Department of Climate Change, Energy, the Environment and Water

# Technical Review Method

## Minimum inflows review

February 2026

# Acknowledgement of Country

The Department of Climate Change, Energy, the Environment and Water acknowledges the traditional custodians of the land and pays respect to Elders past, present and future.

We recognise Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to place and their rich contributions to society.

Artist and designer Nikita Ridgeway, from Aboriginal design agency Boss Lady Creative Designs, created the People and Community symbol.

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# Contents

# 1 Introduction

This document describes the method the Water Group in the New South Wales Department of Climate Change, Energy the Environment and Water (the department) will use to review minimum inflows. Minimum inflows are currently used to determine water availability in NSW regulated river water sources through a process that determines the storage reserves needed to provide water security to the environment and high priority water users.

The current minimum inflows review has two main drivers:

1. regulatory requirements in regulated river water sharing plans to review how minimum inflows are defined
2. Action 4.2 of the NSW Water Strategy which commits the department to *review water allocation and water sharing in response to new climate information*

The review also reflects a commitment to address the issue as part of the settlement of *Nature Conservation Council of New South Wales v Minister for Water, Property and Housing* in relation to its consideration of climate change in the Border Rivers Regulated Water Sharing Plan. This includes a commitment to have the Office of the NSW Chief Scientist and Engineer convene an independent panel to review the minimum inflows project's draft method.

Further information can be found in the Background section of the document.

## 1.1 Minimum inflows project scope

The scope of the minimum inflows project is governed by the project requirements outlined above and consists of four main components:

1. a review of elements in the water allocation process, particularly the assumptions relating to expected inflows, and a consideration of amendments that could incorporate climate change and provide a clearer understanding of water supply risk
2. an impact assessment using scenario modelling that focuses on water balance, environmental and economic assessments
3. an options analysis
4. stakeholder engagement for shortlisted options.

The interaction between these project components is shown in Figure 1. This review method document covers the first component only and does not consider the impact assessment methods, options analysis or stakeholder engagement methods. The current document also does not include a review of methods to amend water sharing plans.

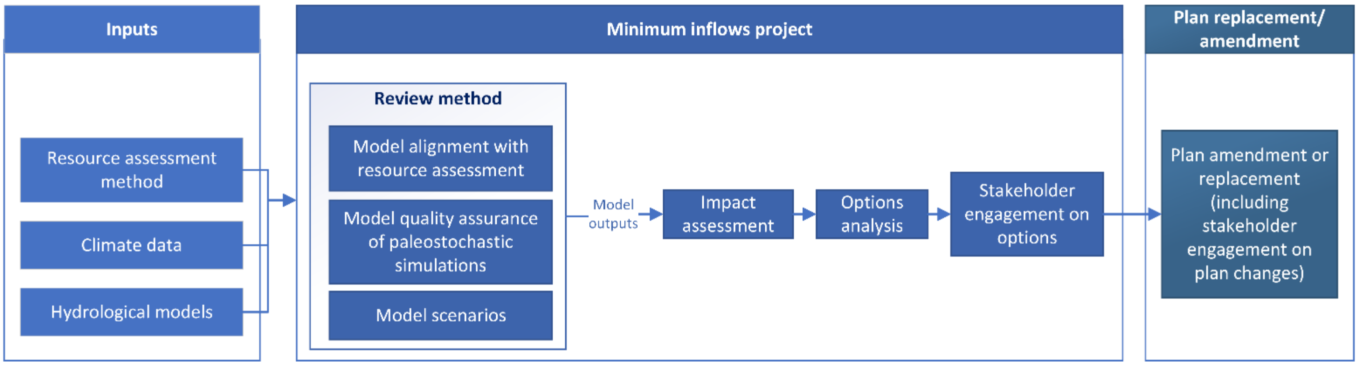


Figure 1. Minimum inflows review scope and component interaction

## 1.2 Document outline

Chapter 2 of this document provides background information on water sharing plans and the general process for allocating water in NSW regulated rivers. This chapter also describes how minimum inflow sequences and storage reserves are currently estimated. Limitations of the current methodology and potential methods to overcome these limitations are discussed. Chapter 2 also provides an overview of our existing hydrological and river system models and the climate datasets used to drive them, including the ways in which climate change risks are typically explored using these datasets and models.

Chapter 3 presents the proposed methods for the four interlinked components of this minimum inflows review: the available water determination (AWD) process, the use of extended stochastic climate sequences in models in representing water allocation, statistical analysis of modelled storage inflows and reserve requirements from these stochastic climate sequences and the use of model scenarios to investigate the potential effects of climate change on water allocation and water security from alternate inflow sequences or storage reserves.

# 2 Background

## 2.1 Water sharing plans and the available water determination process

The *Water Management Act 2000* (the Act) is the primary piece of legislation governing the use of water from surface water environments and groundwater systems across NSW. The management of individual water sources is regulated through water sharing plans, which are statutory instruments established under the Act.

The Act sets out water management principles (s 5) and establishes water licence categories (s 57). Other key functions of the Act regarding the allocation of water include:

- determining the relative priority of each licence type (s 58), with the highest priority given to high priority requirements, including basic landholder rights, domestic and stock requirements and town water supply.
- providing for the preparation of water sharing plans, which prescribe the water sharing rules for each water source and allocation of water to licence categories in priority order
- providing for the allocation of water through available water determinations (AWDs; s 59).

Water sharing plans set out, in detail, how water is to be shared between consumptive users and the environment and how it is to be shared among the consumptive users of a particular water source or group of connected water sources. Valley-specific AWD-based allocation processes are detailed on the department's website. These are referenced for Border Rivers and Murrumbidgee at NSW DPE (2020a) and NSW DPE (2020b) respectively.

### 2.1.1 Water provisions for high priority users and essential supplies

Water sharing plans for regulated rivers include a provision that requires that enough water be reserved to meet high priority requirements during a repeat of the 'period of lowest accumulated inflows'. Inflows during this period define the 'minimum inflow', describing the total volume of water expected to enter the system. The length of the minimum inflow sequence determines the planning horizon, and reserves are held to meet high priority requirements over that planning horizon.

The water sharing plans stipulate that the minimum inflow sequence for each regulated river system is determined using flow information that was held by the department prior to the start of the first water sharing plan for that river system. For most of the inland regulated water sharing plans this date is 1 July 2004. In the NSW Border Rivers, Peel and Belubula it is 2009, 2010 and 2012 respectively.

The lowest accumulated inflow data is drawn from departmental water models. The inflows represented in these models are based on observed flows at stream gauges upstream of the storage. The data at these stations were extended and filled as required through back calculation of inflows and hydrologic modelling of ungauged catchments.

Methods to calibrate headwater inflows and storage inflows are described in Australian Modelling Practice notes collaboratively developed by the department's and other national and state government water management agency modelling groups. Further description of methods are contained in other practice notes prepared for the Australian Modelling Practice; in published model build reports (NSW DPIE 2020a) and an overview available in presentations prepared for stakeholder engagement (NSW DPE 2021a, 2021b, 2022a, 2022b).

#### What is considered high priority requirements?

The water sharing plan details relevant high priority requirements in the maintenance of supply clauses. These include:

- basic landholder rights
- domestic and stock licences
- local water utility licences
- major utility licences
- high security licences
- conveyance licences
- environmental water allowances
- replenishment flow volumes
- end of system flows
- operational requirements such as transmission losses, evaporation, dead storage.

### 2.1.2 Management of severe droughts

Water provisions through the AWD process are not the only tool for managing water allocation in extreme conditions. If predicted inflows do not eventuate, a drought response may be triggered.

For water sharing plans the Extreme Events Policy (NSW DPE 2023a) establishes the principles by which all regulated river water resources will be managed during an extreme event such as a drought or sudden deterioration in water quality. This policy aims to ensure critical human water needs are met and gives effect to the water sharing priorities under s 60 of the Act.

The policy framework establishes a staged approach and provides a range of measures that water managers can deploy as conditions deteriorate. In the case of a severe drought, the management response involves progressively introducing more stringent measures to support the highest priority needs as the event becomes more critical. Incident Response Guides (IRGs) required by the Basin Plan provide further detail on possible actions during drought and water quality events.

When an Extreme Event is announced under s49A or s49B of the Act, such as an extreme water shortage, the priorities of the Act change and water sharing plans may be suspended. During extreme events, such as drought, our focus is on securing water for critical human needs. At these times, under section 60 of the Water Management Act 2000, critical human needs are the first priority and the environment is the second priority. Outside of these extreme events, the priority is providing water for the environment.

### 2.1.3 Review provisions for determining minimum inflows

Since 2004, there have been more severe droughts, with the Millennium (2001 – 2009) and Tinderbox (2017-2020) droughts each causing record low inflows into most water storages, suspension of water sharing plans and triggering the implementation of the Extreme Events Policy and ad hoc drought response measures. This caused uncertainty for water users and generated community concern that the current allocation process and minimum inflow sequence does not consider the plausible impacts of climate change.

Most of the regulated river water sharing plans include a provision that requires a review of options for determining minimum inflows. The review provision includes requirements to determine the impact of any options on planned environmental water (PEW) and other access licences and to consider the views of stakeholders and the broader community.

Work is underway for the remaining regulated river water sharing plans to be amended to include the provision. The text of this review provision from the *Water Sharing Plan for the NSW Border Rivers Regulated Water Source 2021* is reproduced in Appendix 1.

