlands: Inundation of	80,000	>30 days	Commencing in	1-in-4	5

Source	Target	Flow requirement at SA border	Duration	Timing	Frequency	Max time bn events
	temporary wetlands (~ 80% of temporary wetlands) for bird breeding events and frog breeding events			August to September		
DWLBC	Bird breeding: Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, ie provision of nutrients	40,000	90 days	Commencing in July to September	1-in-2	3
DWLBC	Bird breeding: Inundation of temporary wetlands for larger scale bird breeding events	80,000	>30 days *	Commencing in August to September	1-in-4	5
DWLBC	Mosaic habitat: Provide variability in flow regimes at lower flow levels	Variable flows from pool level to 40,000	Variable	Annually	1-in-1	na
DWLBC	Mosaic habitat: Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	60,000	60 days	Spring or early summer	1-in-3	4
DWLBC	Mosaic habitat: Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	70,000	60 days	Spring or early summer	1-in-4	6
DWLBC	Mosaic habitat: Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	80,000	>30 days	Spring or early summer	1-in-4	5
DWLBC	Mosaic habitat: Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	90,000	30 days	Spring or early summer	1-in-5	6
Source	**Specific Aims**	**Water Regime Recommendation**				
River						
EA	Sediment mobilisation and transport	Bankfull flows provided every 2 years for 1 month				
EA	Scour channels and maintain dynamic bank stability	River flows peaking at 30,000 ML/d, 60,000 ML/d, 70,000 ML/d and 80,000 ML/d each for 1 month, once every 5 years				
Floodplain						
EA	Scour channels and maintain dynamic bank stability	30,000	1 month	any time	1-in-5	4
EA	Scour channels and maintain dynamic bank stability	60,000	1 month	any time	1-in-5	5
EA	Scour channels and maintain dynamic bank stability	70,000	1 month	any time	1-in-5	5
EA	Scour channels and maintain dynamic bank stability	80,000	1 month	any time	1-in-5	5

DWLBC, 2010
EA - Ecological Associates, 2010
MDBA, 2010b

Appendix B Frequency of failure for each CLLMM target and volumes of water required to meet the shortfall

Table B.1 Capacity to meet CLLMM flow targets under the without-development, baseline and Guide scenarios

	Scenario				
Target	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	× (230)	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	18 (700)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	7 (251)	1 (564)	1 (482)	1 (354)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	25 (723)	1 (92)	✓	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	4 (386)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	22 (1835)	1 (3074)	✓	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	25 (2056)	2 (3867)	✓	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	25 (2056)	4 (2036)	2 (3694)	1 (4063)
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	12 (712)	2 (1058)	2 (923)	2 (702)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	15 (662)	2 (1367)	2 (1194)	2 (967)
SA minimum flow (max of three previous targets) in 100% of years	✓	15 (662)	2 (1367)	2 (1194)	2 (967)
6000 GL/y 1:3 year frequency	✓	4 (633)	✓	✓	✓
10,000 GL/y 1:7 year frequency	✓	3 (53)	✓	✓	✓

'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data

Table B.2 Capacity to meet CLLMM flow targets, assuming the targets underestimate the necessary water by 5% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	× (527)	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	20 (722)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	7 (301)	1 (614)	1 (532)	1 (404)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y 10-yr rolling average for salt export	✓	27 (838)	1 (252)	1 (77)	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	5 (339)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	22 (2035)	1 (3274)	1 (3104)	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	26 (2224)	2 (4117)	1 (4746)	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	26 (2224)	4 (2177)	3 (2704)	1 (4363)
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	14 (702)	2 (1158)	2 (1023)	2 (802)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	15 (781)	2 (1491)	2 (1319)	2 (1092)
SA minimum flow (max of three previous targets) in 100% of years	✓	15 (781)	2 (1491)	2 (1319)	2 (1092)
6000 GL/y 1-in-3 year frequency	✓	8 (496)	✓	✓	✓
10,000 GL/y 1-in-7 year frequency	✓	5 (344)	✓	✓	✓

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 5355 GL/year.

'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Red shading indicates targets that are met when targets are 5% higher that were not met under the original targets (See Table B.1).

Table B.3 Capacity to meet CLLMM flow targets, assuming the targets underestimate the necessary water by 10% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	× (782)	✓	✓	✓
2000 GL/y rolling average over 3 yrs in 95% of years	✓	21 (786)	✓	✓	✓
1000 GL/y rolling average over 3 yrs	✓	9 (276)	1 (664)	1 (582)	1 (454)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y 10-yr rolling average for salt export	✓	32 (857)	1 (412)	1 (237)	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	5 (372)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	23 (2141)	1 (3474)	1 (3304)	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	27 (2392)	2 (4367)	2 (4194)	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	27 (2392)	4 (2319)	4 (2174)	1 (4663)
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	14 (802)	2 (1258)	2 (1123)	2 (902)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	16 (849)	2 (1617)	2 (1444)	2 (1217)
SA minimum flow (max of three previous targets) in 100% of years	✓	16 (849)	2 (1617)	2 (1444)	2 (1217)
6000 GL/y 1-in-3 year frequency	✓	11 (625)	✓	✓	✓
10,000 GL/y 1-in-7 year frequency	✓	5 (844)	✓	✓	✓

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 5610 GL/year.

'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Red shading indicates targets that are met when targets are 10% higher that were not met under the original targets (See Table B.1).

Table B.4 Capacity to meet CLLMM flow targets, assuming the targets underestimate the necessary water by 20% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	× (1292)	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	25 (918)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	11 (318)	1 (764)	1 (682)	1 (554)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	35 (1088)	4 (227)	1 (557)	1 (228)
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	8 (366)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	27 (2194)	2 (3858)	2 (3723)	1 (3332)
6000 GL – previous 2 years (adjusted) in 95% of years	✓	33 (2594)	2 (4867)	2 (4694)	1 (5263)
SA minimum flow (max of three previous targets) in 95% of years	✓	35 (2447)	4 (2601)	4 (2456)	2 (4467)
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	17 (849)	2 (1458)	2 (1323)	2 (1102)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	17 (1036)	2 (1867)	2 (1694)	2 (1467)
SA minimum flow (max of three previous targets) in 100% of years	✓	17 (1036)	2 (1867)	2 (1694)	2 (1467)
6000 GL/y 1:3 year frequency	✓	13 (1075)	✓	✓	✓
10,000 GL/y 1:7 year frequency	✓	6 (1609)	2 (434)	1 (450)	1 (16) ‡

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 6120 GL/year.

‡ This target is considered to be effectively met, as a difference of 16 GL y is unlikely to be hydrologically or ecologically meaningful in this instance.

'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Red shading indicates targets that are met when targets are 20% higher that were not met under the original targets (See Table B.1).

Table B.5 Capacity to meet CLLMM flow targets, assuming the targets overestimate the necessary water by 5% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	× ‡ (17)	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	14 (787)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	6 (238)	1 (514)	1 (432)	1 (304)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	21 (700)	✓	✓	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	4 (354)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	21 (1656)	1 (2874)	✓	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	23 (1978)	1 (4393)	✓	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	23 (1978)	3 (2490)	2 (3444)	✓
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	12 (612)	2 (958)	2 (823)	2 (602)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	14 (588)	2 (1242)	2 (1069)	2 (842)
SA minimum flow (max of three previous targets) in 100% of years	✓	14 (588)	2 (1242)	2 (1069)	2 (842)
6000 GL/y 1:3 year frequency	✓	3 (447)	✓	✓	✓
10,000 GL/y 1:7 year frequency	✓	✓	✓	✓	✓

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 4845 GL/year.

‡ This target is considered to be effectively met, as a difference of 17 GL y^{-1} is unlikely to be hydrologically or ecologically meaningful in this instance.

'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Green shading indicates targets that are met when targets are 5% lower that were not met under the original targets (See Table B.1).

Table B.6 Capacity to meet CLLMM flow targets, assuming the targets overestimate the necessary water by 10% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	✓	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	12 (758)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	5 (227)	1 (464)	1 (382)	1 (254)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	18 (635)	✓	✓	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	3 (382)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	20 (1537)	✓	✓	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	22 (1816)	✓	✓	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	22 (1816)	3 (2313)	1 (3846)	✓
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	10 (629)	2 (858)	2 (723)	2 (502)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	12 (560)	2 (1117)	2 (944)	2 (717)
SA minimum flow (max of three previous targets) in 100% of years	✓	12 (560)	2 (1117)	2 (944)	2 (717)
6000 GL/y 1-in-3 year frequency	✓	3 (147)	✓	✓	✓
10,000 GL/y 1-in-7 year frequency	✓	✓	✓	✓	✓

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 4590 GL/year.
'✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Green shading indicates targets that are met when targets are 10% lower that were not met under the original targets (See Table B.1).

Table B.7 Capacity to meet CLLMM flow targets, assuming the targets overestimate the necessary water by 20% in order to assess the sensitivity of those targets, under the without-development, baseline and Guide scenarios

	Scenario				
Original target*	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	✓	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	10 (673)	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	3 (256)	1 (364)	1 (282)	1 (154)
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y ten-year rolling average for salt export	✓	13 (531)	✓	✓	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	3 (317)	✓	✓	✓
4000 GL – previous year in 95% of years	✓	16 (1460)	✓	✓	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	17 (1728)	✓	✓	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	17 (1728)	2 (2867)	✓	✓
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	9 (484)	2 (658)	2 (523)	2 (302)
3000 GL – previous 2 years (adjusted) in 100% of years	✓	9 (499)	2 (867)	2 (649)	2 (467)
SA minimum flow (max of three previous targets) in 100% of years	✓	9 (499)	2 (867)	2 (649)	2 (467)
6000 GL/y 1-in-3 year frequency	✓	✓	✓	✓	✓
10000 GL/y 1-in-7 year frequency	✓	✓	✓	✓	✓

* Note that the original targets are specified here for ease of comparison across tables. The actual targets assessed here are 5% lower than those stated. For example, here the first target is assessed as met if the long-term average barrage flow exceeds 4080 GL/year. '✓' indicates the target was met. Figures show the number of occasions on which the target was not met (or '×' where the number of occasions cannot be calculated) and the average volume of additional water (GL) required to achieve the target per occasion is given in parentheses. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Green shading indicates targets that are met when targets are 20% lower that were not met under the original targets (See Table B.1).

Appendix C Proportional change in the volumes of additional water required to meet CLLMM shortfalls

Table C.1 Capacity to meet CLLMM flow targets under the without-development, baseline and Guide scenarios

	Scenario				
Target	without development	baseline	3000	3500	4000
MDBA targets					
5100 GL/y long-term average	✓	✓	✓	✓	✓
2000 GL/y rolling average over 3 years in 95% of years	✓	17%	✓	✓	✓
1000 GL/y rolling average over 3 years	✓	39%	15%	23%	31%
High flow requirements (exact volumes not specified, see below)	NA	NA	NA	NA	NA
3200 GL/y 10-yr rolling average for salt export	✓	3%	54%	1 (57)*	✓
SA Government targets					
Absolute minimum of 650 GL 95% of years	✓	39%	✓	✓	✓
4000 GL – previous year in 95% of years	✓	4%	0%	✓	✓
6000 GL – previous 2 years (adjusted) in 95% of years	✓	11%	–55%	✓	✓
SA minimum flow (max of three previous targets) in 95% of years	✓	11%	11%	–55%	✓
Flows sufficient to replace evaporative losses in Lakes	NA	NA	NA	NA	NA
2000 GL – previous year in 100% of years	✓	22%	17%	22%	29%
3000 GL – previous 2 years (adjusted) in 100% of years	✓	–8%	22%	26%	32%
SA min. flow (max of three previous targets) in 100% of years	✓	28%	22%	26%	32%
6000 GL/y 1-in-3 year frequency	✓	–15%	✓	✓	✓
10,000 GL/y 1-in-7 year frequency	✓	88%	✓	✓	✓

'✓' indicates the target was met. Figures show the proportional increase in water required to meet the target compared with that calculated from the daily flow model. NA is not assessed, either due to insufficient detail in the specification of the target or to an inability to assess the target from barrage flow data. Blue shading indicates targets that are met based on monthly flow model simulations that were not met based on daily flow model simulations and *vice versa* (See Table B.1). * where the target was not met based on the monthly model, but was based on the daily flow model, the number of occasions on which the target was not met is shown with the average flow volume required to meet the targets in parentheses.

Appendix D Flows to South Australia (Gauge 426200)

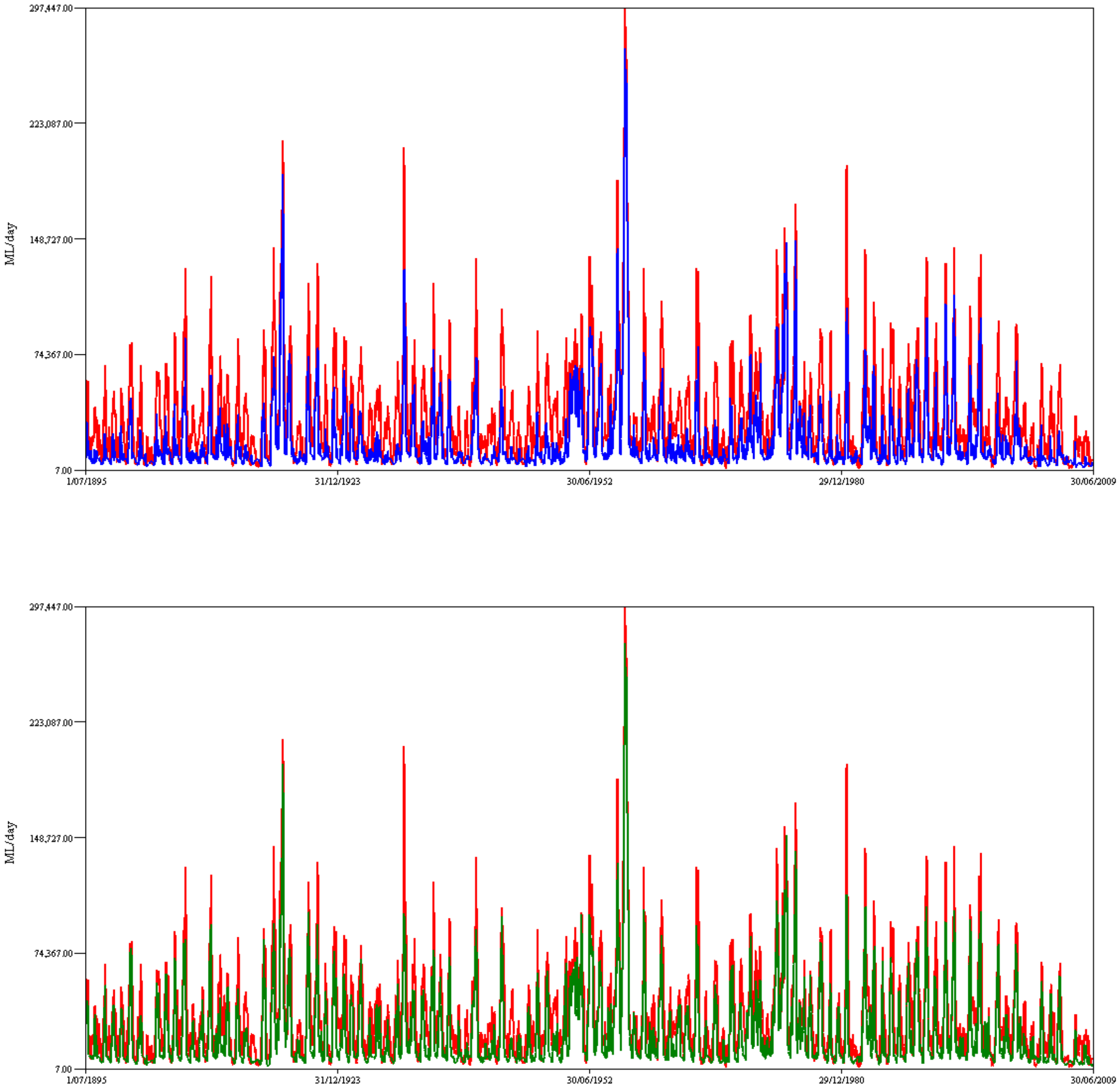


Figure D.1 Daily hydrographs in ML/day at gauge 426200 for the without-development (red), baseline (blue), 3000 (green) scenarios

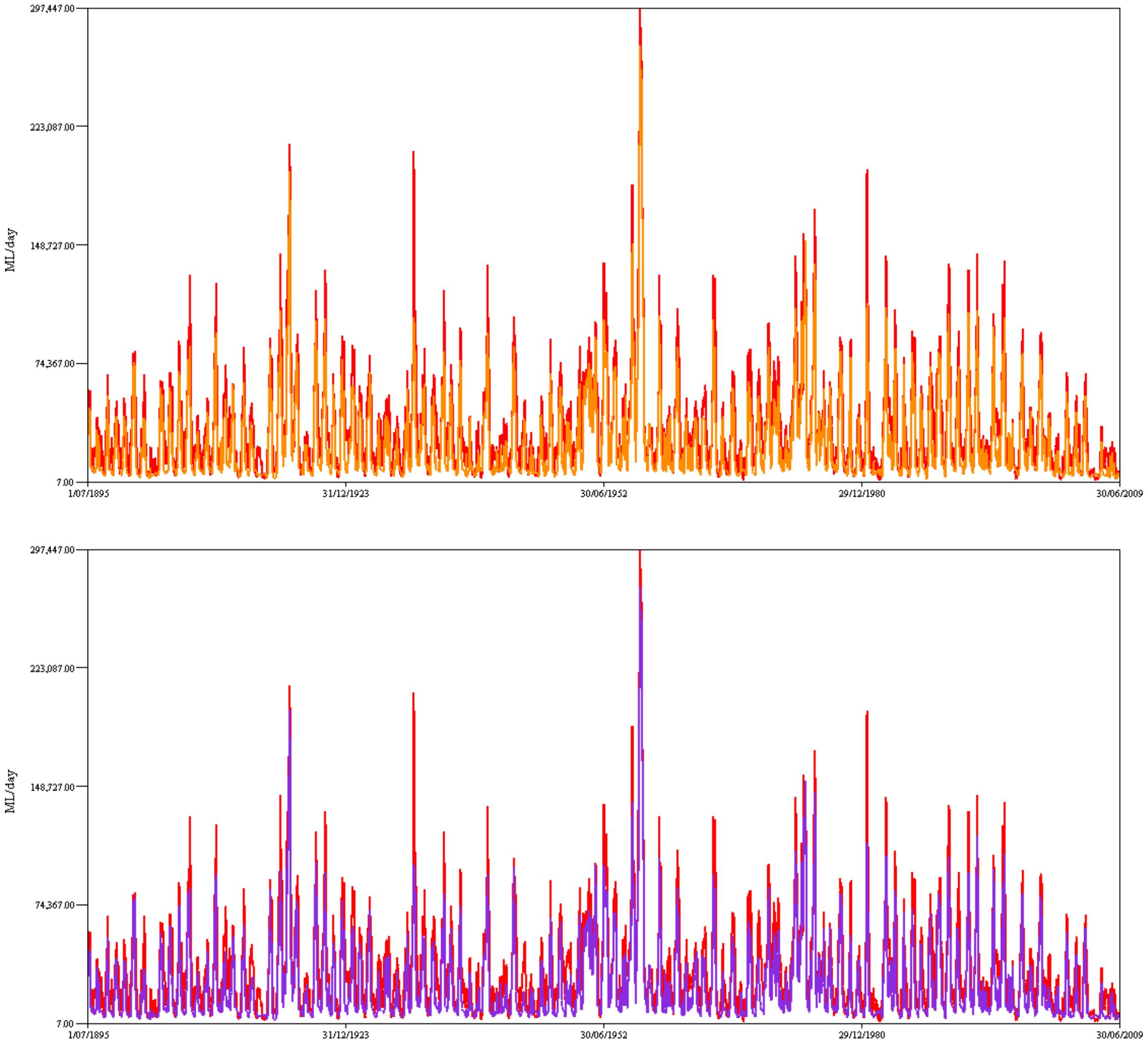


Figure D.2 Daily hydrographs in ML/day at gauge 426200 for the without-development (red), 3500 (orange) and 4000 (purple) scenarios

Part II – Water quality and salinity

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5 Introduction

This chapter presents the results of a review of South Australia's and the Murray–Darling Basin Authority's (MDBA) proposed water quality, salinity and salt load targets. Information on the proposed targets was provided by the South Australian Department for Water (DFW, 2010) and were developed by DFW in recognition of water quality and salinity as key management issues for the River Murray in South Australia. They were developed a result of an independent review of water quality and salinity for the River Murray in South Australia and to inform the State's input to the development of the Basin Plan. The proposed targets are not currently formal Government policy.