### 2.1.4 The NSW Water Strategy

The NSW Water Strategy (NSW DPIE 2021c) sets the strategic direction for water management in NSW and commits to climate change action. Priority 4 of the strategy aims to increase resilience to potential changes in water availability due to variability and climate change.

Action 4.2 of the NSW Water Strategy is 'Review water allocation and water sharing in response to new climate information'. As set out in the Implementation Plan for the strategy, the department will initially test scenarios for water availability and allocations based on climate risk modelling scenarios in a pilot and then expand application to other valleys.

## 2.2 Current water allocation method

### 2.2.1 Allocation process for regulated rivers

In regulated rivers, the volume of water allocated to licence holders varies from year to year based on the licence category. Opening allocations are made at the beginning of the water year[1] on 1 July, with allocation to relevant high priority needs (some planned environmental water requirements, domestic and stock licences, local water utility and major utility licences) prioritised as prescribed in s 59. Once allocations are made for these highest priority licences, and allowing for any existing general security carryover, allocation begins for high security and

[1] The water year is the period 1 July to 30 June the following year

then general security licences. Water cannot be allocated to lower priority licences until high priority requirements are fully met in accordance with the water sharing plan.

The amount of water available to allocate depends on water in storage, account water carried over from the previous water year, water needed to meet high priority requirements, the volume required to run the river (operational requirements), and minimum inflows expected.

Resource assessments are periodically conducted throughout the water year to determine whether additional water can be allocated, for example, after there have been inflows in excess of minimum inflows.

Figure 2 provides an overview of this process.

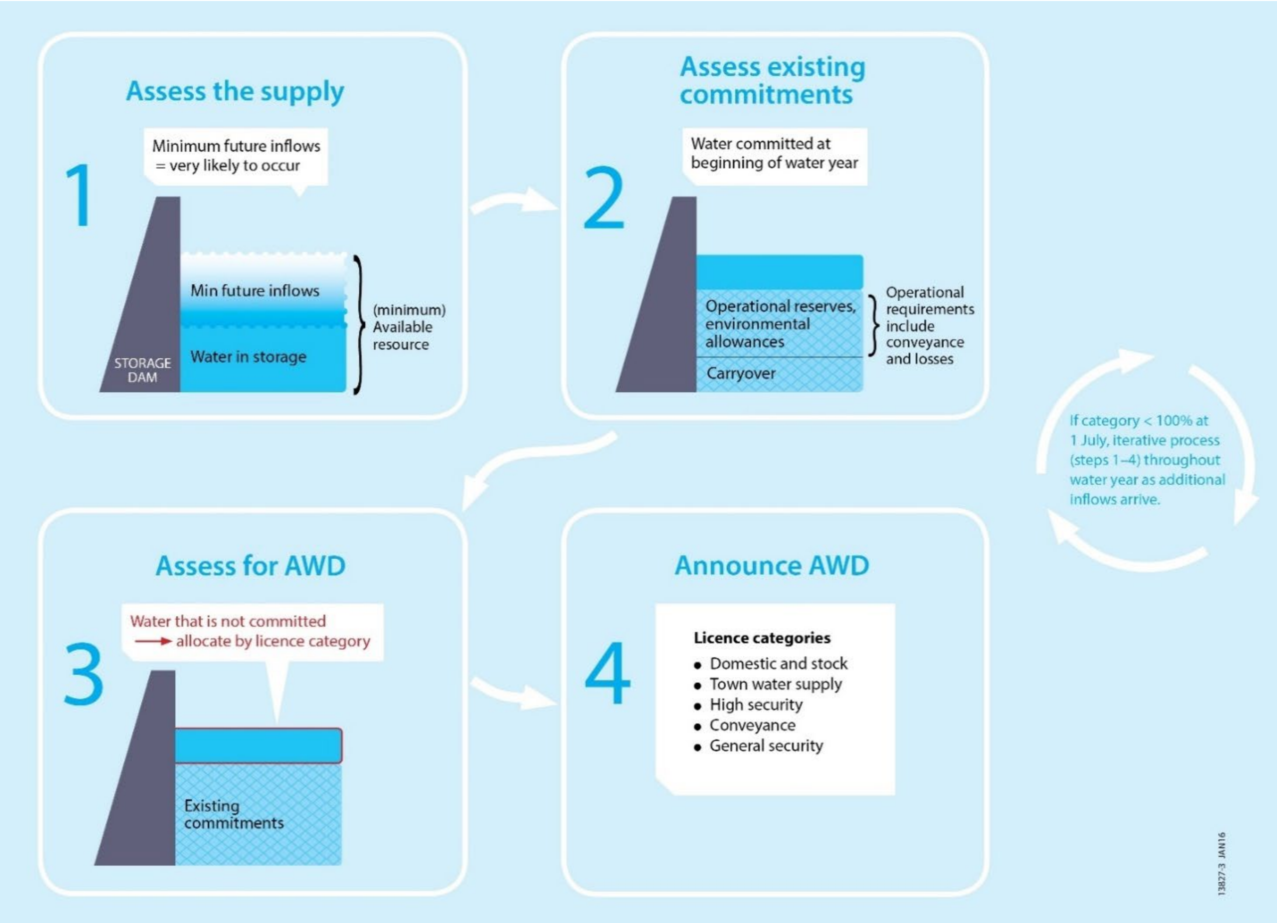


Figure 2. Water allocation process at beginning of the water year

### 2.2.2 Relationship between the storage reserve and minimum inflows

The storage reserve is a volume of water set aside in the storage to meet high priority requirements and operational requirements, offset by the expected minimum inflows. The volume of the necessary storage reserve in any given year is calculated using the following formula:

$$\text{storage reserve} = (\text{high priority requirements} + \text{operational requirements}) - \text{minimum inflows}$$

Thus, the expected minimum inflow volume directly affects the size of the storage reserve. For example, if the high priority requirements and operational requirements are a combined 200 GL and the expected minimum inflows are 110 GL/y, then the storage reserve is 90 GL.

Because of this relationship, any change in the way minimum inflows are determined will result in changes to the calculated storage reserve. These changes in storage reserve may in turn affect AWDs, general security diversions and the water security of high priority users (Figure 3). The respective direction of change in response to change in minimum inflows is shown by (+/-).

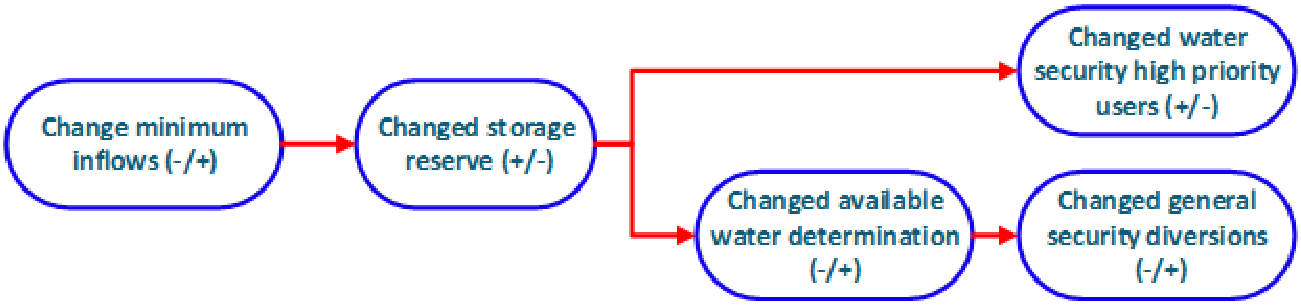


Figure 3. Relationship between minimum inflows, storage reserve, risk level and allocations

### 2.2.3 Limitations of the current approach

There are a number of limitations associated with the minimum inflows and storage reserve aspects of the available water determination process, including:

- reliance on a set climatic period to define the storage reserve means long-term climate variability and change are not considered
- not accounting for improvements in modelling and hydrological analysis tools that could enable them to identify different minimum inflow sequences, especially outside the window for which observational data is available
- a lack of well-understood water security expectations for high security and essential supplies water users, e.g., how often they would expect to see inflows lower than the minimum inflows specified in the water sharing plans
- the current AWD process allows for discretion in estimating some components.

#### 2.2.3.1 Recorded droughts are not representative of long-term climate variability and change

The historical data used to determine the minimum inflow sequence is drawn from observed climate and flow records that started in the 1890s, yielding over approximately 130 years of observed data. These records prior to the first water sharing plans do not include observations made during the periods of new record low inflows that occurred during the Millennium Drought (2001–2009) and the Tinderbox Drought (2017–2020). These record low inflows resulted in the suspension of parts or all of water sharing plans and the need to manage for ‘critical human needs’, causing uncertainty for water users and issues with delivering water to towns.

Given these recent extreme events and the ongoing evidence of climate change impacts such as increased temperature being recorded in NSW, there is concern that water allocation methods based on historical data do not provide an appropriate level of security and certainty, particularly for high priority water users.

The assumption that estimated minimum inflows between the 1890s and 2000s form a sufficiently conservative baseline for the provision of water security to high priority water users has not been borne out by experience. There are lines of evidence in paleoclimate records, stochastic modelling and climate change scenario modelling suggesting that plausible future droughts could be even more severe.

Climate change is expected to have major impacts on rainfall, temperature and evapotranspiration. Continuing with the status quo will increase uncertainty for all water users.

#### 2.2.3.2 Data improvement

The current water sharing plans stipulate the minimum inflow sequences as data held by the department prior to the start of the first water sharing plan. Subsequently, these datasets may have been periodically updated based on additional data and better estimation methods to reflect a principle of continual improvement.

Examples of the source of improvements in pre-first water sharing plan estimates derive from:

- headwater inflow rainfall runoff-model calibration methods that were previously manually calibrated are now calibrated using optimisation software
- methods to estimate ungauged catchment inflows and associated ‘losses’ as part of reach calibration steps have been refined and codified
- additional gauged data during more recent dry periods has become available which has provided an improved data set to calibrate against.

Methods to calibrate headwater inflows and storage inflows are described in Australian Modelling Practice notes collaboratively developed by the department’s and other national and state government water management agency modelling groups.

As a result of these enhanced methods and additional data, and ongoing improvement in our modelling practice, the minimum inflows stipulated in the water sharing plans may not necessarily represent the best currently available estimate of inflows prior to the first water sharing plan.

Further, the inflows used in the plans are based solely on instrumental climate data. There is better data now available to estimate inflows that have occurred with long term climate variability and change. The 10,000-year paleo-stochastic data sets provide a greater sample size of possible climate data inclusive of more extreme dry conditions leading to lower minimum inflow sequences.

## 2.3 Hydrological and river system models

The department has built and maintains daily time-step river system models for all of NSW’s major river systems. These models are used to inform water management policies and planning, evaluate climate risks and monitor and report on how the department is meeting its legal obligations relating to limiting diversions, including water sharing plan provisions.

The models consist of a suite of daily time-step rainfall-runoff models calibrated to quality-assured flow data using rainfall and potential evapotranspiration (PET) data. These calibrated models are then used to generate long-term river flows, which are inputs to river system models that simulate the water storage, allocation, delivery, diversion and streamflow processes.

The models were originally developed in an Integrated water Quantity and Quality simulation Model (IQQM) platform and are currently being progressively transitioned to the national hydrological modelling platform Source. Each river system model is independently reviewed for quality and effectiveness when it undergoes a major upgrade, such as the upgrade of the floodplain harvesting program in the northern basin or is rebuilt using Source.

The models represent the key natural and management-related processes and their interactions in an integrated software framework. Inputs to the models include spatial data, including stream networks and water infrastructure, and temporal data, including time-series flow and climate data.

The build and maintenance of the models follows a best-practice guidelines framework developed in collaboration with other water management agencies to ensure consistency and scientific robustness.

The river system models are updated annually with the prior water year's hydroclimate data for extraction compliance assessment and are periodically upgraded with new data and additional capability. The models are reviewed by independent experts following major upgrades. For example, the NSW Border Rivers model has been independently reviewed on 3 occasions (See Alluvium, 2020; Bewsher 2021; Fifteen50, 2022).

The department maintains scenario variants for models in each valley. The different scenarios may include incremental changes in configuration of model components, sensitivity analysis, changes in calibration over time, and levels of management and development. For statutory and stakeholder trust purposes, particularly diversion compliance and assessing changes for statutory plans, the department recognises the importance of justifying the selection of reference model scenarios.

The department has prepared transparent guidelines for this purpose (NSW DCCEEW, 2023a; 2023b), which has multiple criteria such as existence of documentation, independent reviews, currency of data. These guidelines developed for LTAAEL compliance are relevant for model selection to assess change resulting from this minimum inflows review.

### 2.3.1 Model limitations and assumptions during extreme drought

The department's daily time-step models have been used since the mid -1990s to determine water availability, flows and diversions under varying climate conditions. Their outputs inform and support contemporary water management decisions, such as rule changes in water sharing plans, and to track annual and long-term diversion compliance.

Several design criteria were established to enable the models to meet their objectives. These included the ability to represent key physical and management processes, capture climate variability and water usage under a range of water availability conditions, report at multiple spatial and temporal scales, and allow further updating and extension as required. The objectives and design criteria are reported in more detail in the department's model build reports.[2] Each model build report contains a comprehensive description of the model's conceptualisation, data, calibration, assemblage and overall performance for a range of climate conditions.

As with all models, there are biases and uncertainties associated with the outputs. This is particularly the case during extreme conditions, for example when estimating transmission losses based on river operations. During periods of very low flows, river operations tend to be discretionary and governed by extreme event or drought response policies and frameworks, and more information is needed to better represent these conditions in models.

The valley specific reporting of results will provide an assessment of the impacts of this uncertainty on the outcomes of the modelling, and strategies and methods to mitigate these limitations.

## 2.4 Climate data availability for river system models

The department holds or has ongoing access to multiple sources of climatic data, including both observational climate data and modelled climate data. These data are used in catchment and river system modelling. The datasets and their generation are described briefly in the sections below, as they form the basis of the scenario modelling proposed for this project.

### 2.4.1 Instrumental data

Observational data, including rainfall and temperature data since the 1890s and PET data since the 1970s, are quality-assured and used by the department. These data are then used as inputs in all rainfall-runoff and river systems models.

### 2.4.2 Paleo-stochastic climate data

The department developed a paleoclimate-informed stochastic ('paleo-stochastic') climate dataset to support the development of 13 regional water strategies to plan and manage water needs in each NSW region over the next 20–40 years (NSW DPE 2023b). This dataset was used in the department's water models to comprehensively assess risks related to water availability.

The paleo-stochastic dataset contains 10,000 years of daily climate data produced using a stochastic model calibrated to instrumental data (e.g. rainfall stations) and paleoclimate data obtained from landscape features such as tree rings, cave deposits, coral and ice cores. This dataset provides a better understanding of natural long-term climate variability and the length and severity of droughts that occurred historically, providing a better estimation of climate risks to water security than using observed data only. The paleoclimate-informed dataset includes droughts more severe than those in the 1890–2020 record.

#### 2.4.2.1 Stochastic climate method

The method through which the paleo-stochastic climate data were generated in shown in Figure 4.

[2] For example, New South Wales Department of Planning, Industry and Environment (2020:4–5).

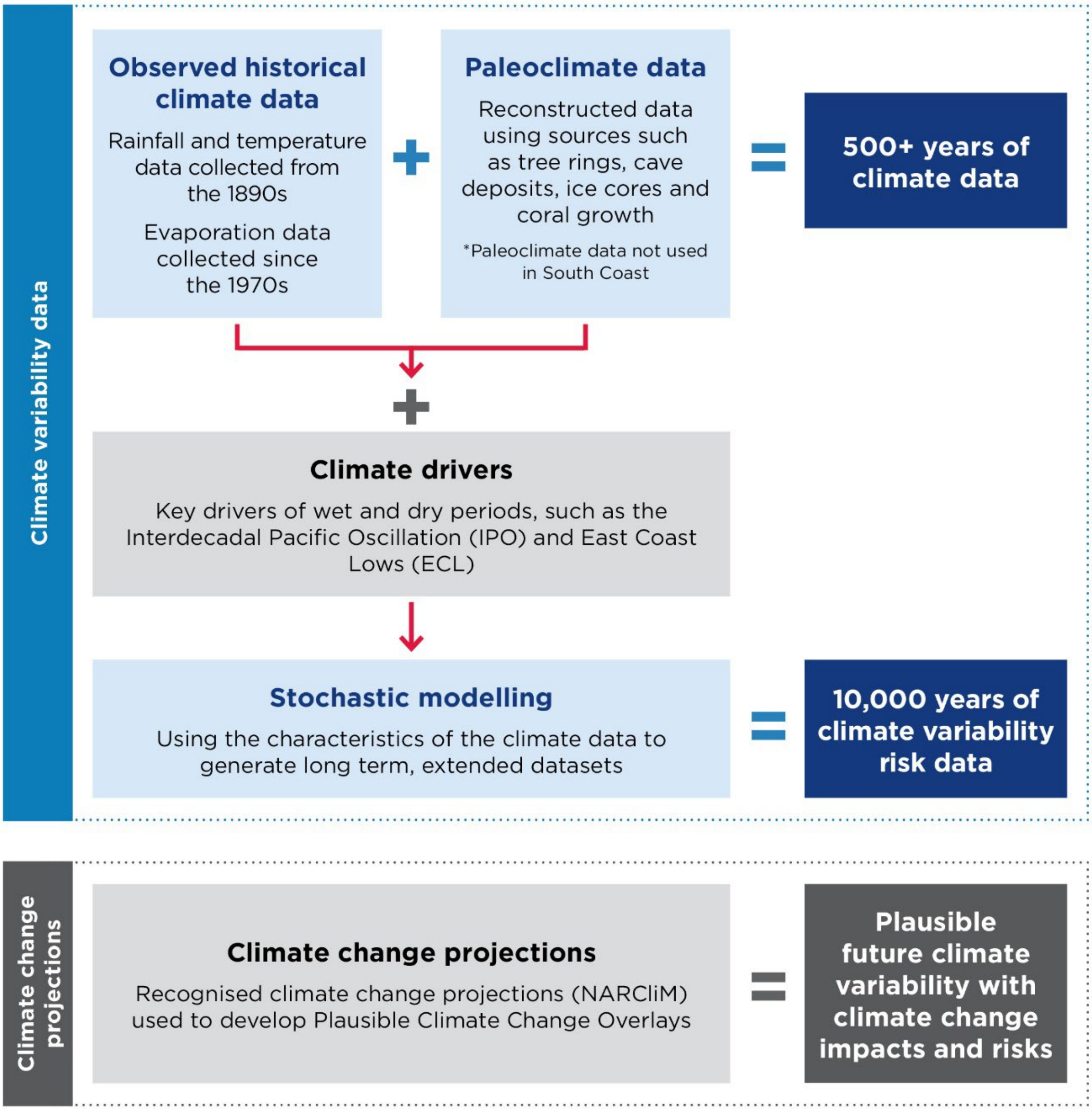


Figure 4. Approach to developing the paleo-stochastic climate dataset

The climatic sequences were generated based on statistics including seasonal mean and standard deviation values, random factors and serial correlation on an annual scale. Serial correlation, a measure of how wet or dry a year is based on whether the previous year was wet or dry, characterises the wet and dry clusters we see in observed records. Combining this characteristic with the random component reproduces the likelihood of extreme events observed in the historical and paleoclimate records.