Information on the MDBA's targets was extracted from the Guide to the proposed Basin Plan (MDBA, 2010a and 2010b). The review relied on water flow, water level and salinity results from BigMod modelling provided by the MDBA for the five scenarios – baseline, without-development and the three Guide scenarios (3000, 3500 and 4000).

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*).

5.1 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 5.1.

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 5.1) 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 5.1), 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 5.1).
- 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 5.1 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 6.1, Table 6.2 and Table 6.3.

6 Water quality

This review encompassed lake alkalinity and cyanobacteria bloom risk, which are the only two parameters apart from salinity for which information was provided by the South Australian Government (DFW,2010). The review was based on statistical analysis of modelling results from BigMod and results were provided by MDBA for the 114-year historical period 1/7/1895–30/6/2009. As BigMod produces results for flows and water levels, but does not provide results for any water quality parameter apart from salinity, it was necessary to use flow and water level based surrogate indicators for analysing the effects of the five scenarios on lake alkalinity and cyanobacteria bloom risk.

6.1 Methodology

Statistical analyses of results from BigMod were undertaken using the eWater River Analysis Package (RAP) available from the eWater Toolkit <www.toolkit.net.au>, supplemented with graphs and some additional statistics extracted using the IQQM graphics package and Excel. Analyses were undertaken for all five scenarios for which BigMod results were available. The following were analysed:

- Occurrences of water levels in Lake Alexandrina below 0.0 and –0.5 m AHD. These thresholds were identified by DENR (J. Higham, pers. comm. 2011) as indicators of increased risk of lake alkalinity. Statistics were evaluated using BigMod results for water levels at Milang for the period from 1/7/1895 to 30/6/2009 (114 years). Analysis of events below –1.0 m AHD was requested but not done as modelled water levels never went as low as this level.
- Flows at Morgan less than or equal to 7000 ML/d in summer (December to February). This threshold was discussed and agreed with SA Water as a flow-based indicator of increased risk of cyanobacteria blooms in the river (wind conditions and solar radiation inputs must also be suitable for blooms to form). 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 was based on information in Maier et al. (2001) and Maier et al. (2004). Statistics of occurrences of flows at Morgan below this threshold were evaluated using BigMod results for the period from 1/7/1895 to 30/6/2009.

6.2 Results of water quality analyses

Lake alkalinity

Results of analysis of modelled occurrences of low water levels in Lake Alexandrina, as indicators of elevated risk of lake alkalinity, are summarised in Table 6.1.

Time series plots of modelled water levels under the baseline and 3000 scenarios are shown in Figure 6.1. The time series plot for the 3000 scenario is representative of the time series for the 3500 and 4000 scenarios, therefore plots for these two scenarios are not shown. An extract from the exceedance plot of water levels for all five scenarios is shown in Figure 6.2.

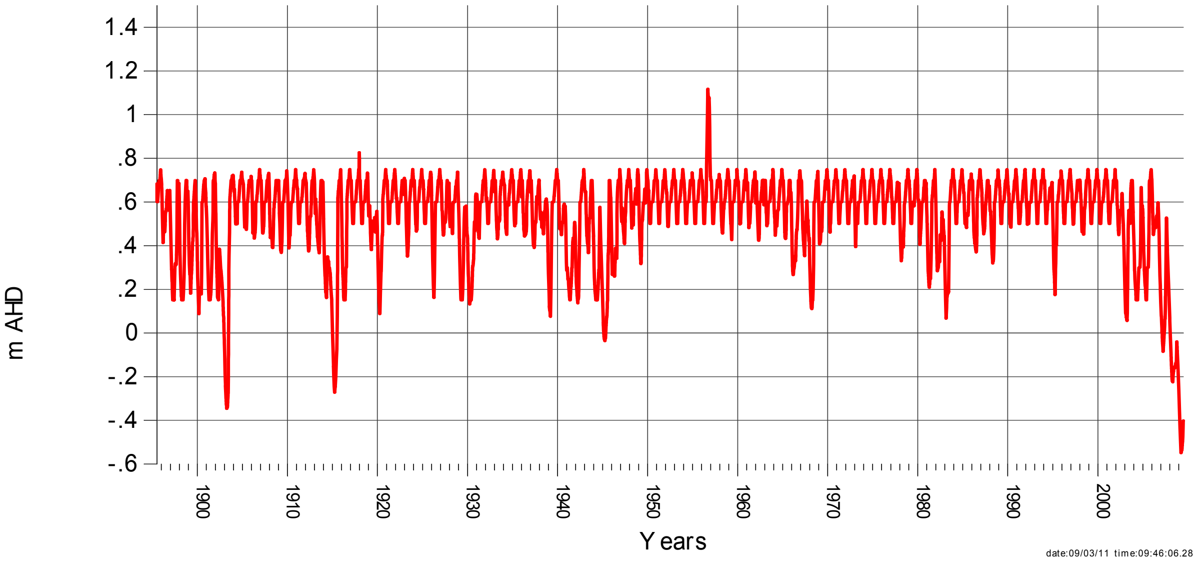
From Figure 6.1 occurrences of modelled water levels below the thresholds of 0.0 and –0.5 m AHD may be seen. Details of these events are presented in Table 6.2. It is emphasised that the results in these two tables can be expected to be sensitive to the pattern of the historical data used as input for the modelling.

Table 6.1 Summary statistics of modelled low water levels in Lake Alexandrina over the 114-year historical period (1/7/1895–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	3000	3500	4000
Minimum water level (m AHD)	0.03	–0.55	–0.23	–0.24	–0.25
Maximum water level (m AHD)	1.21	1.12	1.13	1.13	1.13
Lake Alexandrina less than 0.0 m AHD					
Number of low spells	0	4	5	3	3
Longest low spell (days)	na	186	160	164	166
Mean of low spell troughs (m AHD)	na	–0.18	–0.11	–0.17	–0.18
Mean duration of low spells (days)	na	134.7	95.2	142	145
Total duration of low spells (days)	na	539	476	426	435
Mean period between low spells (days)	na	12,534	9,493	18,851	18,848
Longest period between low spells (days)	na	22,568	24,716	33,456	33,461
Lake Alexandrina less than –0.5 m AHD					
Number of low spells	0	1	0	0	0
Lowest level (m AHD)	na	–0.55	na	na	na
Duration of low spell (days)	na	82	na	na	na

na – not applicable

(a)



(b)

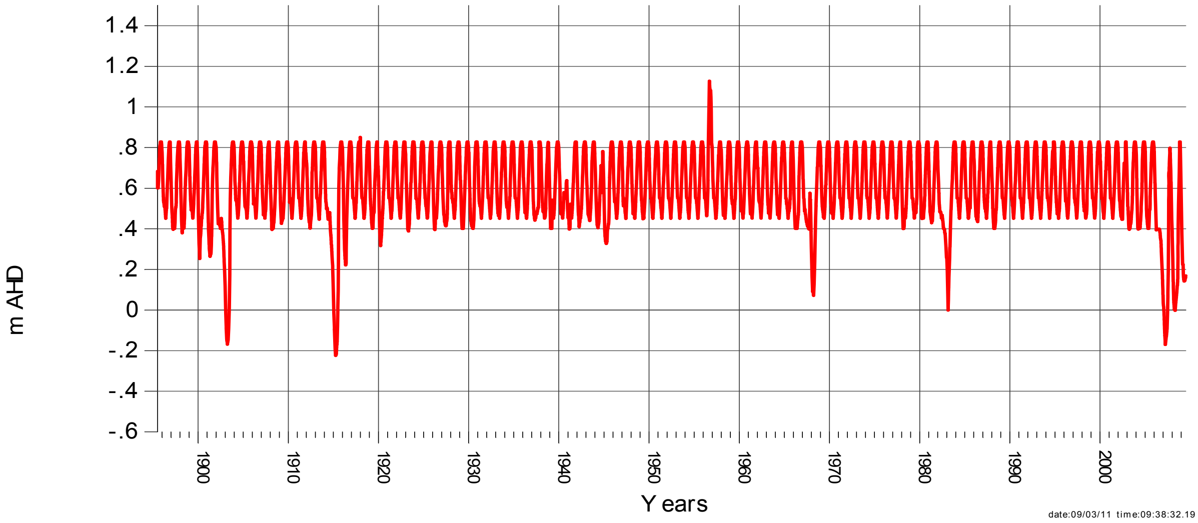


Figure 6.1 Modelled daily water levels in Lake Alexandrina for the 114-year historical period (1/7/1895–30/6/2009) under the (a) baseline and (b) 3000 scenarios

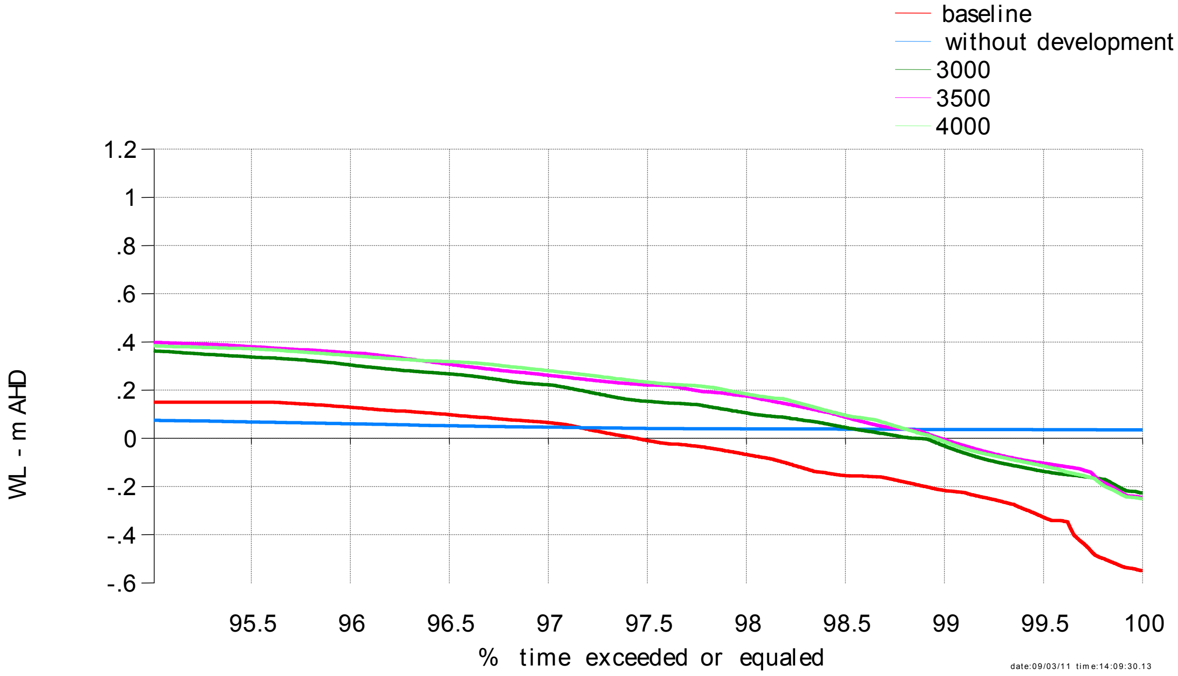


Figure 6.2 Exceedance plots of modelled daily water levels in Lake Alexandrina over the 114-year historical period (1/7/1895–30/6/2009) under the baseline, without-development and Guide scenarios

Table 6.2 Details of modelled events of water levels below 0.0 m AHD in Lake Alexandrina under the baseline and Guide scenarios

Scenario	baseline	3000	3500	4000
		Event 1		
Dates: from – to	18/12/1902–20/6/1903	24/2/1903–15/6/1903	2/3/1903–5/6/1903	25/2/1903–13/6/1903
Duration (days)	185	112	96	109
Minimum water level (m AHD)	–0.36	–0.17	–0.13	–0.17
		Event 2		
Dates: from – to	5/1/1915–8/7/1915	19/1/1915–28/6/1915	19/1/1915–2/7/1915	17/1/1915–2/7/1915
Duration (days)	185	161	165	167
Minimum water level (m AHD)	–0.30	–0.24	–0.24	–0.25
		Event 3		
Dates: from – to	19/2/1945–8/5/1945	na	na	na
Duration (days)	79	na	na	na
Minimum water level (m AHD)	–0.05	na	na	na
		Event 4		
Dates: from – to	na	26/2/1983–1/3/1983	na	na
Duration (days)	na	4	na	na
Minimum water level (m AHD)	na	0.0	na	na
		Event 5		
Dates: from – to	21/2/2007– 19/5/2007	28/1/2007–30/6/2007	4/2/2007–22/6/2007	10/2/2007–18/6/2007
Duration (days)	88	154	139	129
Minimum water level (m AHD)	–0.09	–0.16	–0.13	–0.14
		Event 6		
Dates: from – to	18/1/2008–mid-late 2010*	30/3/2008–1/5/2008	na	na
Duration (days)	18–22 months (550–640 days)	33	na	na
Minimum water level (m AHD)	–0.55	0.0	na	na

*event ongoing at end of modelling period; end date estimated from knowledge of subsequent actual behaviour
na – not applicable

River cyanobacteria bloom risk

Results of analysis of modelled occurrences of low flows at Morgan, less than or equal to 7000 ML/day, as indicators of elevated risk of cyanobacteria blooms in the river, are summarised in Table 6.3. An extract from the plot of flow duration curves for all five scenarios is shown in Figure 6.3.

Table 6.3 Summary of modelled occurrences of daily flows at Morgan less than or equal to 7000 ML/d over the 114-year historical period (1/7/1895–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	3000	3500	4000
All seasons					
Number of low spells	107	282	167	162	169
Longest low spell (days)	248	413	560	559	558
Mean duration of low spells (days)	47	70	100	97	93
Total duration of low spells (days)	5,030	19,740	16,700	15,710	15,720
Summer					
Mean of yearly numbers of summer low spells	0.7	1.8	1.4	1.3	1.4
Median of yearly numbers of low spells in summer	1	2	1	1	1
Median of yearly longest low spells in summer (days)	0	29	48	41	46
Median of yearly mean durations of low spells in summer (days)	0	17	26	24	25
Median of yearly total durations of low spells in summer (days)	0	47	54	48	51
Mean of summer days with Q ≤ 7000 ML/d	12.9	47.4	46.8	42.7	43.1
Median of summer days with Q ≤ 7000 ML/d	0	48	55	48	51

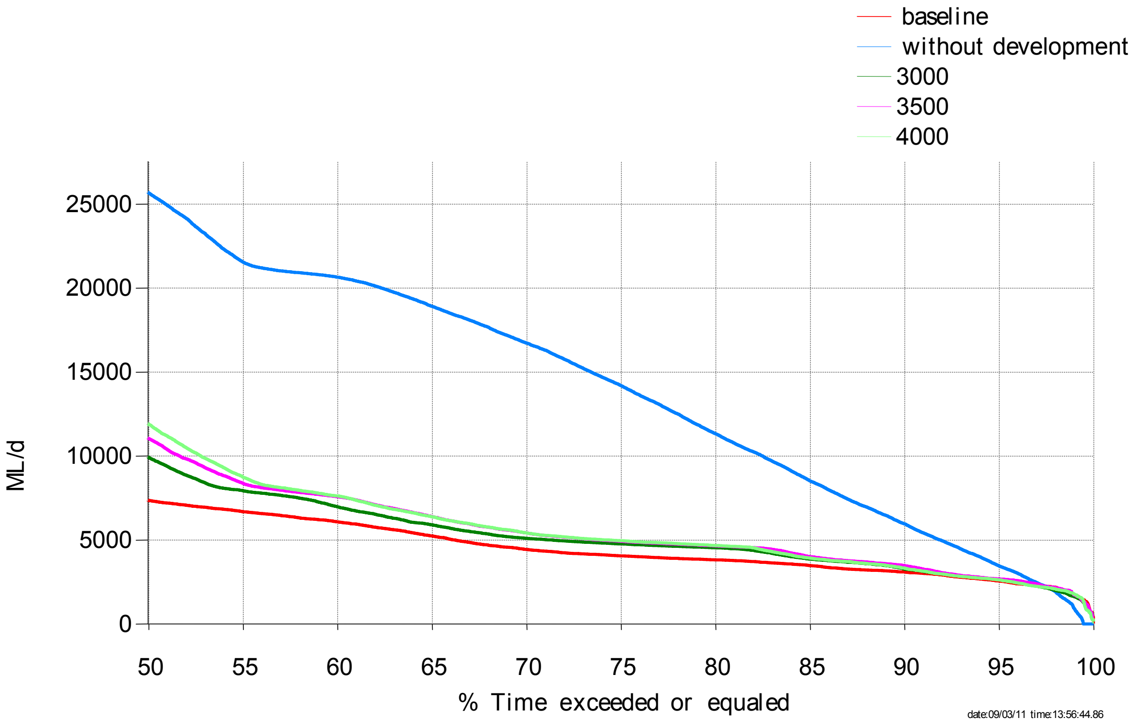


Figure 6.3 Exceedance plots of modelled daily flows at Morgan over the 114-year historical period (1/7/1895–30/6/2009) under the baseline, without-development and Guide scenarios

6.3 Discussion

The objectives and the discussion on the cyanobacteria and alkalinity proposed targets provided by the South Australian Government (DFW, 2010) were reviewed and points identified are discussed below. Discussion of the analyses of BigMod results follows.

Discussion on objectives

Points identified when reviewing the objectives and the discussion on the cyanobacteria and alkalinity targets are:

- The objective that the water level in the lower lakes does not drop below sea level seems to be a change from a previously identified objective that the water level should not drop below 0.55 m (AHD) to enable flood irrigation in the Lower Murray Swamps (Lamontagne et al., 2004). It is noted that this objective only relates to reducing the risk of low lake alkalinity, and that it does not take into account operational issues or water access by irrigators
- The intent of the objective to "achieve and maintain a healthy and diverse freshwater aquatic ecosystem in the river and Lower Lakes" could be clarified as it could be achieved with either a fixed water level or a variable regime, and with clear water (involving macrophytes) or turbid water (involving phytoplankton)
- The objective of "no significant cyanobacterial blooms of public health concern" is not achievable in practical terms
- It is unclear whether South Australia's objective that river water quality must be acceptable as a raw drinking water source is intended to encompass bacteria or not (we acknowledge that sterilisation is a normal part of the treatment process). However, the MDBA (2010b: p 301) state that their raw drinking water targets will not include microbial contaminants or suspended solids that are removed by conventional water treatment processes.