The general stochastic generation process, which is based on the observational record alone, is enhanced when combined with paleoclimate data. For example, the observed record shows a very strong multi-decadal signal in the inland NSW climate, with the first half of the 20th century receiving about 10% less average annual rainfall than the second half of the 20th century.

Paleoclimate records indicate that these wet and dry cycles also appeared in the pre-observational record and were strongly related to positive and negative phases of the

Interdecadal Pacific Oscillation (IPO). A stochastic IPO signal was therefore integrated into the model, a step that intensified the multi-annual wet and dry extremes in the stochastic record.

By combining multi-decadal, annual, seasonal and daily distributions of rainfall and PET at multiple climate sites, the department produced 10,000 years of daily data with full spatial coverage of key climate stations. This dataset that can be used to model all inland river systems in NSW and most of the coastal draining river systems. A full description of this method is provided in NSW DPE (2023), with further technical detail in Leonard et al. (2019) and Leonard et al,.(2023b).

#### 2.4.2.2 Previous reviews of paleo-stochastic climate data

This paleo-stochastic climate data generation approach and its implementation were reviewed by an independent expert panel convened by the Office of NSW Chief Scientist and Engineer. The panel found the approach to be consistent with best practice and appropriate for use in strategic water planning (OSCE, 2020). The panel's findings took into account the department's combination of paleo-stochastic data with monthly climate change factors from the NSW and Australian Regional Climate Model (NARCliM) project.

The panel also recommended that the observational record be tested for 'climatic non-stationarity', or whether there have been trends or step changes in the climate, regardless of attribution. This was considered important in characterising the current climate and in making decisions about how to incorporate future climate change. Subsequent studies in response to that recommendation found a statistically significant increasing temperature trend in the northern inland Murray–Darling Basin (Devanand et al 2020a) and statistically significant increases in temperature and decreases in cool season rainfall in the southern inland Murray–Darling Basin (Devanand, et al, 2020b).

### 2.4.3 Climate change-factored paleo-stochastic data

The NARCliM data is based on General Circulation Models (GCMs) that have been dynamically downscaled using Regional Climate Models (RCMs). These GCMs simulate climatic conditions over the whole planet for extended periods of time using a range of greenhouse gas emission scenarios. For regional water strategy applications, the results of the NARCliM version 1.0, based on the Coupled Model Intercomparison Project version 3 (CMIP3) GCMs, were used to factor the paleo-stochastic data.

For this review, the 10,000-year paleo-stochastic climate sequences will be scaled using NARCliM 2.0. NARCliM 2.0 offers improvements compared to previous versions of NARCliM, such as the most recent CMIP6 GCMs and finer spatial resolution. The NARCliM 2.0 data, which include projections based on the Shared Socioeconomic Pathways (SSPs) emission scenarios SSP1-2.6, SSP2-4.5, and SSP3-7.0 defined by the Intergovernmental Panel on Climate Change, were released in 2024 and 2025.

This review uses the latest NARCliM 2.0 data to consider the impact of climate change. A 2035 period planning horizon was selected to represent the current climate and capture climate impacts expected during the term covered by the updated water sharing plan, and a future trajectory scenario to understand the potential impact of climate change by 2050.

The climate projections have been sourced from the 4-km resolution NARCliM 2.0 modelling suite. This modelling suite comprises five different CMIP6 general circulation models, driven by three emissions scenarios, and downscaled using a regional climate model (WRF) with two distinct physics configurations, resulting in 10 projections for each of three emissions pathways. The 'middle of the road' emissions scenario, SSP2-4.5, is used for this study as the default emissions pathway. This pathway has been chosen because it reflects the most likely continuation of current global trends.

We translate the climate signal into the modelling framework using monthly change factors for temperature and PET and monthly quantile scaling for rainfall, which better preserves thermodynamic changes in rainfall extremes. For all parameters, the median of the 10 scenarios in the SSP2 4.5 modelling ensemble is used to capture the central tendency, avoiding bias from outlier models. The median monthly temperature and PET change factors and monthly quantile change factors are applied to the daily paleo-stochastic climate series centred on 2035 (2020-2049) and 2050 (2035-2064) with respect to the historic baseline (1975-2005).

#### 2.4.3.1 Climate change-factored paleo-stochastic data for the southern connected basin

Ideally, for consistency, NARCliM 2.0 data would be used in reviews of the Murrumbidgee and Murray regulated river water sources. However, we are not in a position to do this in the short to medium term. Instead, our approach will be similar but not identical to that outlined above.

The Murrumbidgee and Murray models operate as water sources within the southern connected basin. Other water sources in that larger system include the Snowy Hydro Water system, which delivers water to the Murrumbidgee and Murray system, the Upper Murrumbidgee catchment, and the Victorian regulated and unregulated tributaries.

These models have been linked as part of the Murrumbidgee Regional Water Strategy project, which incorporates temporally consistent paleo-stochastic data and a dataset in which this paleo-stochastic data are factored by the driest NARCliM 1.0-modelled results.

Updating these model results would require renegotiating model access with other water agencies and conducting computationally intensive model updates within a resource-constrained modelling environment. Neither of these issues can be resolved in the time frame of this project.

We will compare the NARCliM 2.0 -factored paleo-stochastic climate projections with the existing paleo-stochastic and NARCliM 1.0-factored paleo-stochastic projections, which represent changes in 2070 (2060-2079) with respect to a 1990-2009 baseline. The result of this evaluation will inform our choice of which paleo-stochastic model inflow series, paleo-stochastic or NARCliM 1.0-factored paleo-stochastic)  best correspond to our intended model scenarios.

## 2.5 Chapter summary

This chapter presents an overview of the current AWD process, the available hydrological models and the climate datasets used in these models. Datasets and models that will be available to the department for this minimum inflow review include:

- valley-specific catchment and river system models that simulate water storage inflow and the water allocation and delivery process according to water sharing plans
- instrumental data from the 1890s to present, currently used to build and calibrate hydrological and river system models for basin plan compliance purposes and to estimate the minimum inflow sequences that directly determine storage reserves
- paleo-stochastic climate data spanning 10,000 years for climate stations in the instrumental dataset
- NARCliM 2.0-factored paleo-stochastic data under the 'middle-of-the-road' emissions scenario SSP2-4.5 for climate stations in the instrumental dataset for most regulated rivers
- NARCliM 1.0-factored paleo-stochastic data under the high emissions scenario SRES A2 for the Southern Basin.

This chapter also discussed some limitations of the models and methods used to evaluate the minimum inflow sequences used in the AWD process, including:

- the use of recent instrumental data as the only foundation for assumptions regarding minimum inflows and storage reserves
- the lack of information provided on the level of risk associated with the supply of high security water and essential supplies.

The availability of 10,000-year paleo-stochastic climate series data and series that factor for climate change provides an opportunity to investigate the limitations of the current storage reserve assumptions.

The following chapter describes how we intend to incorporate these datasets into the existing models and undertake the minimum inflow review by:

- demonstrating that the models reflect the current AWD process
- demonstrating that the AWD process in the models under 10,000-year paleo-stochastic inputs performs similarly to our current instrumental models
- modelling scenarios that test different AWD inflow and storage reserve assumptions and
- estimating the water supply risk associated with historic and potential future climates.

# 3 Review Method

The proposed review method has four components:

1. an AWD review that assesses model alignment with the AWD process and water sharing plan
2. quality assurance of stochastic simulations
3. storage reserve water balance and statistical analysis of reserve requirements under historic and plausible future climate variations
4. testing of model scenarios and storage reserve assumptions under historic and plausible future climate variations.

The first two components of this review method are designed to provide supporting 'fit for purpose' information on the data and models used for this study.

By reviewing how the models currently align with the AWD process, the mechanisms through which the models estimate storage reserves will be compared to current operational practices. Verification of this alignment will provide confidence that the modelled allocation process reflects current practice and highlight how the model can be adjusted for the scenarios.

The quality assurance component compares instrumental model outputs specifically associated with water allocation with those generated from stochastic model runs. This step is designed to demonstrate that the stochastic simulations are robust and representative and therefore appropriate for testing scenarios that fall outside of the historic flow sequences that limit our current models.

The AWD and quality assurance components support the third and fourth steps, which use storage water balance and river system model scenarios to estimate average return periods of drought stage declarations and changes to the water allocation system under different storage inflow assumptions and climate sequences.

## 3.1 AWD review

The AWD review is designed to investigate how well the model replicates the department's published AWD method. This AWD review will serve as an audit of both the allocation process and the model, ensuring that they both meet water sharing plan requirements and determining where changes are required to better align the two processes. The review will identify discrepancies and investigate their causes in a systematic way. This process is important in understanding the reliability and limitations of the modelling scenarios undertaken in the testing stage (section 3.3).