Discussion on cyanobacteria and alkalinity targets

The following points were identified when reviewing the discussion on the cyanobacteria and alkalinity targets:

- In relation to the recommendation that "trigger values and target values are the same" for cyanobacteria, we point out that these values cannot be the same.
- The preferred target for areas below Lock 1 is for alkalinity to be above 80–100 mg/L for the majority of the time and not below 25 mg/L for any prolonged period (2−3 weeks), with pH maintained between ANZECC guideline values of 6.5–9.0. The target value range for alkalinity of 80−100mg/L seems high.
- For purposes of managing acid sulfate soils it would be useful to monitor changes in alkalinity; to this extent an alkalinity target is valuable. In this context, a water level target (as proposed) may be a valuable aid in managing the wetting and drying regime of adjacent wetlands to reduce the level of sulfide which has built up as a consequence of the constantly high water levels maintained by the locks.

Discussion on lake alkalinity analysis

The following points were identified from the results of the analysis of modelled water levels in Lake Alexandrina:

- Results for Guide scenarios summarised in Table 5.1 show modelled occurrences of water levels in Lake Alexandrina of less than 0.0 m AHD, used as indicators of increased low alkalinity risk in the lake in this project, are reduced in severity and duration compared to baseline conditions, but not eliminated.
- Occurrences of water levels in Lake Alexandrina of less than –0.5 m AHD are modelled as being eliminated under all Guide scenarios.
- Results for individual events, presented in Table 6.2, should be used and interpreted with caution as the severity and duration of future events can be expected to be sensitive to future flow patterns and these will almost certainly be different to patterns in the historical sequence which are the basis of these results.

- It should be noted that the lowest water level modelled was −0.55 m AHD under baseline conditions, which is above the low levels observed in the lake in the drought that ended in 2010. However, the modelling period ended before the end of this drought. Hence, the modelled severity of the last modelled low water level event is likely to have been under-estimated and the benefits of the Guide scenarios could be over estimated, but this is not certain.

Discussion on analysis of river cyanobacteria bloom risk

The following points were identified from the results of the analysis of low flows at Morgan:

- Results for Guide scenarios summarised in Table 6.3 show modelled occurrences of flows in summer less than or equal to the threshold of 7000 ML/d at Morgan are reduced in average number but average durations are longer compared to baseline conditions. Overall, the model results show total durations of these occurrences for the Guide scenarios being only slightly reduced compared to baseline conditions.
- It is possible that the potential for improvements in summer is being under-predicted in the modelling as it is likely most of the additional environmental water available under the Guide scenarios would be delivered in winter and spring, to replicate natural patterns, whereas the need for additional flow for cyanobacteria bloom suppression is in summer. This is supported by the larger reductions in total event durations shown in the results of the analyses for the full year in Table 6.3, compared to the results for summer. Some trade-offs may have to be negotiated by South Australia to change the delivery patterns of environmental water if further improvement in cyanobacteria bloom suppression is required.

7 Review of salinity targets

This review was based on statistical analysis of modelling results from BigMod. For salinity, results were provided by MDBA for the 34.5 year historical period from 1/1/1975 to 30/6/2009. It should be noted that the salinity results are a by-product of flow modelling, as modelling of salinity was not done specifically, but the results are the best available at the time of this report. BigMod results for flows, provided by MDBA for the 114 year historical period 1/7/1895 − 30/6/2009, were also used in the analysis of salt loads. In addition, the review took into consideration:

- the BSMS Annual Implementation Report (AIR) for 2008-09 (MDBA, 2010c), being the latest one publicly available at the time of writing this report; particularly Table 12 in Appendix V
- the report from the MDBA Salinity Targets Review: Environmental Values and Data Analysis, one of four reports prepared by Sinclair Knight Merz for MDBA (MDBA, 2010d)
- the Australian Drinking Water Guidelines (Australian Government, 2004), concentrating on the salinity material; particularly Section 6.2.2, the material on safety factors and Section 6.4.

7.1 Methodology

Statistical analyses of the salinity results from BigMod were undertaken using the eWater River Analysis Package (RAP) available from the eWater Toolkit (<www.toolkit.net.au>), supplemented with graphs and some additional statistics extracted using the IQQM graphics package and Excel. Analyses were undertaken for all five scenarios for which BigMod results were available and were undertaken for the following locations:

- SA border (Lock 6 Upstream results used for salinity)
- Berri (Pumping Station)
- Morgan
- Murray Bridge
- Tailem Bend (results used as representative of Wellington for comparison with targets)
- Lake Alexandrina (Milang results used for salinity).

A number of SA's proposed targets are for a probability of non-exceedance of 99.7%: as RAP does not produce results for this percentile they were extracted from graphs produced by IQQM.

Desired non-exceedance probabilities of proposed SA and MDBA salinity target values were compared with non-exceedance probabilities based on BigMod results by extracting relevant information using the IQQM graphics package, which also produces tables of integer percentiles and values. Statistics were also extracted to evaluate the achievement of MDBA's proposed operational targets, although MDBA did not specify any desired non-exceedance probabilities for these. Results were taken to the nearest whole percentile unless otherwise indicated.

Achievability of MDBA's proposed salt load export target of a minimum of 2 million tonnes per year through the barrages on a 10-year rolling average basis (i.e. 20 million tonnes in any 10 year period) was also investigated. This entailed calculating daily salt loads through the barrages and using these to calculate 10-year rolling averages of salt loads, with the first period starting on 1/7/1975 and following periods starting progressively one year later through to 1/7/1999.

Daily salt loads through the barrages were calculated from Bigmod results via Excel spreadsheets for the period 1/7/1975 − 30/6/2009 using the following equation (this shorter period was used to give whole years for the evaluation of the 10-year rolling averages):

$$\text{Load} = \text{MilangEC} * 0.6(\text{barrage\_outflow})/1000$$

where:

Load = daily salt load (tonnes/d)
MilangEC = Milang salinity value from BigMod (EC or µS/cm)
0.6 = factor to convert EC to mg/L as used in BigMod
barrage_outflow = daily outflow value from BigMod (ML/d)
1000. = units conversion from kg to tonnes

The resultant daily salt loads were used in the calculation of the 10-year rolling averages.

Average annual salt loads at Morgan were calculated for all five scenarios for the period from 1/7/1975 to 30/6/2009, and for baseline conditions for the BSMS Benchmark Period from 1/5/1975 to 30/4/2000 as well.

7.2 Results of salinity analyses

Proposed SA and MDBA salinity target values were compared with results from BigMod for the period from 1/1/1975 to 30/6/2009. Results from the comparison are summarised in Table 7.1.

Salinity non-exceedance curves for Morgan are illustrated in Figure 7.1. Salinity non-exceedance curves for other locations in the river are of similar form and are therefore not shown. Time series plots of daily salinity values at Morgan are shown in Appendix A. Basic statistics from the analyses of salinity results from BigMod at all locations for the period from 1/1/1975 to 30/6/2009 are summarised in Appendix A, for reference.

Table 7.1 Comparison of salinity targets with model results over the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline, without-development and Guide scenarios

Scenario	baseline	3000	3500	4000	without development
SA border					
SA: < 400 EC 99.7% of the time (in a rolling 12-month period).	69	70	72	74	83
MDBA: < 412 EC 80% of the time (from *Water Act 2007*)	72	73	74	76	***84***
MDBA operational target: 310 mg/L (496 EC)	90	88	89	89	*91.5
Berri					
MDBA: < 543 EC 80% of the time (from *Water Act 2007*)	79	***83***	***85***	***86***	***88***
MDBA operational target: 390 mg/L (624 EC)	91	93	94	92	92
Morgan					
SA and MDBA: < 800 EC 95% of the time (Basin Salinity Target)	90	***96***	***98***	***97***	92
MDBA operational target: 500 mg/L (800 EC)	90	***96***	***98***	***97***	92
Murray Bridge					
SA: < 900 EC 99.7% of the time (in a rolling 12 month period)	94	98	98	98	96
MDBA: < 770 EC 80% of the time (from *Water Act 2007*)	***83***	***93***	***95***	***95***	***94***
MDBA operational target: 500 mg/L (800 EC)	86	94	96	96	95
Tailem Bend					
SA: < 900 EC 99.7% of the time (in a rolling 12 month period) **at Wellington**	93	97	*98.5	98	96
Lake Alexandrina					
SA: < 1000 EC 95% of the time	85	95	***96***	***98***	85
SA: < 1500 EC 100% of the time	95	***100***	***100***	***100***	87

Note: non-exceedance percentiles (green cells with numbers in italics indicate a percentile equalling or better than the target value)
* - interpolated

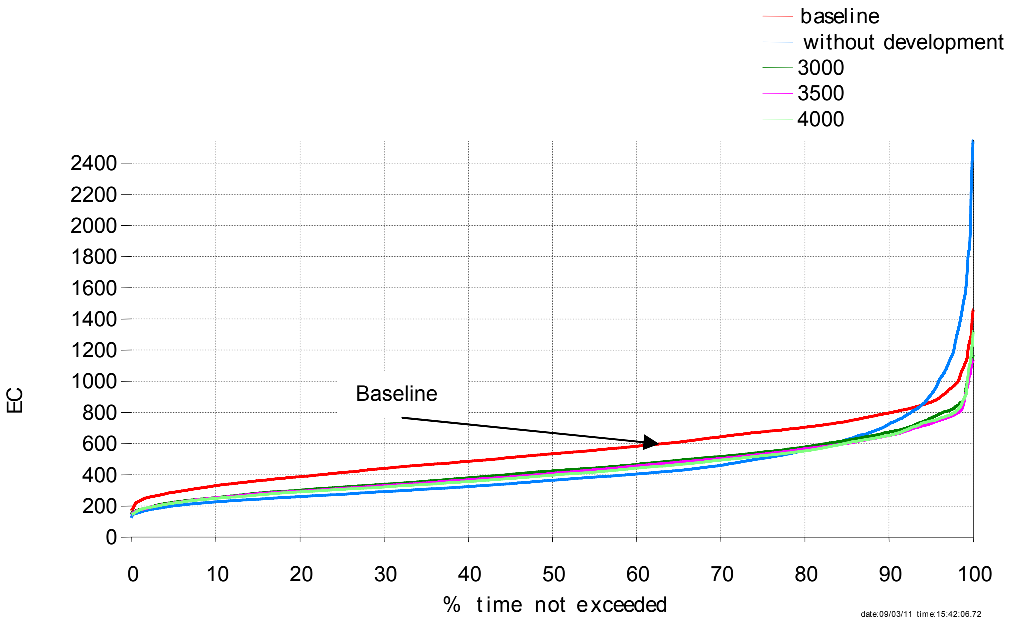


Figure 7.1 Salinity non-exceedance curves for Morgan over the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline, without-development and Guide scenarios

The threshold of 800 EC is used by South Australia as a management target. Amongst other things, it is an important threshold for sensitive crops and eco-systems. Results of analyses of modelled exceedances of this threshold for the full period salinity was modelled are summarised in Table 7.2, including results of sensitivity analyses where the threshold is reduced by 5%, 10% and 20%. The sensitivity analyses provide indications of exceedances that could be expected if salinities were to increase by 5%, 10% and 20%.

The threshold of 1400 EC is used by South Australia as a trigger point for emergency response in relation to water supply. Results of analyses of modelled exceedances of this threshold for the full period salinity was modelled are summarised in Table 7.3. These also include results of sensitivity analyses where the threshold is reduced by 5%, 10% and 20%. The sensitivity analyses provide indications of exceedances that could be expected if salinities were to increase by 5%, 10% and 20%. Further details of exceedance events for both these thresholds and the sensitivity analyses are presented in Appendix A.

Table 7.2 Modelled exceedances of a salinity threshold of 800 EC and with threshold reduced by 5%, 10% and 20% at the SA border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina over the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline and Guide scenarios

Scenario	800 EC	760 EC	720 EC	640 EC
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

Scenario	800 EC	760 EC	720 EC	640 EC
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

Note: values are percent of time in modelled period threshold is exceeded

Table 7.3 Exceedances of threshold of 1400 EC and with threshold reduced by 5%, 10% and 20% at the SA border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina over the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline and Guide scenarios

Scenario	1400 EC	1330 EC	1260 EC	1120 EC
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

Note: values are percent of time in modelled period threshold is exceeded

Results of the evaluation of average annual salt loads through the barrages for the period from 1/7/1975 to 30/6/2009 are summarised in Table 7.4, and are illustrated in Figure 7.2. More details are given in Appendix A. In Table 7.4, results are compared with MDBA's proposed salt load export target of a minimum of 2 million tonnes per year through the barrages on a 10-year rolling average basis (i.e. 20 million tonnes in any 10 year period). Results of analyses of annual salt loads at Morgan are summarised in Table 7.5 and compared with MDBA's salt load target at that location.

Table 7.4 Average annual salt loads (million tonnes/y) through the barrages over all complete years in the salinity modelling period (i.e. 1/7/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	3000	3500	4000
MDBA salt export target at barrages: 2 million tonnes/y (10-year rolling average)	3.62	1.48	1.67	1.71	1.75

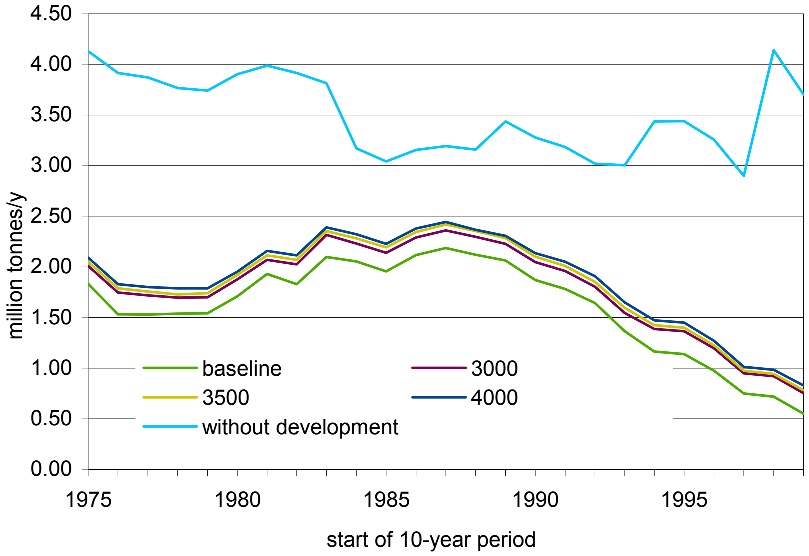


Figure 7.2 Average annual salt loads (million tonnes/y) through the barrages for rolling 10-year periods over all complete years in the salinity modelling period (i.e. 1/7/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Table 7.5 Modelled average annual salt loads at Morgan (million tonnes/y) over all complete years in the salinity modelling period (i.e. 1/7/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	baseline (2)*	3000	3500	4000
MDBA BSMS Basin Salt Load Target: 1.76 million tonnes/y	2.24	1.39	1.69	1.52	1.55	1.57

* Result for BSMS Benchmark Period, 1/5/1975–30/4/2000.

7.3 Discussion

From the analyses of the results from the BigMod modelling, and taking into consideration information in MDBA (2010c and 2010d), the following points have been identified with respect to salinity and salt load targets:

- Modelling results can be expected to be sensitive to sequencing and period of historical data, to assumptions made about delivery patterns for environmental water under the three Guide scenarios, and to assumptions made in modelling salinity.
- The assumption that salinity doubles between the SA border and Murray Bridge is conservatively high. For example, under baseline conditions the average salinity at the SA border is modelled as being 346 EC while the average salinity at Murray Bridge is modelled as being 581 EC; for the 95th percentile the values are 530 EC and 915 EC, respectively (see basic salinity statistics in Appendix A). Smaller differences are modelled under the Guide scenarios. More details are in Appendix A.
- As may be seen from the data in Table 7.1, South Australia’s proposed targets at the SA border, Murray Bridge and Wellington, which each have a probability of non-exceedance of 99.7%, would not be achieved under any of the modelled scenarios, including the scenario of without-development conditions.

- The Basin Salinity Target at Morgan is modelled as being achieved, from the data in Table 7.1, under any one of the three Guide scenarios.
- Values of salinity in Lake Alexandrina in excess of 20,000 EC are modelled as occurring with probabilities of non-exceedance of greater than 99% under without-development conditions (see basic salinity statistics in Appendix A). From inspection of the Bigmod results these very high values of salinity occur during and after about a six month period when the model is simulating inflows from the ocean back into the lake
- From the data in Table 7.1, South Australia's proposed target of salinity in Lake Alexandrina to be less than 1,000 EC for 95% of the time is is modelled as being achieved for the 3500 and 4000 scenarios, and is borderline for the 3000 scenario.
- South Australia's proposed target of salinity in Lake Alexandrina to be always less than 1,500 EC is modelled as being achieved, from the data in Table 7.1, under any one of the three Guide scenarios. However, it is cautioned that this result is obtained from modelling salinity behaviour for a 34½ year historical period and that conditions may arise in the future that cause the threshold to be exceeded. While this caveat is applicable to all the conclusions drawn based on the modelling results, it is particularly relevant in this case.
- MDBA's planning target at the SA border is modelled as being achieved, from the data in Table 7.1, only under without-development conditions.
- From the data in Table 7.1, MDBA's planning targets at Berri and Murray Bridge are modelled as being achieved under any one of the three proposed Guide scenarios. It is worth noting that their planning target at Murray Bridge is modelled as being achieved under baseline conditions as well.
- From the data in Table 7.4, and illustrated in Figure 7.2, MDBA's target for salt load export through the barrages is predicted to be achieved only under without-development conditions. Given the characteristics of the flow and salinity regime in the Murray a 10-year assessment period is quite short, which would make achieving this target more difficult than if a longer period were used. However, as the mean salt load for the full period from 1/7/1975 to 30/6/2009 for all scenarios except without-development conditions is less than the target 2 million tonnes per year, extending the assessment period is not likely to completely resolve this problem. Alternatively, this target may provide the basis of a mechanism for managed dumping of salt from salt disposal basins when river flow conditions are appropriate.
- The results for the average annual salt load at Morgan for baseline conditions for the full period salinity was modelled and the Benchmark Period (Table 7.5) shows the results are sensitive to the choice of modelling period. As the target value is, in part, an artefact of the Benchmark Period, it is therefore seen from comparing the other results in Table 7.5 that the target would be achieved under all three Guide scenarios.
- The threshold of 800 EC is used by South Australia as a management target. Overall, it may be seen from the results in Table 7.2 that under the Guide scenarios, modelled exceedances of this threshold are reduced in severity and duration at all locations compared to baseline conditions, but not eliminated.
- At the SA border and Berri, modelled exceedances of the 800 EC salinity threshold under the three Guide scenarios are higher in number than under baseline conditions (Table 7.2). This may be attributed to river flows dropping to lower rates at various times under these three scenarios than under baseline conditions due to the dams being drawn down faster to supply environmental flow requirements. Refinement of environmental flow rules may overcome this situation.
- However, at Morgan, Murray Bridge and Tailem Bend, modelled exceedances of the 800 EC salinity threshold under the three Guide scenarios are fewer in number than under baseline conditions (Table 7.2). This is likely to be due to interactions between modelled flow and salinity patterns in the river and the modelled operation of salt interception schemes in SA. Refinement of environmental flow rules may shed further light on this.
- The threshold of 1400 EC is used as a trigger point for emergency response in relation to water supply. Under the Guide scenarios it is only for the 4000 scenario that exceedances of the 1400 EC threshold are modelled (see Table 7.3). Exceedances are modelled only at Murray Bridge and Tailem Bend, with one instance at each location. Modelled durations are 3 days and 14 days, respectively. These results may be sensitive to refinement of environmental flow rules as more detailed modelling is undertaken to support Guide implementation, and to the hydrological characteristics of the historical period used in the modelling. The results may therefore be subject to change.
- The high numbers of modelled exceedances of salinity thresholds of 800 EC (Table 7.2) and 1400 EC (Table 7.3) at locations in the river under without-development conditions may be attributed to modelled surface flows

in the river dropping to very low rates at various times, while highly saline groundwater inflows are modelled to continue at their usual rates.