The AWD review will investigate the following elements in the AWD process:

- processes for the estimation of minimum inflows
- allowances for replenishment flows
- assumptions around release patterns of replenishment flows

- allowances for end-of-system flows
- allowances for losses due to evaporation, transmission and operations.

The review will follow the method undertaken recently for the Macquarie and Cudgegong regulated river water source (NSW DPE 2023a).

The AWD review method is summarised below:

- obtain AWD decision history and associated worksheets used to make decisions
- audit a subset of AWD worksheets, comparing worksheet formulas, comments and assumptions to determine:
  - consistency between worksheets
  - consistency with the appropriate water sharing plan
- obtain the most recent river system model for the valley under review and the associated build report
- identify how the AWD process is modelled and how well this corresponds with the AWD worksheets
- compare modelled and observed allocations to identify any variances
- investigate potential reasons for variances, such as how discretionary decisions are made, and consider whether this information could be included in the modelling method.

The outcome of the review will be a chapter in the valley report summarising the current AWD method, how the method is implemented in the model, the suitability or limitations of the model in replicating the current method and recommendations for any model amendments.

## 3.2 Quality assurance of stochastic simulations

Quality assurance was previously conducted on the stochastic data during its development by comparing the statistical distributions of key metrics of stochastic and instrumental climate and comparing the statistical properties of rainfall runoff modelled streamflow using stochastic and instrumental climate as inputs.

An additional stage of quality assurance has been designed specifically to assess the usage of stochastic climate data within the river system models (NSW DPE 2023b), both directly and in estimated inflows. This stage ensures that any potential biases in the climate data are known and can be factored into our assessment of the outcomes of this project.

The method for this additional stage involves comparing the results of model runs using instrumental data against those obtained from the 10,000-year paleo-stochastic model simulations. The same rainfall-runoff models and river system models are used for both sets of model runs, with only the climate and streamflow input sequences differing.

Four main areas describing the major water balance components have been chosen for the model output comparison:

1. storage inflows (24-month inflows and inflow exceedance and probability distribution), used to assess how the stochastic model inflows compare to the instrumental model inflows
2. storage behaviour (storage volume and exceedance of 5%, 10%, 20% and 50% full occurrence), used to assess how well the stochastic model represents critical storage thresholds compared to the instrumental model
3. extractions for high security, general security and supplementary water licences (exceedance curves, overall bias and skill score)
4. model mid-system and end-of-system flows, used to demonstrate similarities in simulated flow distribution.

The quality assurance process produces plots for visual inspection and data tables.

For each model comparison category, we will produce:

1. a skill score based on the similarity of probability distributions (Perkins et al. 2007)
2. an absolute bias figure (%) of the modelled element
3. a p-value reflecting the probability that the two model outputs are consistent
4. an exceedance plot showing the instrumental model data, the median of the stochastic modelled data and a 95% confidence interval associated with the stochastic data.

An example of selected output from the quality assurance process is provided in Table 1 and Figure 7.

Table 1. Example of stochastic modelled results for the annual diversion performance metric

| Statistic | Skill score | Absolute bias (%) | % capture | p-value |
|---|---|---|---|---|
| General security annual extractions | 0.85 | 5.2 | 95 | 0.71 |
| High security annual extractions | 0.88 | 1.9 | 100 | 0.97 |
| Supplementary annual extractions | 0.84 | 6.8 | 85 | 0.71 |

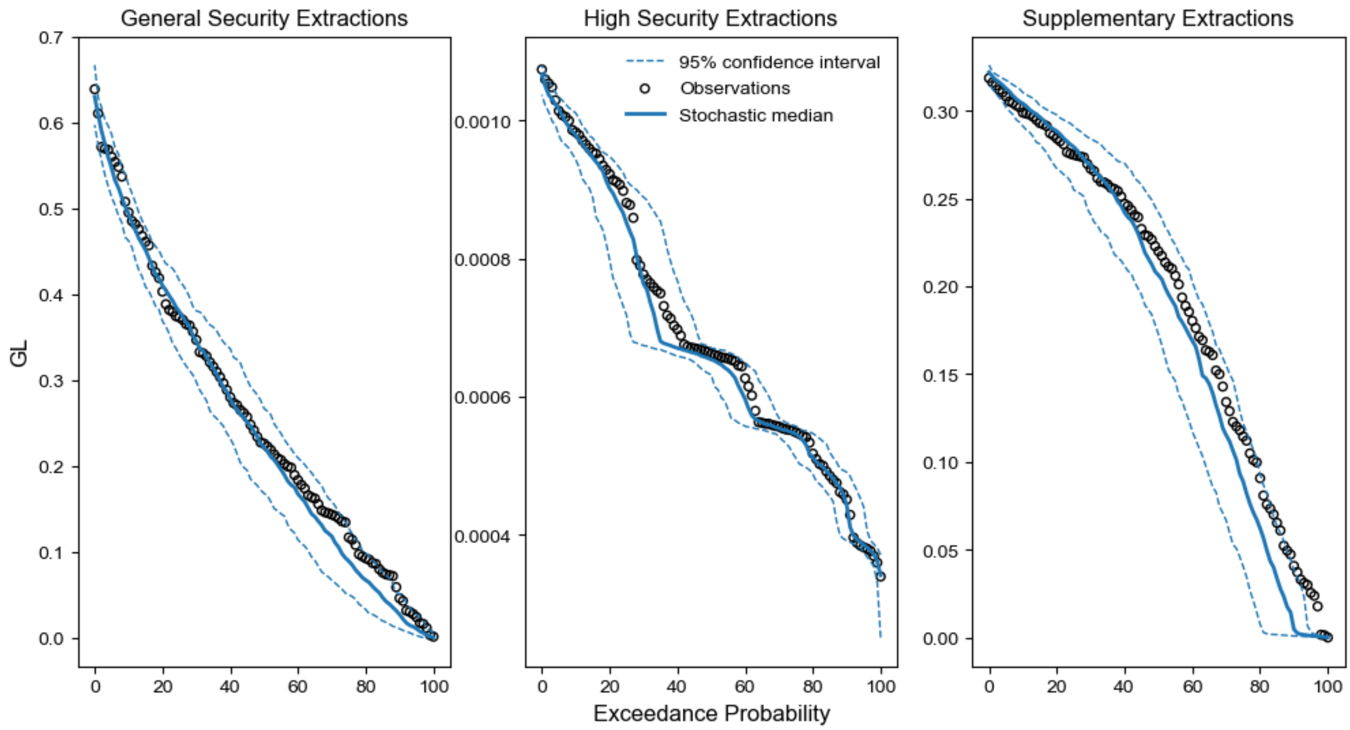


Figure 5. Modelled observed vs stochastic exceedance plots for high security, general security and supplementary access annual extractions

The outcome of the quality assurance step will be a series of graphs and data tables comparing the results of an instrumental model run with the results of a 10,000--year paleo-stochastic model run.

The data tables and plots will be inspected and the model given a fitness ranking to convey the overall confidence in using the 10,000-year paleo-stochastic model runs to assess water supply risks associated with the AWD process. The calculated model bias for the various metrics will most commonly be an overall bias estimate between the instrumental model output and the corresponding paleo-stochastic model output and not paleo-stochastic or instrumental model bias compared to observations. Valley specific model calibration reports detail the instrumental vs observational bias and are reviewed systematically when models are updated. Large relative bias between instrumental and paleo-stochastic model runs (> 10%) will be investigated further by interrogating model inputs and caveats placed on model metrics and results likely to be impacted by the bias. The Valley Lead modeller will be notified of bias issues so that they may be considered in routine model maintenance and upgrade schedules.

## 3.3 Storage reserve water balance

The storage reserve water balance has been determined in the past according to Equation 1.

$$\text{storage reserve} = \text{essential supplies} - \text{minimum inflows} \qquad \textit{Equation 1}$$

Where:

- essential supplies are high priority requirements plus operational water to deliver these requirements

- minimum inflows are the lowest accumulated inflows to the storage from the instrumental record during a planning horizon and held by the department prior to the first water sharing plan.

This water balance is limited by both the instrumental record length and the designated planning horizon. The application of equation 1 results in a maximum storage reserve for the designated planning horizon.

When applying Equation 1 to the paleo-stochastic inflow data, a wider range of inflows and drought sequences will be evident and therefore both the minimum inflow and planning horizon length could be significantly different from historical observations.

To facilitate the interpretation of the equation 1 water balance under paleo-stochastic inflow series length and range, two methods representing slightly different approaches to Equation 1 are applied. Firstly, the estimated storage reserve that matches a range of average recurrence intervals will be calculated and secondly, a time series monthly water balance will be applied to test storage reserve sizing

### 3.3.1 Storage reserve statistical analysis

For this analysis, paleo-stochastic and climate changed storage inflow time series will be analysed as follows:

1. Sum the daily inflow time series to monthly
2. Calculate the rolling sum of inflows for periods ranging from 6 months to 10 years
3. Find the minimum inflow for each of the periods in (2)
4. Rank and list all of the inflow sequences for each of the periods in (2)
5. For each inflow in a sequence period length, select the second lowest inflow volume and check whether it overlaps the first or any of the previous inflow sequences. Discard the sequence if it overlaps and of the previous sequences, or keep it if it is a new unique one and move to the next lowest inflow sequence.
6. The non-overlapping minimum inflow sequences are inspected to find the inflow volume associated with a predefined range of quantiles, for example the 10$^{th}$ lowest inflow represents the minimum inflow threshold that is exceeded 100 times in 10,000 years or on average the 1 in 100 year inflow threshold.
7. Using the output from (6) and a corresponding pro-rata essential supplies table, Equation 1 is applied to each quantile minimum inflow in each sequence length to obtain a table of storage reserve values for the each quantile and sequence length
8. The maximum storage reserve value found along each quantile row is then extracted to provide the final data relating the average return period (quantile values) to the storage reserve as shown in figure 6.

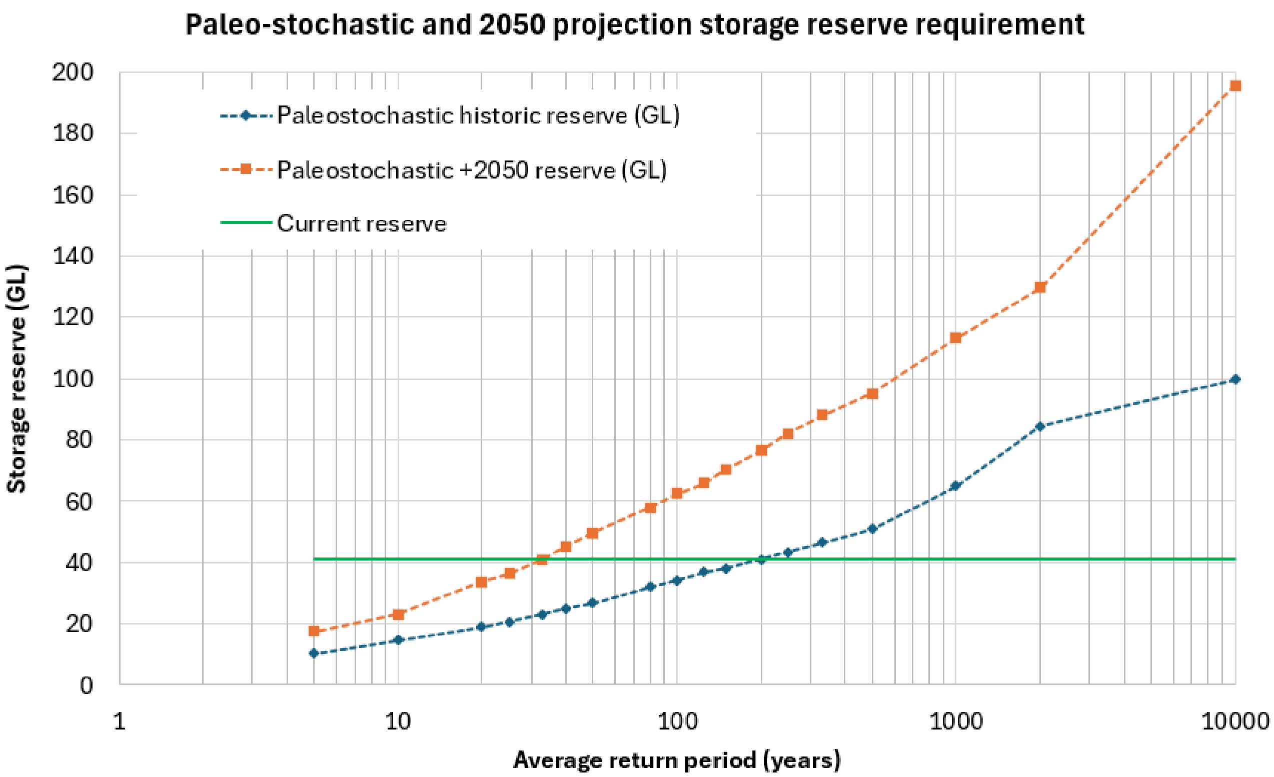


Figure 6 Paleo-stochastic and 2050 trajectory paleo-stochastic reserve requirements for a range of event frequencies (preliminary data – Border Rivers)

### 3.3.2 Storage reserve time series analysis

For this analysis, paleo-stochastic and climate changed storage inflow time series will be analysed as follows:

1. Sum the daily inflow time series to monthly
2. Construct a monthly time step water balance with inflows being the modelled paleo-stochastic inflows and outflows being the monthly pro-rata essential supplies.
3. If the inflows exceed the designated reserve storage volume in the time step, the inflows not required for the essential supplies are spilled from the storage reserve bucket to be used for allocation
4. During a low inflow sequence do not exceed the monthly essential supplies demands, the storage reserve is reduced until it either completely empties or recovers.
5. Each time the storage reserve is emptied completely, an empty event is counted by the water balance model and no additional empty events can be counted until the reserve is fully recovered and back to maximum.
6. The total number of empty events in the 10,000 year time series is then summed to obtain the estimated average emptying rate for a designed storage reserve under the current essential supplies assumptions
7. The time series analysis (2-6) is repeated in a loop for between 50 and 100 storage reserve sizes to obtain a relationship between storage reserve size and average empty frequency as shown in figure 7.

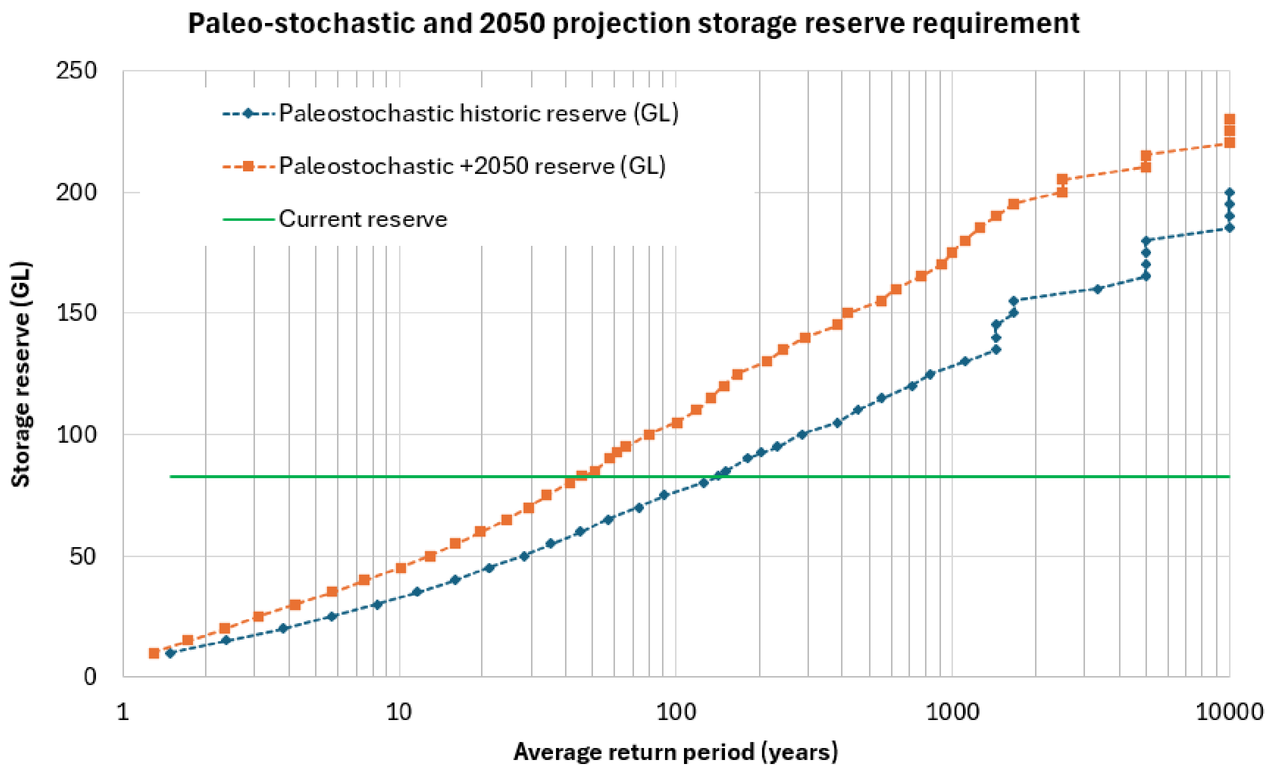


Figure 7 Paleo-stochastic and 2050 trajectory paleo-stochastic reserve requirements derived from a monthly water balance interpretation of Equation 1 (preliminary data – Gwydir)

### 3.3.3 Combining and interpreting the water balance results

Both methods above can be used to estimate the average return frequency that a storage reserve may be emptied under paleo-stochastic or climate change paleo-stochastic inflow conditions. The statistical analysis method may be less conservative but more consistent with how storage reserves were estimated in the past as it assumes the inflows occur evenly over the event duration. The time series analysis method may be more conservative as the storage empty condition may happen during or at the end of the dry period sequence. Both sets of results will be presented to decision makers.

## 3.4 Testing of model scenarios and storage reserve assumptions under historic and future climate variations

The model scenarios proposed for this investigation are sets of models with different hydroclimate inputs along with varying the parameters associated with the storage reserve.

Chapter 2 highlighted the limitations of assessing water supply reliability by using minimum inflow sequences in historic instrumental datasets to calculate storage reserves for high priority water users. This chapter highlights the direct relationship between the minimum inflow sequence and the storage reserve volume.

Our proposed scenario modelling method will systematically vary the storage reserve and evaluate the resulting changes to water supply.  Our method does not presume a particular supply reliability target and instead models the range.