- Sensitivity analyses of exceedances of a threshold of 800 EC show these are sensitive to changes if salinity levels were to increase by 5%, 10% and 20%, especially the 20% change (see Table 7.2). 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 generally similar at any given location.
- Exceedances of a threshold of 1400 EC 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 (see Table 7.3). 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.
- From MDBA (2010b: p 306), MDBA's operational targets are based on consideration of "resource condition limits" for environmental or water usage values at a given location. The target is the lesser of the salinity "resource condition limit" for the most sensitive environmental value and the 95th percentile non-exceedance salinity derived from whatever salinity data is available for the location. Where records are short, confidence intervals (and particularly the 90% confidence interval usually used for assessing reliability of non-exceedance values) are likely to be wide. 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.
- It is therefore apparent MDBA's operational targets would benefit from refinement, if only to include consideration of allowable durations and severities of exceedances, times between events, and management actions that should be taken when the operational target values are exceeded or expected to be exceeded.
- The analytical results obtained for each modelled scenario are based on the assumption that the scenario is fully implemented (i.e the transition from current conditions to conditions that apply to a given scenario is not modelled). It is worth noting that, in reality, any EWRs in the Basin Plan may not be fully implemented until 2019.

7.4 Suggestions for refining operational salinity targets

From the results in Section 7.2 and the points raised in Section 7.3, it is apparent that some of South Australia's proposed targets (DFW, 2010) could beneficially be refined to make them more practical and more closely relevant to the values intended to be protected while others could remain as currently proposed, at least for the time being. Specific points are:

- The target at Morgan could remain as is.
- At the SA border, if a target is desired that is commensurate with the target at Morgan, then a value of 570 EC with a non-exceedance probability of 95% may be appropriate (see basic salinity statistics in Appendix A). If a target with a lesser probability of non-exceedance is desired, then a value of 440 EC with a non-exceedance probability of 80% may be appropriate; this would have the added advantage of having a non-exceedance probability which is the same as for BSMS end-of-valley targets. Achieving this latter target may be subject to refining environmental flow rules in such a way that the required salinity outcome is obtained if the Plan option adopted is the one which saves an average of 3000 GL/year.
- At Murray Bridge, from the available modelling results for the three Guide scenarios, a target of 800 EC with a non-exceedance probability of 95% (i.e. the same as at Morgan) could be achievable in practice with one of the Guide options implemented (see basic salinity statistics in Appendix A). Achieving the target may be subject to refining environmental flow rules in such a way that the required salinity outcome is obtained if the 3000 scenario is adopted. Achieving the target if one of the other two Guide scenarios is adopted may also be sensitive to further refinement of environmental flow rules and it will be necessary to ensure an appropriate outcome is obtained.

- At Tailem Bend/Wellington, from the available modelling results, a target of 800 EC with a non-exceedance probability of 95% could also be achievable in practice with one of the Guide options implemented (see basic salinity statistics in Appendix A). Achieving the target will be subject to refining environmental flow rules in such a way that the required salinity outcome is obtained if the 3000 scenario is adopted. Achieving the target if one of the other two Guide scenarios is adopted may also be sensitive to further refinement of environmental flow rules and it will be necessary to ensure an appropriate outcome is obtained.
- The targets for Lake Alexandrina could remain as they are. However, it is emphasised that this is based on results obtained from modelling salinity behaviour for a 34.5 year historical period and that conditions may arise in the future that cause these targets to be violated. This applies particularly to the target that the 1500 EC threshold should never be exceeded. Also, some parts of the lake are always quite saline (e.g. near Goolwa) and other parts are much fresher. Therefore, in the future, consideration could be given to re-expressing these targets in terms of the modelling assumptions of spatial and temporal averaging, and indicating which parts of the lake they apply to.
- Following the lead of MDBA, an operational target for irrigation could be set which would be applicable during the irrigation season. This could be related to needs of sensitive crops and irrigators' ability to cease diverting from the river for certain periods provided enough warning is given. A threshold of 800 EC and a maximum allowable exceedance duration of 7 days might be appropriate but would need to be confirmed. As for the urban water supply target, if real time forecasting predicted this target would be violated then avoidance management action could be taken; the action being the subject of a plan which would need to be developed.
- Operational targets for other environmental values could also be set, provided thresholds and allowable exceedance durations can be identified. Severities of exceedances and times between exceedances (i.e. recovery times) might also come into consideration. Target values may need to vary to suit seasonal needs of environmental assets.

7.5 Suggestions for establishing future salinity planning targets

In the future, planning targets should be based on the concepts of probabilities of exceedance of salinity thresholds, duration and severity of exceedance, and minimum time intervals between exceedance events, and related more closely to the values intended to be protected. The concepts are illustrated in general terms in Figure 7.3. The targets could be expressed along the lines illustrated in Figure 7.3 or using one of the options shown in Figure 7.4, although it may only be possible to define one or two points on any given curve in which case a table of values may be preferable. The specifics will depend on the needs of the environmental assets affected and the needs of urban and irrigation water users. In principle the concepts are the same as for rainfall intensity-frequency-duration curves.

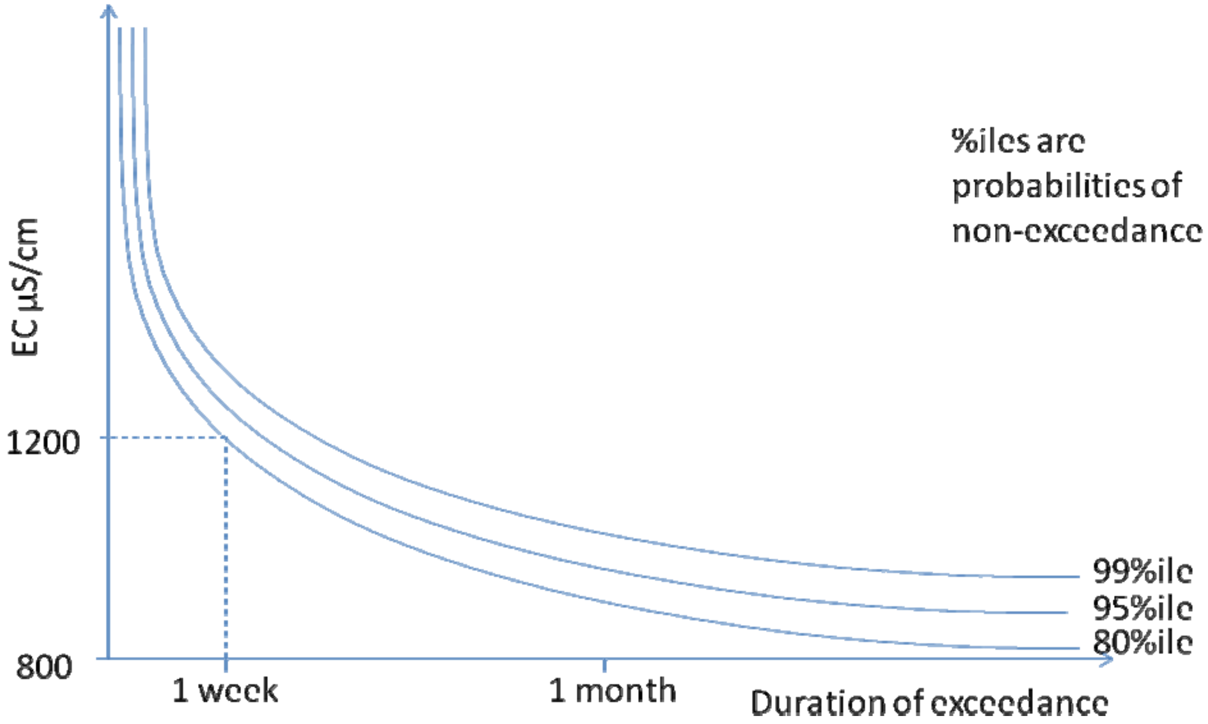
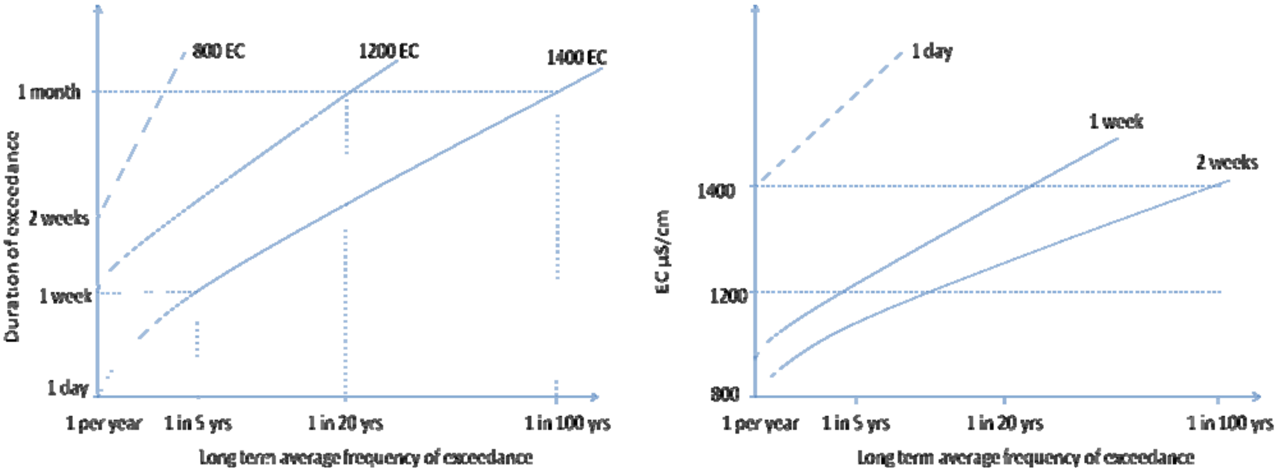


Figure 7.3 Generalised examples of target curves



(a) Sample curves for given salinity values

(b) Sample curves for given event durations

Figure 7.4 Alternative illustrations of planning (aspirational) target curves for (a) given salinity values; and (b) given event durations

References

Australian Government (2004) National Water Quality Management Strategy: Australian Drinking Water Guidelines 6. National Health and Medical Research Council and Natural Resource Management Ministerial Council. ISBN (online): 1864961244. ISBN (print): 186496118X.

DFW (2010) Collation of Proposed SA Water Quality and Salinity Targets. Draft report provided to the project team <SA WQS targets 290910.docx>. South Australian Department for Water, Adelaide.

Lamontagne S, McEwan K, Webster I, Ford P, Leaney F, Walker G (2004) Coorong, Lower Lakes and Murray Mouth. Knowledge gaps and knowledge needs for delivering better ecological outcomes. Water for a Healthy Country National Research Flagship CSIRO: Canberra. ISBN: 0643091556.

Maier HR, Burch MD and Bormans M (2001) Flow management strategies to control blooms of the cyanobacterium, *anabaena circinalis*, in the River Murray at Morgan, South Australia. Regulated Rivers: Resource Management **17**, 637–650. DOI: 10.1002/rrr.623.

Maier HR, Kingston GB, Clark T, Frazer A and Sanderson A (2004) Risk-based approach for assessing the effectiveness of flow management in controlling cyanobacterial blooms in rivers. River Res. Applic. 20: 459–471. DOI: 10.1002/rra.760.

MDBA (2010a) Guide to the proposed Basin Plan. Volume 1 – Overview. MDBA Publication No. 60/10. October. ISBN (online): 978-1-921557-73-6. ISBN (print): 978-1-921557-72-9. Canberra, ACT.

MDBA (2010b) Guide to the proposed Basin Plan. Volume 2 – Technical background. MDBA Publication No. 61/10. October. ISBN (online): 978-1-921557-74-3. ISBN (print): 978-1-921557-75-0. Canberra, ACT.

MDBA (2010c) Basin Salinity Management Strategy 2008-09 Annual Implementation Report. MDBA Publication No. 53/10. February. ISBN (online): 978-1-921557-60-6. ISBN (print): 978-1-921557-62-0. Canberra, ACT.

MDBA (2010d) Salinity Targets Review: Environmental Values and Data Analysis. Prepared for MDBA by Sinclair Knight Merz. Report 1 of 4. MDBA Publication No. 102/10. September. ISBN: 978-1-921783-55-5. Canberra, ACT.

Appendix E More detailed results from salinity and salt load analyses

The following information is presented in this appendix:

- Basic statistics from the analyses of salinity results from BigMod for the period from 1/1/1975 to 30/6/2009 in Table E.1. Percentiles are probabilities of non-exceedance
- Time series plots of modelled daily salinity at Morgan in Figure E.1 for baseline conditions, in Figure E.2 for the 3000 scenario, in Figure E.3 for the 3500 scenario, in Figure E.4 for the 4000 scenario and in Figure E.5 for the without-development scenario
- Modelled 10-year rolling average salt loads through the barrages for the period from 1/7/1975 to 30/6/2009 in Table E.2
- Statistics of exceedances of salinity thresholds of 800 EC and 1400 EC at all locations for the period from 1/1/1975 to 30/6/2009 in Table E.3 and Table E.4, respectively
- Results of sensitivity analyses of exceedances of salinity thresholds of 800 EC and 1400 EC for the period from 1/1/1975 to 30/6/2009:
    - SA border in Table E.5 and Table E.6, respectively
    - Berri in Table E.7 and Table E.8, respectively
    - Morgan in Table E.9 and Table E.10, respectively
    - Murray Bridge in Table E.11 and Table E.12, respectively
    - Tailem Bend in Table E.13 and Table E.14, respectively
    - Lake Alexandrina in Table E.13and Table E.16, respectively.

Table E.1 Basic salinity (EC (µS/cm) statistics at SA border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina for the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline, without-development and Guide scenarios

Scenario	Mean	Median	80th percentile	95th percentile	99.7th percentile	Maximum
	EC (µS/cm)					
SA border						
baseline	346	340	442	530	712	836
without development	315	272	381	593	1967	2977
3000	351	334	443	563	807	1033
3500	344	326	436	556	763	1035
4000	342	319	431	569	879	1374
Berri						
baseline	431	414	545	664	994	1202
without development	358	308	451	716	1552	2374
3000	400	384	516	666	903	996
3500	391	374	504	644	886	971
4000	388	366	496	660	972	1150
Morgan						
baseline	554	535	705	866	1276	1459
without development	437	365	557	914	2066	2544
3000	447	425	578	764	1082	1167
3500	435	409	567	729	1076	1139
4000	429	397	553	745	1145	1321
Murray Bridge						
baseline	581	557	748	915	1354	1580
without development	420	367	528	812	1813	2545
3000	465	434	624	810	1128	1281
3500	452	417	607	759	1104	1241
4000	443	406	593	748	1163	1411
Tailem Bend						
baseline	598	576	772	936	1409	1664
without development	428	369	542	847	1774	2556
3000	480	444	644	853	1159	1353
3500	466	428	622	805	1136	1312
4000	456	416	609	789	1201	1457
Lake Alexandrina						
baseline	801	728	943	1389	2959	2976
without development	1328	461	687	6207	22006	23308
3000	562	516	680	1009	1349	1364
3500	544	502	655	971	1250	1271
4000	524	480	641	917	1247	1250

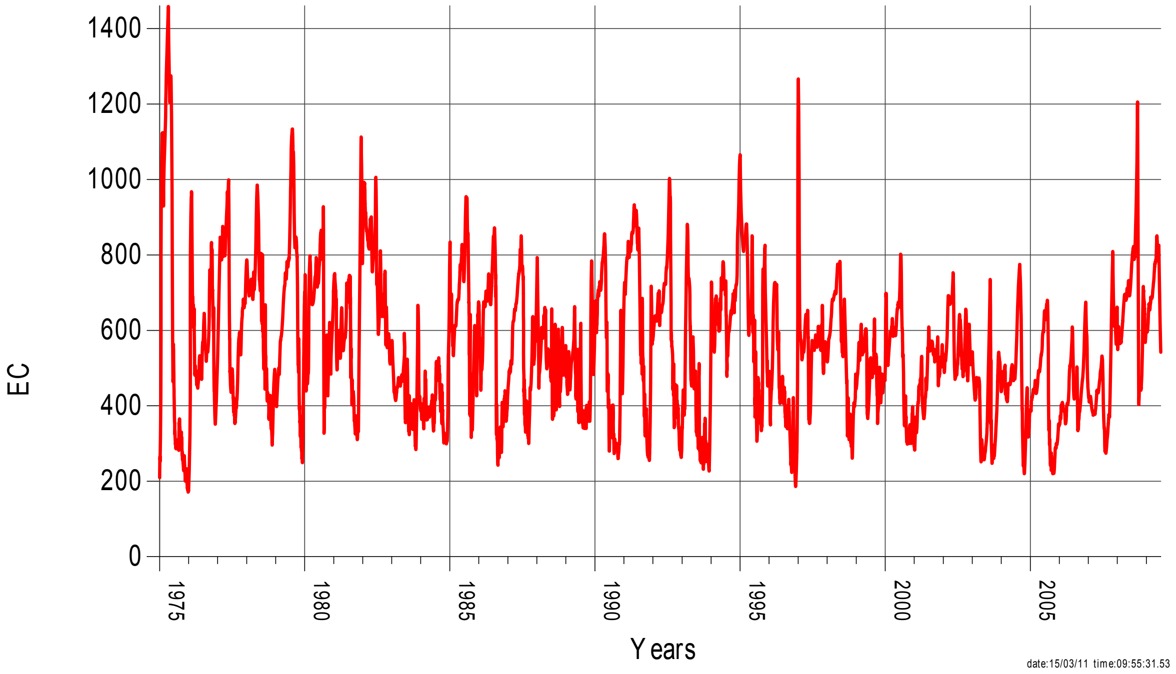


Figure E.1 Daily salinity at Morgan for the full period of salinity modelling (1/1/1975–30/6/2009) under the baseline scenario

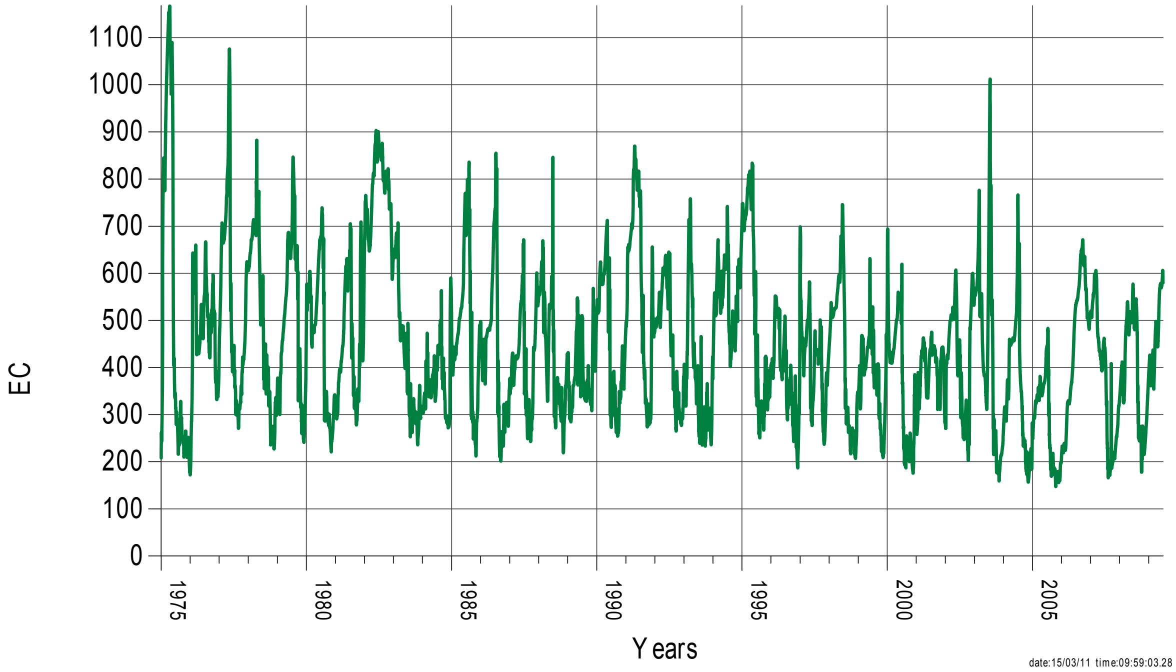


Figure E.2 Daily salinity at Morgan for the full period of salinity modelling (1/1/1975–30/6/2009) under the 3000 scenario

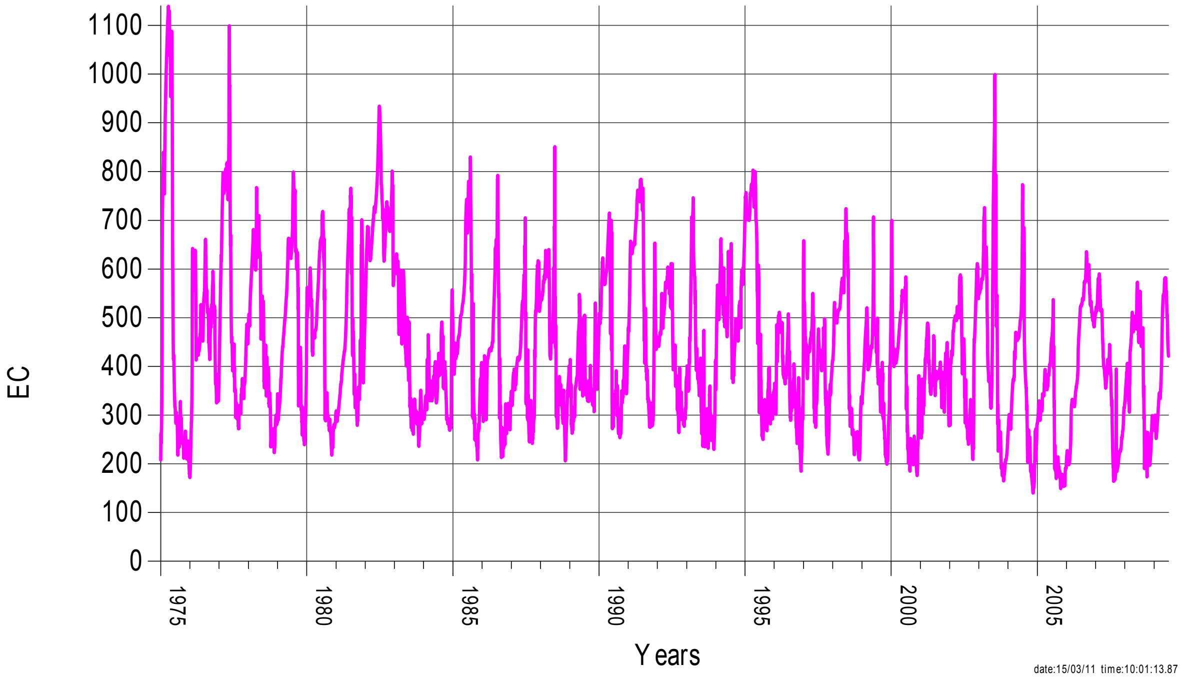


Figure E.3 Daily salinity at Morgan for the full period of salinity modelling (1/1/1975–30/6/2009) under the 3500 scenario

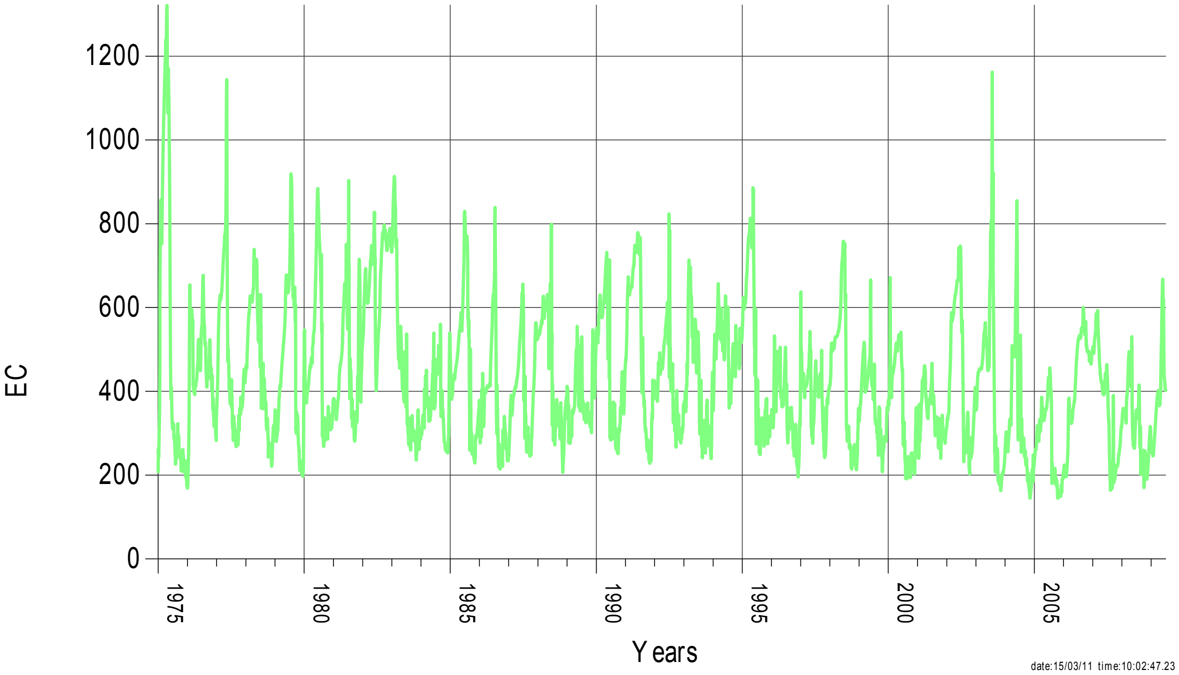


Figure E.4 Daily salinity at Morgan for the full period of salinity modelling (1/1/1975–30/6/2009) under the 4000 scenario

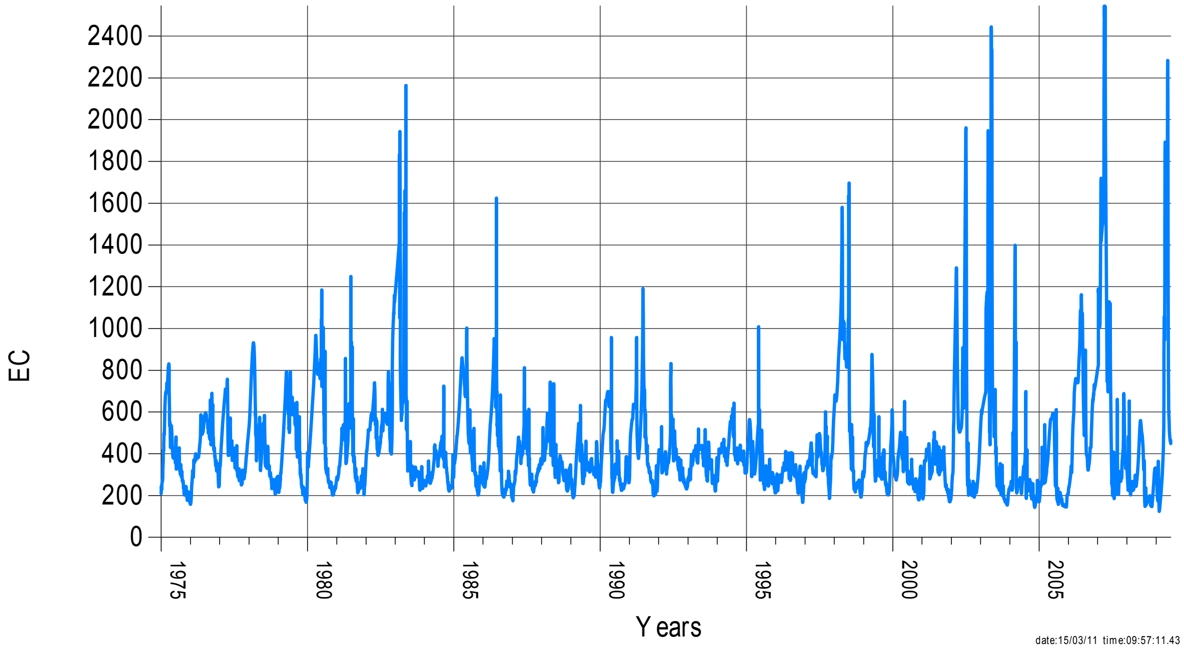


Figure E.5 Daily salinity at Morgan for the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development scenario

Table E.2 Modelled 10-year rolling average annual salt loads (million tonnes/y) through the barrages over the period 1/7/1975–30/6/2009 under the without-development, baseline and Guide scenarios

Date from	Date to	without development	baseline	3000	3500	4000
1/07/1975	30/06/1985	4.13	1.83	2.01	2.05	2.09
1/07/1976	30/06/1986	3.91	1.53	1.75	1.79	1.83
1/07/1977	30/06/1987	3.87	1.53	1.72	1.76	1.8
1/07/1978	30/06/1988	3.77	1.54	1.7	1.73	1.79
1/07/1979	30/06/1989	3.74	1.54	1.7	1.74	1.79
1/07/1980	30/06/1990	3.90	1.71	1.88	1.92	1.95
1/07/1981	30/06/1991	3.99	1.93	2.07	2.12	2.16
1/07/1982	30/06/1992	3.92	1.83	2.03	2.07	2.11
1/07/1983	30/06/1993	3.81	2.10	2.32	2.36	2.39
1/07/1984	30/06/1994	3.17	2.05	2.23	2.28	2.32
1/07/1985	30/06/1995	3.04	1.95	2.14	2.19	2.23
1/07/1986	30/06/1996	3.15	2.12	2.29	2.34	2.38
1/07/1987	30/06/1997	3.19	2.19	2.36	2.42	2.44
1/07/1988	30/06/1998	3.16	2.12	2.3	2.35	2.37
1/07/1989	30/06/1999	3.44	2.06	2.23	2.28	2.31
1/07/1990	30/06/2000	3.28	1.87	2.05	2.1	2.14
1/07/1991	30/06/2001	3.18	1.78	1.96	2.01	2.05
1/07/1992	30/06/2002	3.02	1.64	1.8	1.85	1.91
1/07/1993	30/06/2003	3.00	1.36	1.54	1.59	1.65
1/07/1994	30/06/2004	3.44	1.16	1.39	1.42	1.47
1/07/1995	30/06/2005	3.44	1.14	1.36	1.4	1.45
1/07/1996	30/06/2006	3.26	0.97	1.2	1.23	1.27
1/07/1997	30/06/2007	2.90	0.75	0.95	0.98	1.01
1/07/1998	30/06/2008	4.14	0.72	0.92	0.94	0.99
1/07/1999	30/06/2009	3.70	0.55	0.75	0.78	0.83
Full period						
1/07/1975	30/06/2009	3.62	1.48	1.67	1.71	1.75

Table E.3 Exceedances of salinity threshold of 800 EC at the SA border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	3000	3500	4000
SA border					
Number of high spells	25	2	8	6	13
Longest high spell (days)	52	11	12	12	19
Mean duration of high spells (days)	12.1	6.0	5.0	5.0	5.2
Total duration of high spells (days)	302	12	40	30	68
Mean period between high spells	427	1941	1408	1972	879
Longest period between high spells (days)	1452	1941	5434	5435	2545
Berri					
Number of high spells	27	3	6	5	8
Longest high spell (days)	55	103	69	53	76
Mean duration of high spells (days)	17.3	39.7	17.3	18.4	14.6
Total duration of high spells (days)	467	119	104	92	117
Mean period between high spells (days)	388	3561	2049	2565	1505
Longest period between high spells (days)	1441	4565	5466	5464	2973
Morgan					
Number of high spells	37	38	19	12	17
Longest high spell (days)	139	139	129	95	96
Mean duration of high spells (days)	24.6	31.7	23.3	17.6	16.1
Total duration of high spells (days)	909	1205	442	211	274
Mean period between high spells (days)	322	307	553	926	652
Longest period between high spells (days)	1092	2668	2974	2982	2970
Murray Bridge					
Number of high spells	37	47	16	15	18
Longest high spell (days)	152	164	258	119	159
Mean duration of high spells (days)	17.6	36.0	41.4	30.7	24.7
Total duration of high spells (days)	650	1690	663	460	445
Mean period between high spells (days)	329	236	733	711	587
Longest period between high spells (days)	1091	1493	2868	2886	2988
Tailem Bend					
Number of high spells	39	54	18	16	23
Longest high spell (days)	138	174	267	115	169
Mean duration of high spells (days)	19.9	37.4	46.4	40.1	24.5
Total duration of high spells (days)	777	2018	835	642	563
Mean period between high spells (days)	309	198	646	745	511
Longest period between high spells (days)	1091	1491	2872	2891	2990
Lake Alexandrina					
Number of high spells	8	18	6	6	7
Longest high spell (days)	708	1208	557	551	327
Mean duration of high spells (days)	254.0	276.4	230.7	213.0	154.3
Total duration of high spells (days)	2032	4975	1384	1278	1080
Mean period between high spells (days)	1348	439	2212	2234	1894
Longest period between high spells (days)	5263	932	4226	4236	4247

Table E.4 Exceedances of salinity threshold of 1400 EC at the SA border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Scenario	without development	baseline	3000	3500	4000
SA border					
Number of high spells	12	0	0	0	0
Longest high spell (days)	30	na	na	na	na
Mean duration of high spells (days)	8	na	na	na	na
Total duration of high spells (days)	96	na	na	na	na
Mean period between high spells (days)	949	na	na	na	na
Longest period between high spells (days)	4384	na	na	na	na
Berri					
Number of high spells	9	0	0	0	0
Longest high spell (days)	16	na	na	na	na
Mean duration of high spells (days)	5.2	na	na	na	na
Total duration of high spells (days)	47	na	na	na	na
Mean period between high spells (days)	1182	na	na	na	na
Longest period between high spells (days)	4391	na	na	na	na
Morgan					
Number of high spells	13	1	0	0	0
Longest high spell (days)	67	15	na	na	na
Mean duration of high spells (days)	13.7	15	na	na	na
Total duration of high spells (days)	178	15	na	na	na
Longest period between high spells (days)	785	na	na	na	na
Number of high spells	4308	na	na	na	na
Murray Bridge					
Number of high spells	12	1	0	0	1
Longest high spell (days)	26	30	na	na	3
Mean duration of high spells (days)	9.3	30	na	na	3
Total duration of high spells (days)	112	30	na	na	3
Mean period between high spells (days)	859	na	na	na	na
Longest period between high spells (days)	4337	na	na	na	na
Tailem Bend					
Number of high spells	11	2	0	0	1
Longest high spell (days)	22	33	na	na	14
Mean duration of high spells (days)	9.4	21	na	na	14
Total duration of high spells (days)	103	42	na	na	14
Mean period between high spells (days)	946	12232	na	na	14
Longest period between high spells (days)	4341	12232	na	na	na
Lake Alexandrina					
Number of high spells	8	1	0	0	0
Longest high spell (days)	534	582	na	na	na
Mean duration of high spells (days)	215.9	582.0	na	na	na
Total duration of high spells (days)	1727	582	na	na	na
Mean period between high spells (days)	1391	na	na	na	na
Longest period between high spells (days)	5289	na	na	na	na

na – not applicable

Table E.5 Sensitivity of modelled exceedances of salinity threshold of 800 EC at the SA border over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	25	30	31	41
Longest high spell (days)	52	53	55	61
Mean duration of high spells (days)	12.1	11.3	12.2	12.2
Total duration of high spells (days)	302	339	379	500
Mean period between high spells (days)	427	352	339	251
Longest period between high spells (days)	1452	1450	1436	1089
baseline				
Number of high spells	2	2	4	10
Longest high spell (days)	11	17	26	73
Mean duration of high spells (days)	6.0	9.5	7.7	11.4
Total duration of high spells (days)	12	19	31	114
Mean period between high spells (days)	1941	1939	2390	789
Longest period between high spells (days)	1941	1939	3060	2181
3000				
Number of high spells	8	10	13	25
Longest high spell (days)	12	14	35	39
Mean duration of high spells (days)	5.0	6.3	7.2	7.5
Total duration of high spells (days)	40	63	93	188
Mean period between high spells (days)	1408	1093	879	436
Longest period between high spells (days)	5434	3024	3024	1445
3500				
Number of high spells	6	6	11	27
Longest high spell (days)	12	17	22	44
Mean duration of high spells (days)	5.0	6.3	4.7	6.3
Total duration of high spells (days)	30	38	52	169
Mean period between high spells (days)	1972	1971	1058	458
Longest period between high spells (days)	5435	5433	3364	1751
4000				
Number of high spells	13	14	20	26
Longest high spell (days)	19	24	32	44
Mean duration of high spells (days)	5.2	6.4	5.9	9.5
Total duration of high spells (days)	68	89	119	246
Mean period between high spells (days)	879	810	552	473
Longest period between high spells (days)	2545	2544	2543	1467

Table E.6 Sensitivity of modelled exceedances of salinity threshold of 1400 EC at the SA border over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	12	13	12	41
Longest high spell (days)	30	33	31	61
Mean duration of high spells (days)	8.0	10.2	9.1	12.2
Total duration of high spells (days)	96	132	109	500
Mean period between high spells (days)	949	867	948	251
Longest period between high spells (days)	4384	4384	4384	1089
baseline				
Number of high spells	0	0	0	0
Longest high spell (days)	na	na	na	na
Mean duration of high spells (days)	na	na	na	na
Total duration of high spells (days)	na	na	na	na
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3000				
Number of high spells	0	0	0	0
Longest high spell (days)	na	na	na	na
Mean duration of high spells (days)	na	na	na	na
Total duration of high spells (days)	na	na	na	na
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3500				
Number of high spells	0	0	0	0
Longest high spell (days)	na	na	na	na
Mean duration of high spells (days)	na	na	na	na
Total duration of high spells (days)	na	na	na	na
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
4000				
Number of high spells	0	1	1	1
Longest high spell (days)	na	3	4	5
Mean duration of high spells (days)	na	3	4	5
Total duration of high spells (days)	na	3	4	5
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na

na – not applicable

Table E.7 Sensitivity of modelled exceedances of salinity threshold of 800 EC at Berri over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	27	34	35	51
Longest high spell (days)	55	59	62	70
Mean duration of high spells (days)	17.3	15.7	17.3	15.8
Total duration of high spells (days)	467	534	605	807
Mean period between high spells (days)	388	304	293	233
Longest period between high spells (days)	1441	1433	1091	1089
baseline				
Number of high spells	3	8	12	33
Longest high spell (days)	103	112	111	145
Mean duration of high spells (days)	39.7	22.4	22.7	27.2
Total duration of high spells (days)	119	179	272	898
Mean period between high spells (days)	3561	1010	636	354
Longest period between high spells (days)	4565	3238	3233	4781
3000				
Number of high spells	6	14	15	28
Longest high spell (days)	69	83	96	147
Mean duration of high spells (days)	17.3	12.4	20.3	28.0
Total duration of high spells (days)	104	173	304	784
Mean period between high spells (days)	2049	809	742	368
Longest period between high spells (days)	5466	2955	2950	1127
3500				
Number of high spells	5	8	10	30
Longest high spell (days)	53	82	86	104
Mean duration of high spells (days)	18.4	20.5	19.5	21.6
Total duration of high spells (days)	92	164	195	648
Mean period between high spells (days)	2565	1504	1167	348
Longest period between high spells (days)	5464	2964	2954	1140
4000				
Number of high spells	8	14	18	32
Longest high spell (days)	76	84	94	103
Mean duration of high spells (days)	14.6	12.6	15.6	24.7
Total duration of high spells (days)	117	176	280	791
Mean period between high spells (days)	1505	806	611	319
Longest period between high spells (days)	2973	2945	2940	1421