Using this method and modelling multiple storage reserves for a single climate series, we will develop supply reliability response curves that reflect changes in storage reserve volume under that climate scenario. We will do this separately for all climate series. We anticipate that these response curves will be sufficiently robust to allow some interpolation between points, allowing us to evaluate potential impacts to water supply for a given return period storages falling below critical supply thresholds.

Building on the enhanced expression of natural variability contained in the paleo-stochastic climate data developed by the department, this method has been chosen to account for limitations and risks with adopting a single projected climate change scenario as a substitute for the instrumental climate:

- while we understand that the climate is generally projected to be hotter and drier which will mean lower flows, there is still a level of uncertainty to the extent of change. This makes it difficult to 'choose' a most appropriate projected climate change scenario and apply it to the current method given the validity of individual scenarios
- adopting a storage reserve based on the potential range of natural variability and projected climate change scenarios allows the department to be suitably conservative based on a risk-based scenario
- the storage reserve method appears to be more adaptable. As we get a better understanding of the future climate, adjusting the storage reserve volume based on risk is a simpler and more transparent option that can readily be amended as we better understand plausible future climate conditions.

We anticipate that our daily time step river system models will be sufficiently robust to model water storage behaviour using different storage reserve assumptions under normal water sharing plan operational conditions for all hydroclimate conditions. When very dry inflow sequences occur, these models will indicate when and how often water storages will drop below specific critical storage levels. In such cases, models will not allocate water to general security water accounts and will be operating to only supply the essential requirements.

At some point during very dry sequences, water storages will drop to a point where water sharing plans may be suspended. This typically occurs before a storage reserve is depleted to the extent these critical requirements cannot be met. In such cases where water sharing plan suspension is likely, model assumptions surrounding the provision of essential supplies may no longer be robust. This is because river system models have been built and calibrated to represent water sharing plan conditions and not necessarily extreme cases where water sharing plans are suspended. In such cases, we anticipate that the models can still be used to indicate the likelihood of entering an essential supplies only phase, but not necessarily the storage behaviour whilst in this phase.

To provide some indication of storage behaviour whilst in an essential supplies phase, the methods in Section 3.3 will be applied This approach is likely to give a better understanding of storage behaviour during the essential supplies phase of drought sequences, whereas the daily time step models will give a better understanding of the overall water supply impacts during normal operations from changes to the storage reserve.

### 3.4.1 Baseline climate series used for scenario modelling

The anticipated model scenarios will be built using data that are currently available (see review in Chapter 2), namely the instrumental historic series and the 10,000-year paleo-stochastic climate dataset. These two datasets will be used for baseline series modelling representing a historical position from which we measure change. Three model output series will be produced using these datasets:

- Series 1: Instrumental data up to the cutoff date specified in the water sharing plan
- Series 2: Instrumental data covering more recent drought sequences (up to 2020)
- Series 3: Historic climate data - the paleo-stochastic 10,000--year sequence

### 3.4.2 Climate change series used for scenario modelling

For current and near future climate representation, two additional series will be created by scaling the 10,000-year paleo-stochastic climate series as follows:

- Series 4 – Current Climate Scenario: a paleo-stochastic 10,000-year sequence with monthly scaling of PET and monthly quantile scaling of rainfall reflecting 2035 conditions under the NARCliM 2.0 SSP2-4.5 model ensemble median. This sequence is designed to represent a plausible near future climate in the next 10 years, given that water sharing plans have a 10-year planning cycle. Changes to potential evapotranspiration are driven primarily by increased temperatures and are predicted to be significant enough to be represented in the near future modelling series. Projected changes in rainfall (including, in some cases, the direction of change) are less certain and therefore have a smaller contribution to projected changes. As the Series 4 simulations are designed to represent the 2035 water sharing plan period, this series will be interpreted as the basecase water sharing plan purposes.
- Series 5 – Future Climate Scenario: a paleo-stochastic 10,000-year sequence with monthly scaling of PET and monthly quantile scaling of rainfall reflecting 2050 conditions under the NARCliM 2.0 SSP2-4.5 model ensemble median. The year 2050 was selected because it provides the most likely trajectory for continued climate change beyond the Water Sharing Plan term, noting that further in the future uncertainty increases. The data in series 5 would equate to a global temperature increase of 2.0 °C over pre-industrial levels by 2050.[3] The series 5 model runs are intended to inform the longer-term adaptive pathways.

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[3] For more information, see the NARCliM website: www.climatechange.environment.nsw.gov.au/projections-map.

The proposed model series are summarised in Table 2.

Table 2. Proposed model series. Note: Data for the Southern Basin is scaled using NARCliM 1.0.

| Dataset no. | Description | Rationale |
|---|---|---|
| 1 | Observed data 1895–2004 | **Historic reference**. Existing water sharing plan specifications. |
| 2 | Observed data 1895–2020 | **Reference data updated to 2020.** Incorporates recent droughts in most plan areas. |
| 3 | Historic Climate Scenario<br>10,000-year paleo-stochastic data used in the quality assurance step | **The baseline data model series**. Best estimate of historic supply reliability risk for storage reserve size. The point from which we measure change. |
| 4 | Current Climate Scenario<br>10,000-year paleo-stochastic data factored with SSP2-4.5 2035 rainfall and PET changes under NARCliM 2.0 | **The basecase current climate model series.** Best estimate of risk from variability and change covering the current water sharing plan review period. The series we use for the updated water sharing plan |
| 5 | Future Climate Scenario<br>10,000-year paleo-stochastic data factored with SSP2-4.5 2050 rainfall and PET changes under NARCliM 2.0 | **The climate change trajectory series**. An indication how far storage reserves may need to be pushed to maintain supply reliability in subsequent Water Sharing Plans. This is the series we use to inform future planning constraints. |

### 3.4.3 Model scenarios

The proposed model scenarios for each climate series are intended for the development of supply reliability response curves to changes in storage reserve volume.

Under each of the 5 climate input series, we propose to model at least 5 storage reserve settings, from which other potential storage reserve volumes can be inferred via interpolation:

- S0, the current storage reserve with the current minimum inflow sequence
- S1, the current reserve increased by 25% of the current minimum inflow sequence
- S2, the current reserve increased by 50% of the current minimum inflow sequence
- S3, the current reserve increased by 75% of the current minimum inflow sequence
- S4, the current reserve increased by 100% of the current minimum inflow sequence.

The key outputs from the model scenarios and the associated data analysis methods are presented in section 3.4. However, one of the key outputs from this scenario modelling method is the relationship between supply changes for the various licenced water user categories resulting from storage reserve changes and/or climate change

In designing this study to produce these outputs, we suggest that in future water sharing plans, supply reliability should define storage reserve requirements, rather than historic storage reserves defining future supply reliability. If an expected supply reliability is prescribed, the storage reserve requirement can become adaptable to climate change. The model scenarios outlined above can then be used to provide an indication of the potential impacts associated with changes to the storage reserve.

## 3.5 Data analysis

The analysis of model scenario results will systematically cover three main areas of model data interrogation:

- hydrologic metrics
- environmental metrics
- economic metrics.

This section only covers hydrologic metrics. Separate methodology documents will be produced to describe the environmental and economic analysis. The outcomes of the environmental and economic analyses are likely to be important in arriving at an appropriate storage reserve.

Table 3 outlines the standard hydrological metrics expected to be generated for each valley. Any additional valley-specific metrics identified will be outlined in forthcoming reports on the outcomes of the review in each valley. The analysis metrics include allocations to each licence category, diversions, storage behaviour and flow.

Table 3. Summary of hydrologic metrics

| Category | Component | Rationale |
|---|---|---|
| **Mean annual diversions** | • General security<br>• High security<br>• Domestic and stock*<br>• Local water utilities<br>• Supplementary<br>• Planned environmental water (PEW)<br>• Inter-valley transfer (where relevant) | Determine the impact of model scenarios on diversions |
| **Average Allocations** | • General security average allocations and account balances on 1 July, 30 | • Understand the impact of model scenario on allocations, and carryover |

| | | |
|---|---|---|
| | September and 30 June and average over whole period<br>• High security average allocation on 1 July, 30 September and 30 June<br>• Conveyance average allocations and account balances on 1 July, 30 Sept and 30 June and average over whole period<br>• Local water utility, major utility and domestic stock average allocations on 1 July, 31 December and 30 June<br>• Account-based average PEW effective allocations on 1 July, 30 September and 30 June<br>• Occurrence of no allocations for each licence type | where applicable, for different water users.<br>• The Basin Plan requires protection of the effectiveness of PEW.<br>• Improve understanding of how often allocations are zero |
| **Storage behaviour** | • Frequency and volume of spills<br>• Average yearly volume of spills<br>• Percentage of time below nominated thresholds | • Climate change is predicted to bring more extremes, which may mean more extreme floods, and holding a higher storage reserve may result in more spills and loss of productivity. These metrics assist us in understanding the impact that the volume held in the storage reserve will have on spills.<br>• This metric shows how often a dam will fall below certain thresholds in future climate scenarios, providing more understanding of when the Extreme Events Policy may be triggered or when security may be reduced for high priority licences. |
| **Mean annual streamflow** | At targeted gauges | Determine changes to hydrology and flow patterns, particularly cease to flow periods for towns and key basic landholder rights reaches. The |

| | | |
|---|---|---|
| | | environmental and economic impact assessments will determine impacts based on modelled changes to streamflow data. |
| **Transparent and translucent flows** | • Average volume released<br>• Percentage of time flows are activated | Understand how future climate scenarios may trigger transparent and translucent flows and the subsequent environmental impacts of these flows. |
| **End-of-system flow releases** | Number of days the minimum flow rule was met | Understand the impact of storage reserve volumes on meeting end-of-system flow targets |
| **Replenishment flow releases** | • Percentage of years fully delivered<br>• Average volume released | Understand the impact of holding different storage reserve volumes on replenishment flow delivery. There is significant operator discretion in how replenishment flows are delivered, and they can be met by tributary inflows, so they may be triggered differently in models compared to how they are used in river systems. |
| **Level of security** | Level of security for high priority needs | Understand how the supply reliability changes for high priority users under different storage reserve and climate scenarios |
| **Supplementary events** | Number and duration of supplementary events | To understand the impact of model scenarios on supplementary events |

* The stock and domestic rights usage in the river system is included in the water sharing plans. However, as we do not have usage data, and the relevant volumes are comparatively small compared with other water balance components, this usage is generally treated as an unaccounted difference in the operational and planning models. We are providing an indicator based on flow along a river they can access.