Table E.8 Sensitivity of modelled exceedances of salinity threshold of 1400 EC at Berri over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	9	11	11	15
Longest high spell (days)	16	18	20	28
Mean duration of high spells (days)	5.2	5.2	7.3	9
Total duration of high spells (days)	47	57	80	135
Mean period between high spells (days)	1182	945	948	743
Longest period between high spells (days)	4391	4302	4297	4287
baseline				
Number of high spells	0	0	0	1
Longest high spell (days)	na	na	na	14
Mean duration of high spells (days)	na	na	na	14
Total duration of high spells (days)	na	na	na	14
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3000				
Number of high spells	0	0	0	0
Longest high spell (days)	na	na	na	na
Mean duration of high spells (days)	na	na	na	na
Total duration of high spells (days)	na	na	na	na
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3500				
Number of high spells	0	0	0	0
Longest high spell (days)	na	na	na	na
Mean duration of high spells (days)	na	na	na	na
Total duration of high spells (days)	na	na	na	na
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
4000				
Number of high spells	0	0	0	2
Longest high spell (days)	na	na	na	3
Mean duration of high spells (days)	na	na	na	2
Total duration of high spells (days)	na	na	na	4
Mean period between high spells (days)	na	na	na	10313
Longest period between high spells (days)	na	na	na	10313

na – not applicable

Table E.9 Sensitivity of modelled exceedances of salinity threshold of 800 EC at Morgan over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	37	41	42	54
Longest high spell (days)	139	144	161	226
Mean duration of high spells (days)	24.6	25.7	30.3	32.8
Total duration of high spells (days)	909	1054	1274	1773
Mean period between high spells (days)	322	286	274	203
Longest period between high spells (days)	1092	1092	1091	946
baseline				
Number of high spells	38	41	57	79
Longest high spell (days)	139	167	222	242
Mean duration of high spells (days)	31.7	41.2	39.2	48.5
Total duration of high spells (days)	1205	1691	2233	3828
Mean period between high spells (days)	307	272	184	112
Longest period between high spells (days)	2668	1484	1153	576
3000				
Number of high spells	19	19	22	42
Longest high spell (days)	129	218	248	346
Mean duration of high spells (days)	23.3	34.2	39.4	38.5
Total duration of high spells (days)	442	649	867	1617
Mean period between high spells (days)	553	561	471	243
Longest period between high spells (days)	2974	2843	1711	1136
3500				
Number of high spells	12	22	25	40
Longest high spell (days)	95	95	125	159
Mean duration of high spells (days)	17.6	19.0	28.0	34.6
Total duration of high spells (days)	211	418	699	1384
Mean period between high spells (days)	926	492	419	241
Longest period between high spells (days)	2982	2973	1728	1147
4000				
Number of high spells	17	24	25	37
Longest high spell (days)	96	95	193	213
Mean duration of high spells (days)	16.1	21.2	31.9	38.1
Total duration of high spells (days)	274	508	798	1409
Mean period between high spells (days)	652	444	413	309
Longest period between high spells (days)	2970	2962	1423	1812

Table E.10 Sensitivity of modelled exceedances of salinity threshold of 1400 EC at Morgan over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	13	14	13	21
Longest high spell (days)	67	73	78	81
Mean duration of high spells (days)	13.7	14.7	19.2	17.0
Total duration of high spells (days)	178	206	250	358
Mean period between high spells (days)	785	724	781	510
Longest period between high spells (days)	4308	4307	4307	2471
baseline				
Number of high spells	1	1	3	5
Longest high spell (days)	15	25	43	83
Mean duration of high spells (days)	15	25	17.3	22.6
Total duration of high spells (days)	15	25	52	113
Mean period between high spells (days)	na	na	3952	3042
Longest period between high spells (days)	na	na	7891	6359
3000				
Number of high spells	0	0	0	1
Longest high spell (days)	na	na	na	24
Mean duration of high spells (days)	na	na	na	24
Total duration of high spells (days)	na	na	na	24
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3500				
Number of high spells	0	0	0	2
Longest high spell (days)	na	na	na	8
Mean duration of high spells (days)	na	na	na	7
Total duration of high spells (days)	na	na	na	14
Mean period between high spells (days)	na	na	na	7
Longest period between high spells (days)	na	na	na	7
4000				
Number of high spells	0	0	1	4
Longest high spell (days)	na	na	8	36
Mean duration of high spells (days)	na	na	8	11.2
Total duration of high spells (days)	na	na	8	45
Mean period between high spells (days)	na	na	na	3436
Longest period between high spells (days)	na	na	na	9572

na – not applicable

Table E.11 Sensitivity of modelled exceedances of salinity threshold of 800 EC at Murray Bridge over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	37	42	41	55
Longest high spell (days)	152	158	164	177
Mean duration of high spells (days)	17.6	18.9	23.1	24.4
Total duration of high spells (days)	650	794	946	1340
Mean period between high spells (days)	329	286	290	207
Longest period between high spells (days)	1091	1090	1090	955
baseline				
Number of high spells	47	59	66	73
Longest high spell (days)	164	227	240	335
Mean duration of high spells (days)	36.0	38.7	46.8	59.2
Total duration of high spells (days)	1690	2286	3087	4318
Mean period between high spells (days)	236	177	146	114
Longest period between high spells (days)	1493	1489	853	591
3000				
Number of high spells	16	23	36	50
Longest high spell (days)	258	273	304	436
Mean duration of high spells (days)	41.4	37.1	34.3	45.2
Total duration of high spells (days)	663	854	1235	2258
Mean period between high spells (days)	733	498	302	195
Longest period between high spells (days)	2868	2861	1715	1077
3500				
Number of high spells	15	21	34	47
Longest high spell (days)	119	121	134	401
Mean duration of high spells (days)	30.7	29.3	27.4	42.6
Total duration of high spells (days)	460	616	933	2003
Mean period between high spells (days)	711	559	330	213
Longest period between high spells (days)	2886	2879	1205	1076
4000				
Number of high spells	18	22	31	47
Longest high spell (days)	159	175	184	198
Mean duration of high spells (days)	24.7	26.2	26.1	36.7
Total duration of high spells (days)	445	577	809	1723
Mean period between high spells (days)	587	534	367	220
Longest period between high spells (days)	2988	1842	1452	1100

Table E.12 Sensitivity of modelled exceedances of salinity threshold of 1400 EC at Murray Bridge over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	12	11	12	15
Longest high spell (days)	26	29	31	35
Mean duration of high spells (days)	9.3	12.2	13.1	13.6
Total duration of high spells (days)	112	134	157	204
Mean period between high spells (days)	859	943	855	715
Longest period between high spells (days)	4337	4333	4329	2488
baseline				
Number of high spells	1	3	5	7
Longest high spell (days)	30	37	50	87
Mean duration of high spells (days)	30	16.3	17.4	30.3
Total duration of high spells (days)	30	49	87	212
Mean period between high spells (days)	na	6105	3058	2020
Longest period between high spells (days)	na	7911	7193	4744
3000				
Number of high spells	0	0	1	1
Longest high spell (days)	na	na	9	39
Mean duration of high spells (days)	na	na	9	39
Total duration of high spells (days)	na	na	9	39
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3500				
Number of high spells	0	0	0	1
Longest high spell (days)	na	na	na	33
Mean duration of high spells (days)	na	na	na	33
Total duration of high spells (days)	na	na	na	33
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
4000				
Number of high spells	1	2	1	1
Longest high spell (days)	3	6	22	51
Mean duration of high spells (days)	3	4.5	22	51
Total duration of high spells (days)	3	9	22	51
Mean period between high spells (days)	na	7	na	na
Longest period between high spells (days)	na	7	na	na

na – not applicable

Table E.13 Sensitivity of modelled exceedances of salinity threshold of 800 EC at Tailem Bend over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	39	40	42	52
Longest high spell (days)	138	186	192	207
Mean duration of high spells (days)	19.9	24.0	26.7	30.1
Total duration of high spells (days)	777	960	1121	1566
Mean period between high spells (days)	309	296	278	215
Longest period between high spells (days)	1091	1090	1090	959
baseline				
Number of high spells	54	57	58	73
Longest high spell (days)	174	235	336	347
Mean duration of high spells (days)	37.4	47.9	58.7	65.0
Total duration of high spells (days)	2018	2732	3403	4747
Mean period between high spells (days)	198	175	160	108
Longest period between high spells (days)	1491	864	857	594
3000				
Number of high spells	18	25	30	45
Longest high spell (days)	267	313	427	439
Mean duration of high spells (days)	46.4	43.7	51.7	56.7
Total duration of high spells (days)	835	1092	1551	2552
Mean period between high spells (days)	646	447	354	227
Longest period between high spells (days)	2872	2865	1187	1078
3500				
Number of high spells	16	24	32	45
Longest high spell (days)	115	127	210	407
Mean duration of high spells (days)	40.1	37.3	40.8	50.2
Total duration of high spells (days)	642	896	1306	2257
Mean period between high spells (days)	745	475	339	218
Longest period between high spells (days)	2891	2883	1169	1078
4000				
Number of high spells	23	24	37	45
Longest high spell (days)	169	178	186	254
Mean duration of high spells (days)	24.5	31.6	30.1	47.2
Total duration of high spells (days)	563	759	1115	2126
Mean period between high spells (days)	511	481	297	236
Longest period between high spells (days)	2990	1843	1454	822

Table E.14 Sensitivity of modelled exceedances of salinity threshold of 1400 EC at Tailem Bend over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	11	11	13	16
Longest high spell (days)	22	23	25	37
Mean duration of high spells (days)	9.4	10.8	11.5	13.9
Total duration of high spells (days)	103	119	149	223
Mean period between high spells (days)	946	944	784	666
Longest period between high spells (days)	4341	4340	4338	2498
baseline				
Number of high spells	2	3	6	8
Longest high spell (days)	33	45	54	85
Mean duration of high spells (days)	21	22.7	20.2	29.6
Total duration of high spells (days)	42	68	121	237
Mean period between high spells (days)	12232	6107	2445	1731
Longest period between high spells (days)	12232	7908	4758	4721
3000				
Number of high spells	0	1	1	1
Longest high spell (days)	na	9	22	46
Mean duration of high spells (days)	na	9	22	46
Total duration of high spells (days)	na	9	22	46
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
3500				
Number of high spells	0	0	1	1
Longest high spell (days)	na	na	17	42
Mean duration of high spells (days)	na	na	17	42
Total duration of high spells (days)	na	na	17	42
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na
4000				
Number of high spells	1	1	1	3
Longest high spell (days)	14	19	26	59
Mean duration of high spells (days)	14	19	26	21.7
Total duration of high spells (days)	14	19	26	65
Mean period between high spells (days)	na	na	na	1408
Longest period between high spells (days)	na	na	na	2100

na – not applicable

Table E.15 Sensitivity of modelled exceedances of salinity threshold of 800 EC in Lake Alexandrina (over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	800 EC	800 EC – 5% = 760 EC	800 EC – 10% = 720 EC	800 EC – 20% = 640 EC
without development				
Number of high spells	8	10	13	14
Longest high spell (days)	708	719	759	1051
Mean duration of high spells (days)	254.0	210.7	177.8	212.1
Total duration of high spells (days)	2032	2107	2312	2969
Mean period between high spells (days)	1348	1040	763	732
Longest period between high spells (days)	5263	4596	2391	2369
baseline				
Number of high spells	18	21	22	21
Longest high spell (days)	1208	1238	1265	2763
Mean duration of high spells (days)	276.4	269.8	294.7	391.9
Total duration of high spells (days)	4975	5665	6484	8230
Mean period between high spells (days)	439	339	284	212
Longest period between high spells (days)	932	733	690	594
3000				
Number of high spells	6	8	11	17
Longest high spell (days)	557	578	609	923
Mean duration of high spells (days)	230.7	204.4	181.5	189.4
Total duration of high spells (days)	1384	1635	1996	3220
Mean period between high spells (days)	2212	1545	1046	578
Longest period between high spells (days)	4226	2879	2809	1365
3500				
Number of high spells	6	7	9	15
Longest high spell (days)	551	570	596	920
Mean duration of high spells (days)	213.0	206.0	200.6	186.7
Total duration of high spells (days)	1278	1442	1805	2801
Mean period between high spells (days)	2234	1835	1331	691
Longest period between high spells (days)	4236	4217	2873	1387
4000				
Number of high spells	7	8	10	14
Longest high spell (days)	327	405	466	917
Mean duration of high spells (days)	154.3	164.5	159.0	181.3
Total duration of high spells (days)	1080	1316	1590	2538
Mean period between high spells (days)	1894	1591	1208	764
Longest period between high spells (days)	4247	4228	2960	1673

Table E.16 Sensitivity of modelled exceedances of salinity threshold of 1400 EC in Lake Alexandrina over the full period of salinity modelling (1/1/1975–30/6/2009) under the without-development, baseline and Guide scenarios

Item	1400 EC	1400 EC – 5% = 1330 EC	1400 EC – 10% = 1260 EC	1400 EC – 20% = 1120 EC
without development				
Number of high spells	8	7	7	7
Longest high spell (days)	534	642	649	661
Mean duration of high spells (days)	215.9	253.4	257.9	265.1
Total duration of high spells (days)	1727	1774	1805	1856
Mean period between high spells (days)	1391	1615	1610	1602
Longest period between high spells (days)	5289	5288	5285	5279
baseline				
Number of high spells	1	2	3	6
Longest high spell (days)	582	608	637	901
Mean duration of high spells (days)	582.0	363.5	305.0	231.7
Total duration of high spells (days)	582	727	915	1390
Mean period between high spells (days)	na	108	4359	1785
Longest period between high spells (days)	na	108	8656	4278
3000				
Number of high spells	0	1	2	3
Longest high spell (days)	na	88	139	192
Mean duration of high spells (days)	na	88	85.5	114.7
Total duration of high spells (days)	na	88	171	344
Mean period between high spells (days)	na	na	9471	4667
Longest period between high spells (days)	na	na	9471	9135
3500				
Number of high spells	0	0	1	1
Longest high spell (days)	na	na	20	168
Mean duration of high spells (days)	na	na	20	168
Total duration of high spells (days)	na	na	20	168
Mean period between high spells (days)	na	na	na	NA
Longest period between high spells (days)	na	na	na	NA
4000				
Number of high spells	0	0	0	1
Longest high spell (days)	na	na	na	157
Mean duration of high spells (days)	na	na	na	157
Total duration of high spells (days)	na	na	na	157
Mean period between high spells (days)	na	na	na	na
Longest period between high spells (days)	na	na	na	na

na – not applicable

Part III – Delivery of a flow regime to meet South Australia's environmental water requirements

Contents

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8 Introduction

This Part includes information on the river system modelling associated with meeting South Australia's environmental flow requirements and contains:

- an overview and key messages (this chapter)
- an overview of the modelling approach (Chapter 9)
- a presentation and description of results (Chapter 10)
- a discussion of key findings (Chapter 11).

8.1 Overview

In addition to reviewing the science underpinning the Guide to the proposed Basin Plan (Guide), the project team undertook modelling, in addition to that provided by the Murray–Darling Basin Authority (MDBA), to determine the volume and pattern of delivery of flow to meet the MDBA and South Australian Government's environmental water requirements (MDBA EWRs and SA EWRs respectively). For this purpose, two optimised daily flow scenarios were developed for each of the key environmental assets (Riverland–Chowilla and the Coorong, Lower Lakes, and Murray Mouth (CLLMM)). The terms used to describe these flows are:

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

The EWR criteria used to derive these optimised flows are listed in Appendix A to this Part, noting that the EWRs for Riverland–Chowilla are based on **daily** flow characteristics (e.g. 90 days inundation) while the EWRs for the CLLMM are based on **annual** volume characteristics (e.g. 5100 GL/year long-term average).

The analysis concentrated on the SA EWRs, presented as the flows needed to deliver environmental water to South Australia if the flow regime to satisfy South Australia's EWRs were adopted. 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.

The MDBA's CLLMM EWRs were analysed, but only on an average annual basis as this is how they were derived for the Guide.

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).

There were three components to the analysis:

1. Data analysis of the without-development, baseline and Guide scenarios (supplied by MDBA)
2. Translating the barrage flow required for CLLMM EWRs to the South Australian border
3. Considering release limitations of upstream supply storages.

The modelling period for data analysis was 1/7/1895 to 30/6/2009. Annual results are presented for a 1st July water year.

The methodology for translating barrage flow and considering release limitations is described in Section 9 River system modelling approach.

The Guide scenarios include an implicit environmental release policy that is constrained by the modelled without-development flows i.e. is not releasing more water than would have occurred under without-development conditions. The environmental release policy used by the MDBA in these scenarios is not known. Consequently the environmental flows in these scenarios are not optimised for delivering water to South Australia. The analysis in this report focuses on the annual volumes produced by these scenarios as an indication of what could be delivered to South Australia if the annual distribution specified by South Australia were adopted. However, if the implied priority of delivering water to upstream environmental assets was changed the amount of annual volume reaching South Australia would also change.

The Guide scenarios represent the distribution of licences in the regions as published in the Guide to the proposed Basin Plan (MDBA, 2010). The 3000, 3500 and 4000 scenarios contribute 1765 GL/year, 2041 GL/year and 2355 GL/year increases on baseline flows respectively at the border. The South Australian border flows in the Guide scenarios include the water to be supplied to South Australian consumptive users. These scenarios assume a reduction in this usage as a function of the sustainable diversion limits (SDLs). The usage for the baseline, 3000, 3500 and 4000 scenarios are 665, 492, 462 and 433 GL/year respectively. The reduction in use in the Guide scenarios is modelled as a SDL reduction in SA irrigation use.

8.2 Key messages

Results are described below and summarised in Table 8.1.

Delivery of Riverland–Chowilla environmental water requirements

- If the Riverland–Chowilla EWRs optimised flows are met 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.
- 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 that delivers an average annual volume of 8958 GL.
- Despite being met on an average annual 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 SA EWRs are not 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.
- For the 4000 scenario 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.
- Climate change impacts could significantly reduce the volume supplied in all of the scenarios. This will be exacerbated in dry periods, which will extend the shortfall periods. This will further reduce the ability to meet SA’s EWRs optimised flows.

Delivery of CLLMM environmental water requirements

- The MDBA CLLMM EWRs optimised flow requires an average annual volume of 6116 GL at the border, which can be met under all of the Guide scenarios, when downstream use is accounted for.
- The SA CLLMM EWRs optimised flow requires an average annual volume of 5379 GL at the border, which can be met under the baseline and all Guide scenarios, when downstream use is accounted for.
- 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.
- 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 8.1 Summarised assessment of delivering MDBA and SA Riverland–Chowilla and CLLMM EWRs optimised flows under the without-development, baseline and Guide scenarios, based on daily, average annual, annual and five-year rolling average figures

	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

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 10.7).
- 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 10.8).

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. As the amount of SDL water that is released increases this draws down the storage more which reduces the amount of water that is spilled
- 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.

9 River system modelling approach

This chapter provides a summary of the river system modelling approach and a description of the methodology used in extracting results.

9.1 General

There are a range of jurisdictional river system models such as IQQM (Integrated Quantity-Quality Model), REALM (Resource Allocation Model), MSM (Murray Monthly Simulation Model), BigMod, St George and Snowy which are used to model regions within the Murray-Darling Basin (the Basin). These models run long historical sequences (at least 114 years) to determine the impacts of water management options over a range of historic climate conditions. They have been developed over a number of years and have been the primary tool for developing existing water sharing plans.

As part of the Murray-Darling Basin Sustainable Yields Project (CSIRO, 2007) CSIRO developed a framework that linked all the Basin models to run a range of development and climate scenarios to understand the impacts on water availability and use throughout the Basin.

With a project region of more than one million square kilometres, this study provided a benchmark for undertaking water assessments over large areas in a consistent fashion, enabling valid comparisons across river valleys. While river models for individual tributaries had been used previously for assessing water availability, they had not been done consistently across the Basin. The study also enabled the cumulative flow-on impacts from tributaries into the main trunks of the Darling and Murray rivers to be explored.

The MDBA's plans for new sustainable diversion limits (SDLs) for the Basin have been supported by a range of modelling capabilities provided by many parties, including CSIRO. The modelling framework developed by CSIRO plays a key role in understanding the impacts of the SDLs on water users throughout the Basin.

The modelling capability that underpins the Guide is derived from models and data provided by the Basin States, the MDBA and CSIRO and are similar to those used as part of the Murray-Darling Sustainable Yields Project in 2008. CSIRO has linked these models within the Integrated River System Modelling Framework (IRSMF) (Yang, 2010) to enable the MDBA to evaluate alternative scenarios in a consistent fashion. CSIRO made adjustments to allow them to be used for including environmental water demands, changing licences and demands, as specified by the MDBA.

The IRSMF allows water sharing plans to be explored under different climate and development conditions; and can be used to study individual valleys, explore linked valleys and whole-of-basin. Model scenarios, model outputs and summary results are stored in a database so that information generated by the models can be reproduced as required.

Much of the analysis in this Chapter is based on modelling results supplied by the MDBA from MSM-BigMod (MDBC, 2001) when it was run in conjunction with other models in the IRSMF. Results from other models were not supplied. The MDBA also supplied the version of MSM-BigMod that was used in their analysis so that we could conduct further modelling.

The models used by the MDBA were peer reviewed (Podger et al., 2010). The review concluded that the models and methods used to develop SDLs for the Basin are considered to be world's best practice, given the scale of the modelling work and the time constraints. Peer review by water management committees, experts and as part of the Murray-Darling Basin Sustainable Yields Project, has found them adequate for their intended use (i.e. developing water-sharing plans). Caution needs to be exercised in using the models outside the original purposes for which they were developed in particular for low flows and presenting results on a daily basis.

9.2 Estimating the contributions of upstream regions

The estimation of contributions of upstream regions to flow crossing the South Australian border was determined by using results from the without-development scenario and:

1. considering the contributions of upstream regions from the Darling at Burtundy plus anabranch inflows, Murrumbidgee at Balranald and Darlot, Murray at Hume, Ovens at Peechelba, Goulburn at McCoy's Bridge, Campaspe at Rochester and Loddon at Appin South
2. adjusting Hume releases for any NSW and Victorian Murray demands by subtracting these demands off the release
3. lagging the daily flows by the travel times from the region boundary to the South Australian border
4. for each month, finding the ratio between the regional contribution to the total contribution
5. for each month, for the MDBA's and South Australia's optimised environmental flow requirements, multiplying this requirement by the contribution of each region
6. summing the monthly contributions of each region over the 114-year period to determine the average annual amount met by each region.

9.3 Estimating release constraints on meeting environmental flow requirements

To estimate release constraints to meeting South Australian environmental flow targets a Source river system model (eWater, 2011) was built for the major storages that can potentially supply water to South Australia (Figure 9.1). The model contains the following headwater storages: Cawndilla, Menindee, Pamamaroo, Wetherell, Burrinjuck, Blowering, Hume, Eildon and Lake Victoria.

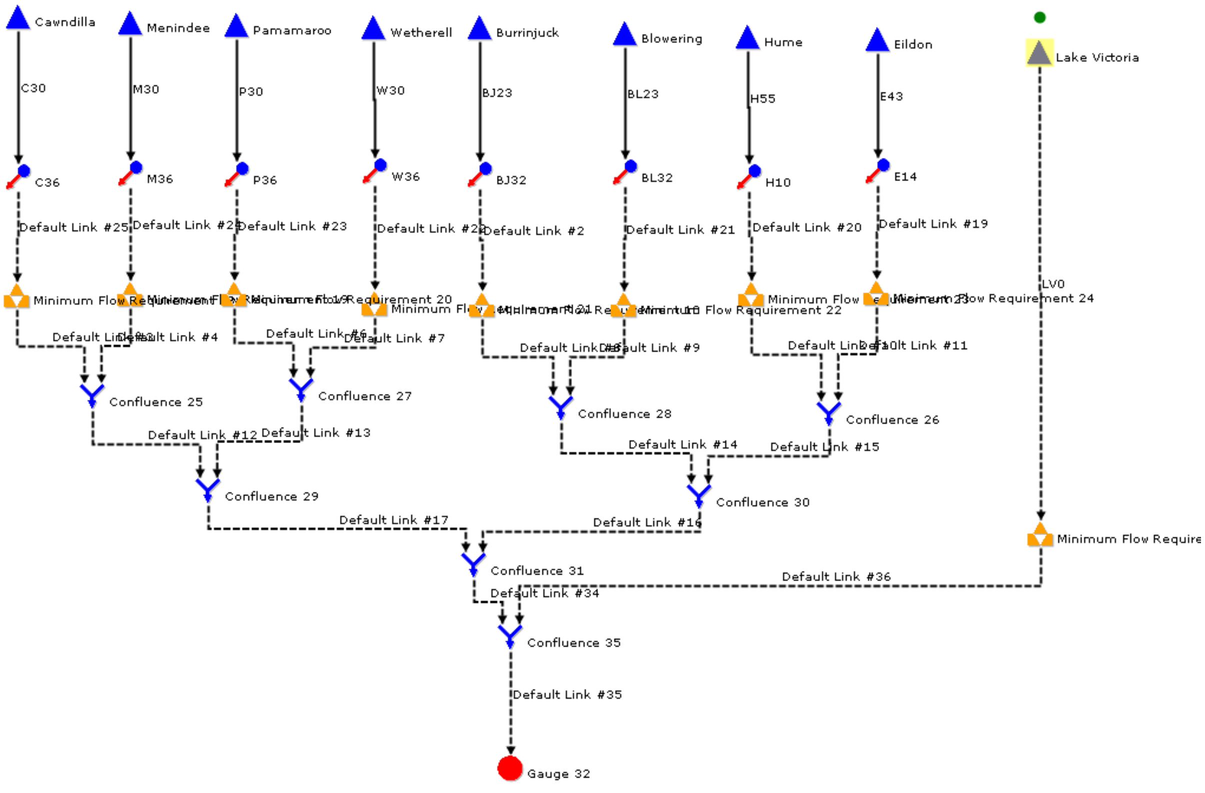


Figure 9.1 Source River model of supply storages built for estimating release constraints

The storage level, volume and area relationships as well as the outlet and spillway relationships for each of the storages was configured. Any river delivery constraints, e.g. Tumut River maximum flow, were included in storage outlet relationships. An analysis of travel times from each of the storages to the South Australian border was undertaken to derive the travel times shown in Table 9.1. These were included in the model as lag times.

Table 9.1 Average travel times (days) from supply storage to the SA border

Storage	Cawndilla	Menindee	Pamamaroo	Wetherell	Burrinjuck	Blowering	Hume	Eildon	Lake Victoria
Travel time (days)	30	30	30	30	23	23	55	43	0

A delivery loss was included for each of the supply storages based on efficiencies tabled in the Murray-Darling Basin Sustainable Yields report (CSIRO, 2008b).

A demand equal to the shortfall between flow under the 4000 scenario and optimised environmental flow was added to each supply storage.

A time series of daily storage levels from the 4000 scenario was added to each storage to force the model each day to these storage levels. Note that MSM and Eildon monthly results were disaggregated to daily by linear interpolation.

The model was run and the flow at the gauge at the bottom was extracted. This flow represents the extra flow that could have been supplied by the upstream storages on that day. Note that this method does not allow for the impact of this extra release on the storage outlet capacity and assumes that the water would be available in environmental licences.

The volume available in upstream storages each year was determined by taking the sum of the minimum active volume of all storages in each water year. This is then compared against the annual shortfall volume to determine if there is sufficient stored volume to meet the shortfall. This does not consider whether the water could be released or whether it is available in environmental licences.

9.4 Building the EWRs optimised daily flows

9.4.1 Riverland–Chowilla

Optimised flows at the border were derived directly for Riverland–Chowilla. The MDBA and SA Government specifications are listed in Table 9.2 and Table 9.3 respectively.

Table 9.2 EWRs used to derive the daily flow pattern for the MDBA Riverland–Chowilla EWRs optimised flow

	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 9.3 EWRs used to derive the daily flow pattern for the SA Riverland–Chowilla EWRs optimised flow

	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				

9.4.2 Coorong, Lower Lakes, and Murray Mouth

The MDBA and SA government flow requirements at the barrages are detailed in Table 9.4.

Table 9.4 Barrage EWRs used to derive the flow pattern for the MDBA and SA CLLMM EWRs optimised flow

Rule	Requirement
MDBA	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
	3200 GL/y rolling average over 10 years in 100% of years
SA	650 GL/y rolling average over a year in 95% of years
	2000 GL/y rolling average over 2 years in 95% of years
	F(t) + F(t-1) + min(F(t-2),2000) > 6000 GL in 95% of years*
	Maximum of previous 3 conditions
	1000 GL/y rolling average over 2 years in 100% of years
	F(t) + F(t-1) + min(F(t-2),1000) > 3000 GL in 100% of years*
	Maximum of previous 2 conditions
	6000 GL/y 1:3 y frequency
	10,000 GL/y 1:7 y frequency

F – the annual flow
t – the current year

9.5 Transfer of Barrage environmental flow requirements to the border

To be able to have a total flow SA requirement at the border for both Riverland–Chowilla and CLLMM the CLLMM EWRs need to be transferred up to the border. Note the Riverland–Chowilla EWRs are already at the border. The method for transferring CLLMM EWRs to the border is described below:

1. obtain the annual without-development flows at the barrages
2. find the annual flow that just meets all of the MDBA and SA EWRs subject to not being larger than without-development conditions
3. disaggregating this to a daily EWR based on the without-development daily flows at the barrages
4. lagging the flows by 13 days which is the average travel time from the border
5. aggregating these flows to annual totals
6. disaggregating based on the without-development flow at the border ensuring that the without-development flow is not exceeded
7. running BigMod with the daily time series at Step 6 substituted in as the border flow
8. comparing the average annual required barrage flow (Step 2) and the modelled flows. If the difference is less than 10 GL/year stop
9. for each year, determining a ratio between the required annual flow at the barrages (Step 2) and the modelled annual flows at the barrages
10. adjusting the required annual border flows (Step 5) by this ratio –go to Step 6.

10 Modelling results

10.1 Meeting EWRs on an average annual basis

From the modelling described in Sections 9.4 and 9.5, the average annual volumes required to meet the EWRs optimised flows were derived. These are listed in Table 10.1.

Table 10.1 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

10.1.1 Meeting Riverland–Chowilla EWRs on an average annual basis

The average annual volumes to South Australia required to meet the MDBA and SA Riverland–Chowilla EWRs optimised flows (Table 10.1) under the without development, baseline and Guide scenarios are shown in Figure 10.1 and Table 10.2. A comparison between volumes extracted from the BigMod daily model and the Guide annual model is also shown in Table 10.2.

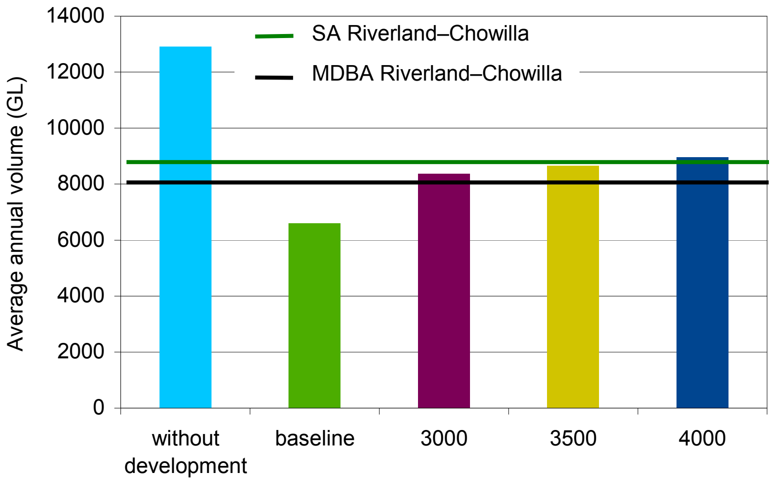


Figure 10.1 Average annual volume (GL) to Riverland–Chowilla under the without-development, baseline and Guide scenarios compared to the volumes required to meet MDBA and SA Riverland–Chowilla EWRs optimised flows (shown using the black and green horizontal lines respectively)

Table 10.2 Average annual flow (GL/y) to Riverland–Chowilla under the without development, baseline and Guide scenarios (with comparison to flows 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

Figure 10.1 and Table 10.2 show that the average annual volume of 8040 GL required to meet MDBA Riverland–Chowilla EWRs daily optimised flow is met under all Guide scenarios while the average annual volume of 8729 GL required to meet SA Riverland–Chowilla EWRs daily optimised flow is only met under the 4000 scenario.

The Riverland–Chowilla EWRs optimised flows have been developed to ensure the required frequencies are met. By constraining the frequencies to match without-development frequencies, the amounts required for MDBA and SA Riverland–Chowilla EWRs can be reduced from 8040 GL/year and 8279 GL/year to 7619 GL/year and 7829 GL/year respectively. By constraining to without development flows the most efficient delivery outcome can be achieved. However, when operating the river perfect knowledge is not available - consequently the requirement will fall somewhere between the two numbers provided.

10.1.2 Meeting CLLMM EWRs on an average annual basis

The average annual flows out the barrage to meet MDBA and SA CLLMM EWRs optimised flows under the Guide scenarios (Table 10.1) are shown in Figure 10.2 and Table 10.3. A comparison between flows extracted from the MDBA daily model and the Guide annual model is also shown in Table 10.3.

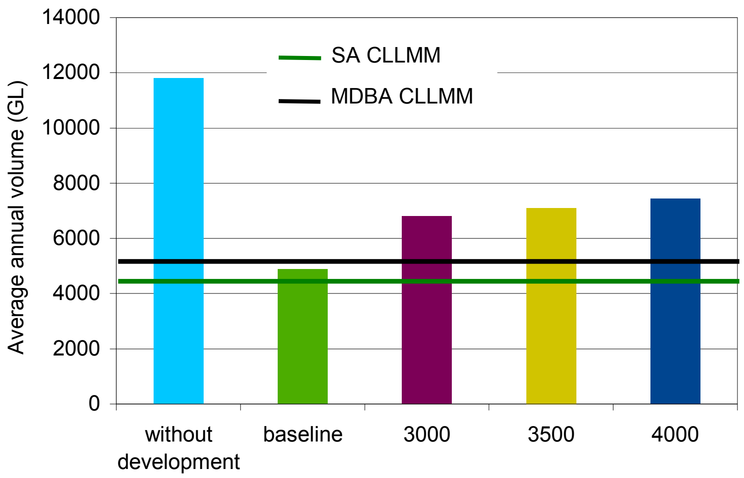


Figure 10.2 Average annual volume (GL) out the barrages under the without-development, baseline and Guide scenarios compared to the volumes required to meet MDBA and SA CLLMM EWRs optimised flows (shown using the black and green horizontal lines respectively)

Table 10.3 Average annual flow (GL/y) out the barrages under the without development, baseline and Guide scenarios (with comparison to flows 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 10.3 and Figure 10.2 show that the average annual volume of 5100 GL required 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.

10.2 Annual flow shortfall across the border and out the barrages

There is significant variability in the annual flow across the border in all scenarios as shown in Figure 10.3. The variability needs to be considered by looking at meeting EWRs on an annual basis, particularly for years which require high annual flows.

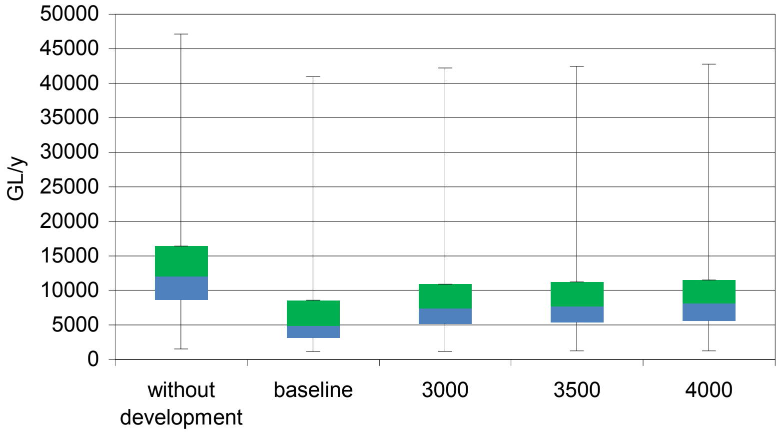


Figure 10.3 Annual across-border annual flow variability shown as quartiles for the without-development, baseline and Guide scenarios

10.2.1 Meeting Riverland–Chowilla EWRs optimised flow on an annual basis

Figure 10.4 shows the shortfall in meeting the SA Riverland–Chowilla EWRs optimised flow at the border under the baseline and Guide scenarios, on an annual basis.