## 3.6 Reporting framework

The proposed reporting framework for the review method has two components:

1. a methods report, which will document the model input data, models and data processing methods and provide an overview of the entire project and details of the modelling methodologies in valley-specific reports

2. a series of valley-specific reports containing the results of the AWD review, the quality assurance analysis and the results of the storage reserve scenario modelling.

## 3.7 Adaptive management and review

The minimum inflows and storage reserve assessment methodology presented in this document forms part of an adaptive management framework. The modelled flows underpinning the reserve volume assessments are not forecasts, but estimates of the volume of water required under a changing climate to meet essential supplies at an agreed level of risk. As new climate projections become available, river operational requirements relating to essential supplies are updated and river system models are continuously improved, reserve estimates are likely to require adaptation. The primary mechanism for this adaptation is the water sharing plan update and amendment cycle. The water sharing plan amendment cycle will therefore include new information on reserve estimates reflecting the next water sharing plan period and trajectory reserve estimates based on the most up to date climate projections, models and essential supplies requirements. The climate projections for the new basecase and trajectory scenarios will adapt to the planning period anticipated for the updated water sharing plan.

Within the water sharing plan amendment cycle, several updates to NARCliM projections are anticipated. At this time, trajectory (2050) reserve risk assessments may be updated however refinements to the in-place (2035) water sharing plan reserve will remain until the next water sharing plan update to provide certainty to all water users.

Severe drought resulting in plan suspension during the period of a water sharing plan may also trigger a review of the climate projections and associated risk profile of the current reserve settings. However, as the reserve methodology presented in this report is based on reserve selection reflecting an agreed level of risk, water sharing plan suspension alone will not be a trigger to revisit the reserve settings.

# 4 References

### Published

Alluvium (2020). Review of NSW Border Rivers Model Build, Scenarios and Environmental Outcomes reports relevant to Floodplain Harvesting Policy implementation. Letter to NSW DPIE Healthy Floodplains Projects Delivery 9 November 2020.

Bewsher (2021). Independent review of water resource plan models for the NSW Border Rivers. Murray Darling Basin Authority.

Devanand, A., Leonard, M., and S. Westra (2020a). Assessment of non-stationarity in the northern basin. NSW Department of Climate Change Energy, the Environment and Water. PUB24/328.

Devanand, A., Leonard, M., and S. Westra (2020b). Assessment of non-stationarity for stochastic time series generation in the southern basin. NSW Department of Climate Change Energy, the Environment and Water. PUB24/330

Fifteen50 (2022). Murray-Darling Basin Authority – Independent Review of proposed NSW baseline diversion limits for floodplain harvesting: Border Rivers and Gwydir SDL resource units. Murray Darling Basin Authority.

Leonard, M., Westra, S., and B. Bennett (2019). Multisite rainfall and evaporation data generation for the Macquarie Valley. NSW Department of Climate Change, Energy the Environment and Water. PUB24/326.

Leonard, M., Nguyen, D.C.H, and S. Westra (2020). Evaluation report for multisite rainfall, evapotranspiration and temperature data generation of the southern region. NSW Department of Climate Change, Energy the Environment and Water. PUB24/329.

NSW DCCEEW (2023a). Guidelines to select scenario models for assessing compliance to long-term average annual extraction limits. NSW Department of Climate Change, Energy, the Environment and Water | PUB23/1342.

NSW DCCEEW (2023b). LTAAEL Compliance assessment for NSW Border Rivers Regulated River Water Source. NSW Department of Climate Change, Energy, the Environment and Water | PUB23/1069.

NSW DPE (2020a). Water Allocation Methodology. NSW Border Rivers Regulated River Water Source. Department of Planning and Environment | PUB20/389.

NSW DPE (2020b). Water Allocation Methodology. Murrumbidgee Regulated River Water Source. NSW Department of Planning and Environment | PUB20/832

NSW DPE (2023a). Extreme Events Policy. Policy framework for the management of NSW water resources during extreme events. NSW Department of Planning & Environment | INT22/155102.

NSW DPE (2023b). Climate datasets for assessing climate risk in regional water strategies. NSW Department of Planning and Environment | PUB23/429.

NSW DPIE (2020a). Building the river system model for the Border Rivers Valley regulated river system. NSW Department of Planning, Industry and Environment | PUB20/885.

NSW DPIE (2020b). Floodplain harvesting entitlements for the NSW Border Rivers regulated river system. NSW Department of Planning, Industry and Environment | PUB20/884.

NSW DPIE (2021a). Compliance with water management principles -Water Sharing Plan for the Border Rivers Regulated River Water Source 2020. NSW Department of Planning, Industry and Environment | PUB21/79

NSW DPIE (2021b). Extraction limits. How the extraction limits work and differences. NSW Department of Planning, Industry and Environment | PUB21/470.

NSW DPIE (2021c). NSW Water Strategy. NSW Department of Planning, Industry and Environment | PUB20/882.

## Unpublished

NSW DPE (2021a). Workshop 1 – 25-10-2021 – Modelling principles and objectives. Namoi Source Model – Stakeholder engagement -Powerpoint presentation (unpublished).

NSW DPE (2021b). Workshop 2 – 02-11-2021 – Flows for the Namoi Source model Namoi Source Model – Stakeholder engagement -Powerpoint presentation (unpublished).

NSW DPE (2022a). Workshop 3 – 31-05-2022 – Demands in the Namoi Source model. Namoi Source Model – Stakeholder engagement -Powerpoint presentation (unpublished).

NSW DPE (2022b). Workshop 4 – 07-11-2022 – Evaluation and reference scenarios. Namoi Source Model – Stakeholder engagement -Powerpoint presentation (unpublished).

NSW DPE (2023a). Review of Macquarie allocations to inform modelling (Unpublished).

NSW DPE (2023b). Validating climate risk data for use in Border Rivers water sharing (unpublished).

# 5 Revision History

| Version number | Date published | Changes |
|---|---|---|
| 1.0 | September 2024 | Original document |
| 2.0 | September 2025 | -Updates to include updated information on climate data scenarios and data analysis methods, and method for the storage reserve water balance.<br>-Improved information in response to OCSE recommendations. |
| | | |

# Appendix 1

Provision within the Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2021 requiring review of the 'Maintenance of water supply' clause.

*57 Maintenance of water supply*

*(1) In this clause, the period of lowest accumulated inflows to the water source is identified by flow information held by the Department prior to 1 July 2009.*

*(2) The operator must operate the water supply system in such a way that water would be able to be supplied during a repeat of the period of lowest accumulated inflows to the water source, to meet the following:*

*(a) the annual water requirements of persons exercising domestic and stock rights and native title rights,*

*(b) available water determinations of 100% of share components for domestic and stock access licences and local water utility access licences,*

*(c) available water determinations of 1 ML per unit share for regulated river (high security) access licences.*

*(3) For the purpose of subclause (2), the operator must set aside sufficient volumes of water from inflows into the water source and in reserves held in Pindari Dam and Glenlyon Dam water storages.*

**Note.** Reserves is defined in the Dictionary.

*(4) During the first 5 years of this plan, the Minister will undertake a review of this clause that considers the following:*

*(a) options for redefining the period of lowest accumulated inflows to the water source,*

*(b) whether different periods should apply to different categories of access licences,*

*(c) the impact of any options for change on planned environmental water and each category of access licence, and*

*(d) the views of stakeholders and the broader community.*

*(5) On the basis of the review referred to in subclause (4), the Minister may make such amendments to this clause as are reasonably necessary to not jeopardise the critical needs of basic landholder rights, domestic and stock access licence holders and local water utility access licence holders.*

*(6) Any amendments made under subclause (5) cannot substantially alter the long-term*

*average annual amount of water able to be extracted under water access licences.*

Notes.

1 If satisfied that it is in the public interest to do so, the Minister may amend this clause under s.45 (1) (a) of the Act to such an extent that it substantially alters the long-term average annual amount of water able to be extracted under water access licences. If this Page 46 Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2021 occurs, compensation may be payable under chapter 3 Part 2 Division 9 of the Act.

2 Section 10.28 of the Basin Plan requires that a water resource plan must ensure there is no net reduction in the protection of planned environmental water from the protection provided under State water management law immediately before the commencement of the Basin Plan