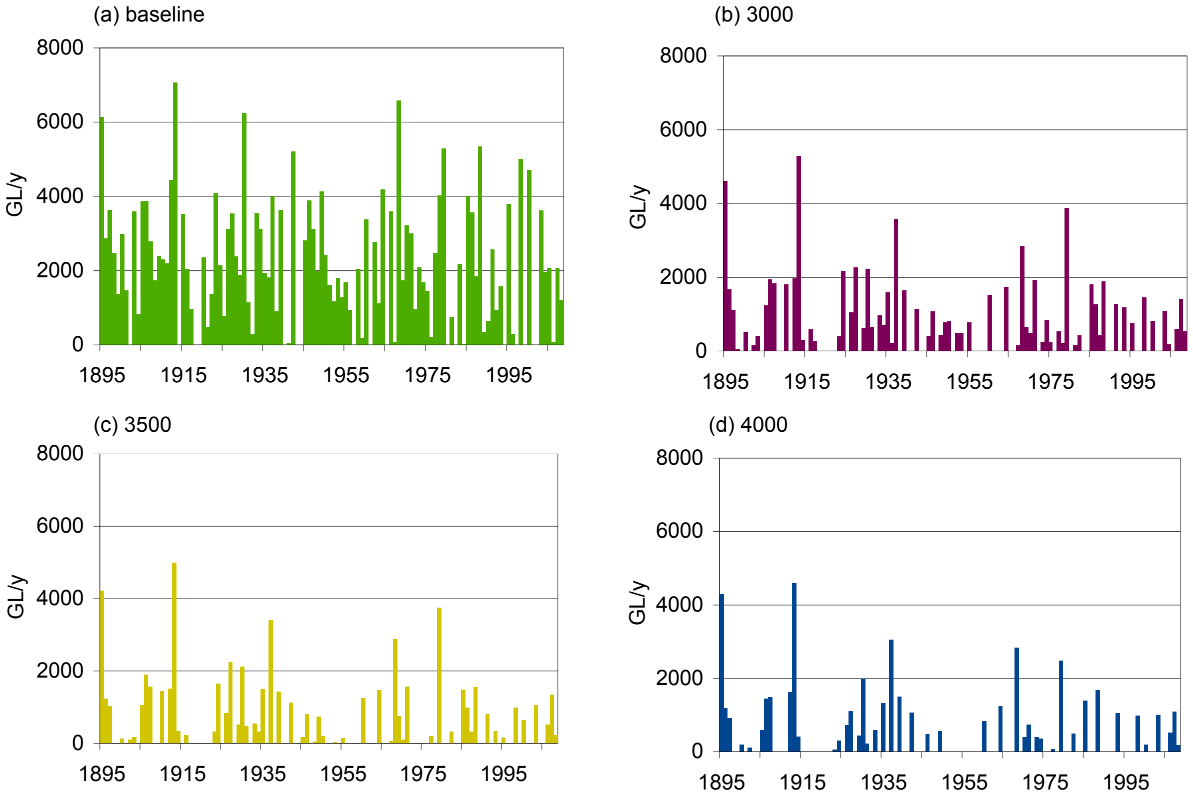


Figure 10.4 Annual shortfall (GL) in meeting SA Riverland–Chowilla EWRs optimised flow under the (a) baseline and (b-d) Guide scenarios

Table 10.4 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 10.4 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 10.4 Number of 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

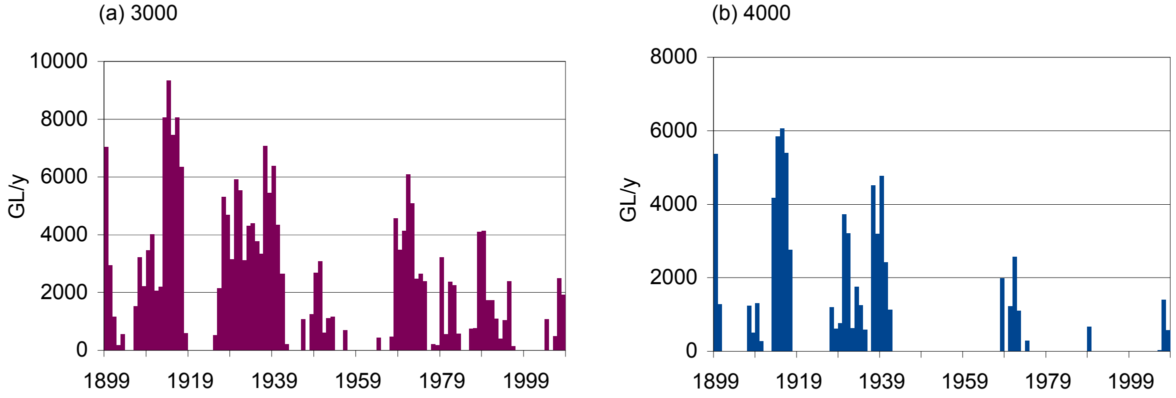


Figure 10.5 Five-year rolling average shortfall (GL) in meeting SA Riverland–Chowilla EWRs optimised flow under the (a) 3000 and (b) 4000 scenario

Figure 10.5 shows a five-year rolling 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.

10.2.2 Flows out the barrages to meet CLLMM EWRs optimised flow on an annual basis

Figure 10.6 shows the annual shortfall in meeting 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.

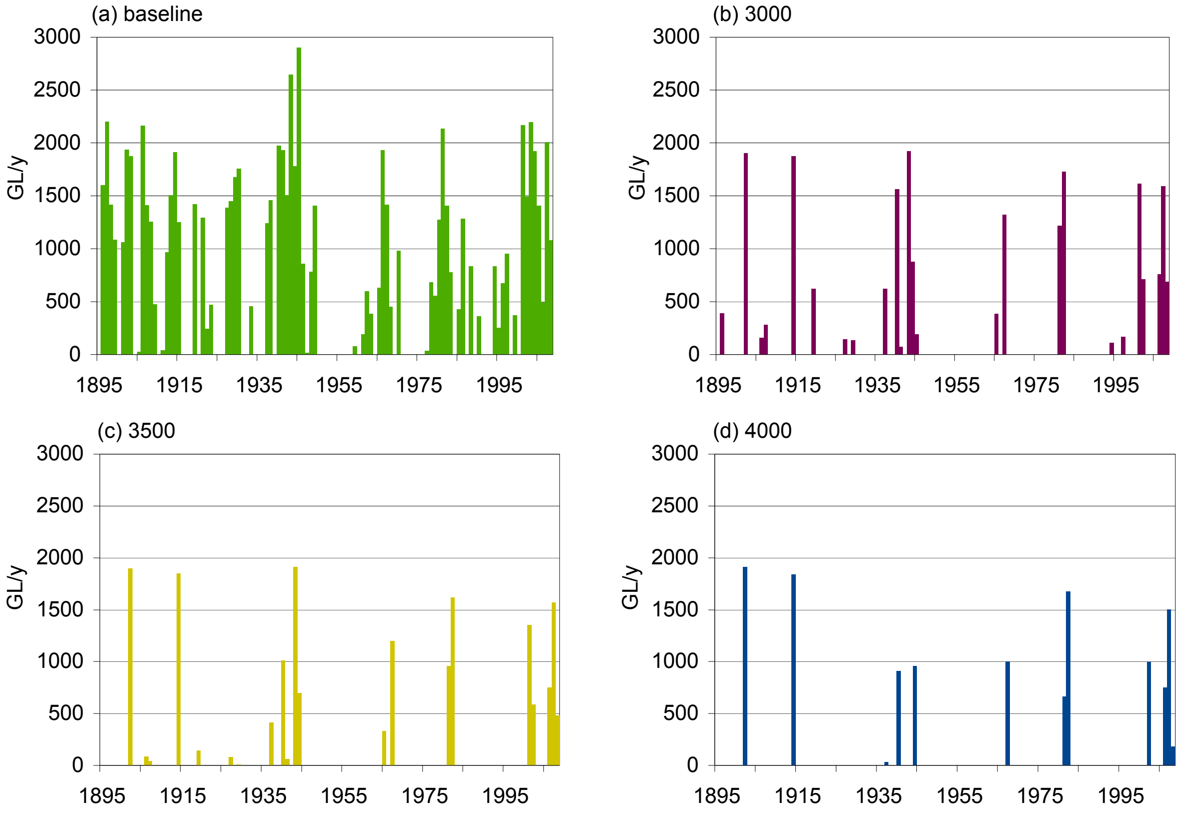


Figure 10.6 Annual shortfall (GL) in meeting the SA CLLMM EWRs optimised flow under the (a) baseline and (b-d) Guide scenarios

Table 10.5 shows that there are 12 years of shortfall under the 4000 scenario with the largest shortfall of 1908 GL occurring in 1902. There are 71 years of shortfall under the baseline scenario with the largest shortfall of 2900 GL in 1945. Table 10.6 shows the components of the EWR that are not met for each of the scenarios. All criteria are almost met under the 4000 scenario, with three of the criteria not being met only 2% of the time. Table 10.6 also shows that if the SA Riverland–Chowilla EWRs optimised flow is met all of the CLLMM EWRs are also met.

Table 10.5 Number of years in which SA CLLMM EWRs optimised flow is not met 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

Table 10.5 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 10.6 Meeting MDBA and SA CLLMM EWRs optimised flows under the without-development, baseline and Guide scenarios

		Scenario					Riverland–Chowilla EWR	
Environmental flow rule		without-development	baseline	3000	3500	4000	SA	MDBA
MDBA CLLMM EWR	5100 GL/y long-term average	11,810	4870	6804	7107	7447	7253	7007
	2000 GL/y rolling average over 3 years in 95% of years	100%	79%	98%	98%	98%	99%	100%
	1000 GL/y rolling average over 3 years in 100% of years	100%	94%	99%	99%	99%	100%	100%
	3200 GL/y rolling average over 10 years in 100% of years	100%	77%	99%	99%	100%	100%	100%
SA CLLMM EWR	650 GL/y rolling average over 1 year in 95% of years	100%	89%	95%	95%	96%	100%	100%
	2000 GL/y rolling average over 2 years in 95% of years	100%	76%	94%	95%	97%	98%	100%
	F(t) + F(t-1) + min(F(t-2),2000) > 6000 GL in 95% of years	100%	73%	94%	95%	97%	98%	100%
	Maximum of previous 3 conditions 95% of years	100%	71%	92%	93%	95%	98%	100%
	1000 GL/y rolling average over 2 years in 100% of years	100%	89%	98%	98%	98%	100%	100%
	F(t) + F(t-1) + min(F(t-2),1000) > 3000GL in 100% of years	100%	88%	98%	98%	98%	100%	100%
	Maximum of previous 2 conditions 100% of years	100%	88%	98%	98%	98%	100%	100%
	6000 GL/y 1-in-3 year frequency	1	4	2	2	2	2	2
	10000 GL/y 1-in-7 yearfrequency	2	10	5	4	4	3	8

F – the annual flow

t – the current year

Red cells identify where criteria are not met

10.3 Delivering optimised flows to the South Australian border

10.3.1 CLLMM EWRs at the border

The SA and MDBA CLMM EWRs optimised flows were transferred to the border by iterating the method described in Section 9.5. The annual hydrographs at the border are shown in Figure 10.7.

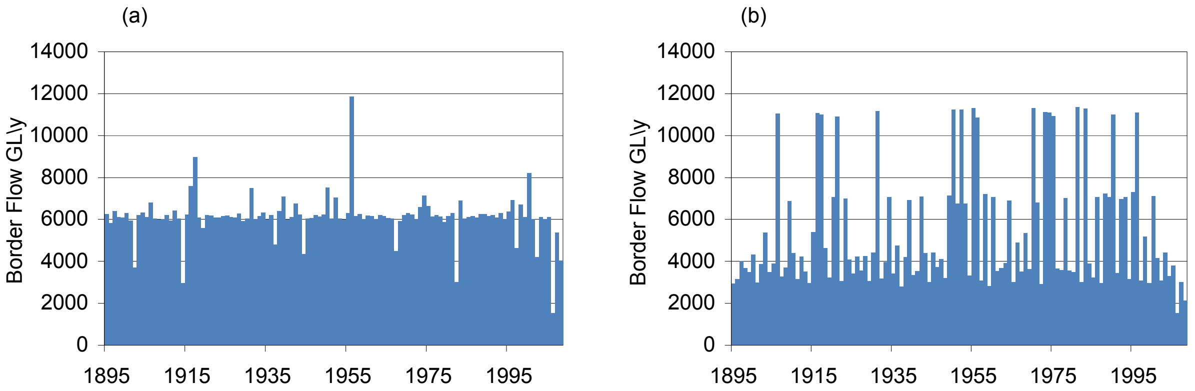


Figure 10.7 Flows at the SA border for (a) MDBA CLMM EWRs optimised flow and (b) SA CLMM EWRs optimised flow

10.3.2 Under the without-development scenario

Table 10.7 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 10.7 Contributions of upstream regions to the without-development border flow (as a proportion of the without-development border flow) and to MDBA and SA CLLMM EWRs optimised flows

	Contributing region				
Scenario	Murray	Ovens	Goulburn Campaspe Loddon	Murrumbidgee	Darling
	proportion of without-development flow				
without development	0.27	0.11	0.25	0.20	0.16
MDBA CLLMM EWRs	0.27	0.12	0.26	0.20	0.16
SA CLLMM 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.

10.3.3 Under the Guide scenarios

A comparison was made between the upstream contributions under each of the Guide scenarios. This comparison is shown in Figure 10.8 and Table 10.8. 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.

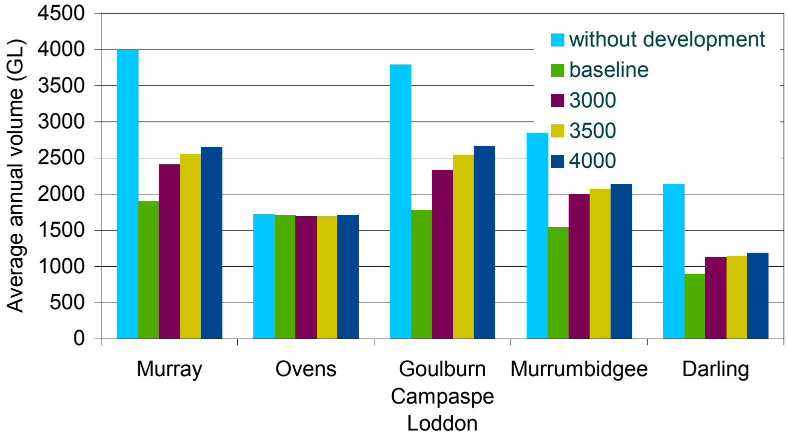


Figure 10.8 Upstream contributions (GL) to flows at the South Australian border under the without-development, baseline and Guide scenarios

Table 10.8 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 10.8 shows that under the baseline scenario the Darling contribution is less than other regions and that the Ovens contribution is approximately the same as without-development conditions. The contributions improve considerably 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 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.

10.4 Release limitations

There are three ways that release limitations have been considered for the 4000 scenario:

1. annual shortfalls
2. daily shortfalls
3. available volume.

On an average annual basis there is sufficient volume in the system to meet the SA EWRs optimised flow. To meet annual requirements large volumes of water would need to be held in storages and released in extended dry periods to meet SA EWRs optimised flow. This would require sufficient capacity in storages to hold this water and a change in the way that the environmental water is released from storages. No consideration was given to holding reserves in previous years to meet environmental water requirements.

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 underestimate 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 optimised flow is 1913. Note this analysis assumed that all the remaining volume in storage is available for environmental releases. This may not be the case as stored water may belong to other users including critical human water needs.

11 Discussion of key findings

If the Riverland–Chowilla EWRs optimised flow is met 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. SA EWRs optimised flow can be met on an average annual basis under the 4000 scenario but cannot be met on an annual basis under any scenarios (Table 8.1). This is due to having more water than required in the wetter years and less water than required in dry years. To further exacerbate this problem many of the dry periods exceed 5 years (Figure 10.5).

Recognising that the Guide scenarios represent an implied release strategy the report considered different operational practices that might meet all of the SA EWRs. The five-year rolling average for SA Riverland–Chowilla EWRs optimised flow under the 4000 scenario (Figure 10.5) indicates that a volume in excess of 4000 GL would need to be carried over for long dry periods to ensure that the EWRs are met. Although theoretically this is possible; operationally it may be difficult for the Commonwealth Environmental Water Holder (CEWH) to hold water during extended dry periods when other environmental assets in the Basin may require watering. The SA CLLMM EWRs optimised flow can be met on a five-year rolling average under the 4000 scenario, suggesting that small reserves could be carried over to meet those environmental water requirements.

The study found that, under the 4000 scenario, in all but one year (1913) there was sufficient volume in upstream storages to meet the shortfall in SA EWRs optimised flow. This indicates that for all but this year there would be sufficient volume to meet SA annual shortfall, however, the water that remains in storage during these dry periods may be reserved for critical human water needs and not available for environmental release.

The SA CLLMM EWRs optimised flow relates to delivering annual volumes and is consequently easier to meet through regulation. The Riverland–Chowilla EWRs optimised flow requires large events to meet some of the requirements, in particular, maintaining and improving the health of black box woodlands which require flows in excess of 100,000 ML/day (Table 9.2 and Table 9.3). It is considerably more difficult to meet daily event requirements due to flooding and outlet limitations. Under the 4000 scenario there are 44 years where the Riverland–Chowilla daily EWRs optimised flow shortfalls cannot be met. The large events can only be generated by storages spilling. The spilling frequency of storages is influenced by the amount of water released for the environment, as the environmental licence and use increases this causes the storages to draw down more which in turn reduces the size of spills. This influences the frequency of high flow events (greater than 80,000 ML/day) for Riverland–Chowilla (see ‘Environmental water requirements’, Part I of this report).

As part of the brief for this study we were asked to comment on the potential impacts of climate change. The MDBA did not provide climate change scenarios for any of the Guide scenarios so only a qualitative assessment can be made. The Guide to the proposed Basin Plan (MDBA, 2010) estimated that climate change impact would be 3%. Table 4-16 in the Sustainable Yields report ‘Water Availability in the Murray’ (CSIRO, 2008a) suggests under the median 2030 climate scenario (Scenario Cmid) flows will decrease by 17%. The number estimated by MDBA was integrated over the period until the first review of the Basin Plan (about 2010), i.e. not for 2030, but seems low in comparison to Murray-Darling Basin Sustainable Yields Project results. Nonetheless climate change presents a significant risk given that all of the SA EWRs are not met under the Guide scenarios, and this will be exacerbated with between 3−17% less water. Shortfalls would be significantly larger and more frequent.

In determining the contributions of upstream regions 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 only recover 50% of the water that is available under without-development conditions (Table 10.8).

The shortfalls in the annual volumes only occur during dry periods when storage volumes are low and the storages consequently do not have additional outlet capacity to meet this shortfall. The approach that has been taken does not consider releasing water to meet the shortfall and consequently the amount available to meet the shortfall will be less than assumed in the analysis. Consequently there are likely to be more years that EWRs would not be met.

References

CSIRO (2007) Overview of project methods. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Water for a Healthy Country Flagship, CSIRO, Australia. 12pp.

CSIRO (2008a) Water availability in the Murray. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Water for a Healthy Country Flagship, CSIRO, Australia. 217pp.

CSIRO (2008b) Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Water for a Healthy Country Flagship, CSIRO, Australia. 67pp.

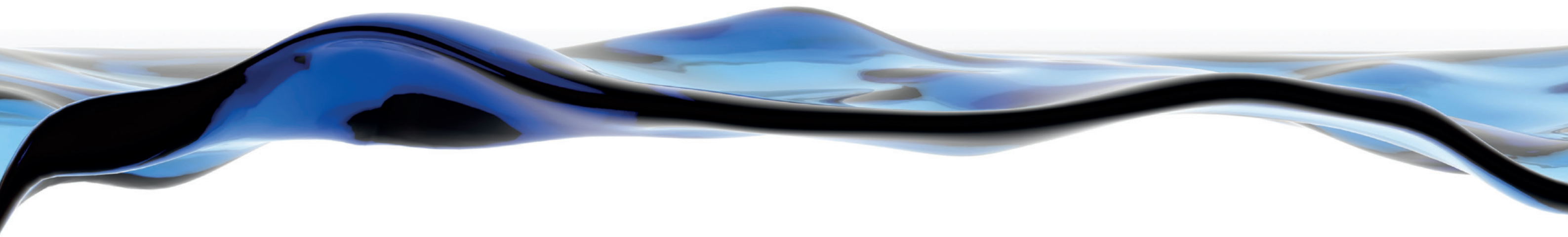
MDBA (2010) Guide to the proposed Basin Plan: Technical background, Murray−Darling Basin Authority, Canberra.

MDBC (2001) Model River: River Murray System Daily Model. MDBC Report RMSDM 009. Murray−Darling Basin Commission, Canberra.

eWater (2011) Source Rivers Flyer. eWater Cooperative Research Centre publication. Accessed on 20 March 2011 from <http://www.ewater.com.au/products/ewater-source/for-rivers/>.

Podger GM, Barma D, Neal B, Austin K and Murrihy E (2010) River system modelling for the Basin Plan: Assessment of fitness for purpose. CSIRO: Water for a Healthy Country Flagship, Canberra, December 2010, pp 64.

Yang A (2010) The Integrated River System Modelling Framework. A report to the Murray−Darling Basin Authority. Water for a Healthy Country Flagship, CSIRO, Canberra, June 2010.



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