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MURRAY–DARLING BASIN AUTHORITY

Constraints Under a Future Climate

Stress Test of Sustainable Diversion Limit Adjustment Mechanism Constraints Projects Under Climate Change

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin
The Murray−Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations, the Northern Basin Aboriginal Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated.

Aboriginal people should be aware that this publication may contain images, names or quotations of deceased persons.

Contents

Executive Summary

Key messages

- Opportunities to piggy-back on top of unregulated flows and environmental water availability are expected to reduce under a future climate. However, while reduced in frequency, piggy-back opportunities will still occur and there will be enough environmental water available to use them
- Under a future climate, flow constraints will continue to limit the environmental outcomes achievable by water managers
- A future climate (2060) will be distinct from the long-term historical record, but average projections are not dissimilar to conditions experienced since 1997
- In the near future (2030) natural variability is projected to predominate over trends due to greenhouse gas emissions (CSIRO & BOM,2020).
- More sophisticated analysis of existing data will not produce more precise information given the large range in projections and is highly unlikely to change the overarching messages presented.

Background

As part of the SDLAM, Basin states proposed 36 supply measures that could allow additional water to remain available for consumptive use while still achieving Basin Plan desired environmental outcomes. This package included measures to relax constraints on the delivery of water for the environment.

Constraint relaxation is an important component of Basin Plan implementation. It allows for increased inundation of environmentally important wetlands and floodplains through improved use of water that has been recovered for the environment.

The delivery of these measures requires changes to river management arrangements in partnership with investment in infrastructure such as roads, bridges, and levees. Investment in this type of infrastructure requires a consideration of their long-term utility, especially in light of changes in water availability and river flows that are anticipated to result from climate change.

The analysis presented here has been designed to produce results within the required timeframe but to also inform and contribute to more rigorous investigations of the implications of changing climate on constraints projects in the future.

Analysis Development

There are two key elements to be investigated to elucidate the impact of a changing climate on delivering flows relevant to constraints relaxation:

- Changes in opportunities to 'piggy-back' on other flows
- Changes in held environmental water availability.

The Guidelines for Assessing the Impact of Climate Change on Water Availability (DEWLP 2020) provide a methodology for assessing changes in water availability by adjusting inflows. However, it is unknown if this method was suitable to assess the projected impact of climate change on high flow events (piggy-back opportunities) as these events could conceivably be impacted by both the projected overall reduction in rainfall and the projected increase in high intensity rainfall events.

As such, rainfall-runoff models were required to be driven by inputs that represent climate change projections. There are numerous products and techniques available to do this, and the combination of products and techniques used will influence the outcome. The full suite of products and methods available were therefore utilised.

Undertaking this approach across multiple catchments is a very time-consuming process so a ‘proxy’ analysis was required. Ovens River flows were selected as the proxy as this unregulated tributary typically represents the primary source of unregulated flow events that environmental water can add to. To represent the combination of analytical approaches being undertaken the analysis was split into a review of existing information and two analytical elements.

Review of Existing Literature & Model Data

This theme comprised of a review of recently published literature to understand the current state of climate projections related to constraints relaxation projects and a review of previous modelling to understand what constitutes a piggy-back opportunity i.e., what type of flows are a trigger for operating above existing flow constraints.

Element 1 – Piggy-back Opportunities Analysis

Multiple Global Climate Models (GCM) and Regional Climate Models (RCM) and scaling techniques were used to generate future climate flow time series for the Ovens River. These time series together with the information garnered under the review of existing data can then be used to elucidate the projected changes in the frequency of flows relevant to constraints projects. i.e., what is the frequency of piggy-back opportunities currently and how is this projected to change?

Element 2 – Environmental Water Availability Analysis

The Source Murray Model (SMM) was used to develop the analysis with inflows to the Murray and Lower Darling systems developed using the Guidelines for Assessing the Impact of Climate Change on Water Availability (DEWLP 2020). This approach involved the development of 8 model scenarios including post-1975 and post-1997 historic reference periods and low, medium, and high climate change projection scenarios centred at 2045 and 2070. This information was then used to infer if enough environmental water will likely be available to take piggy-back opportunities when they present.

Review Findings

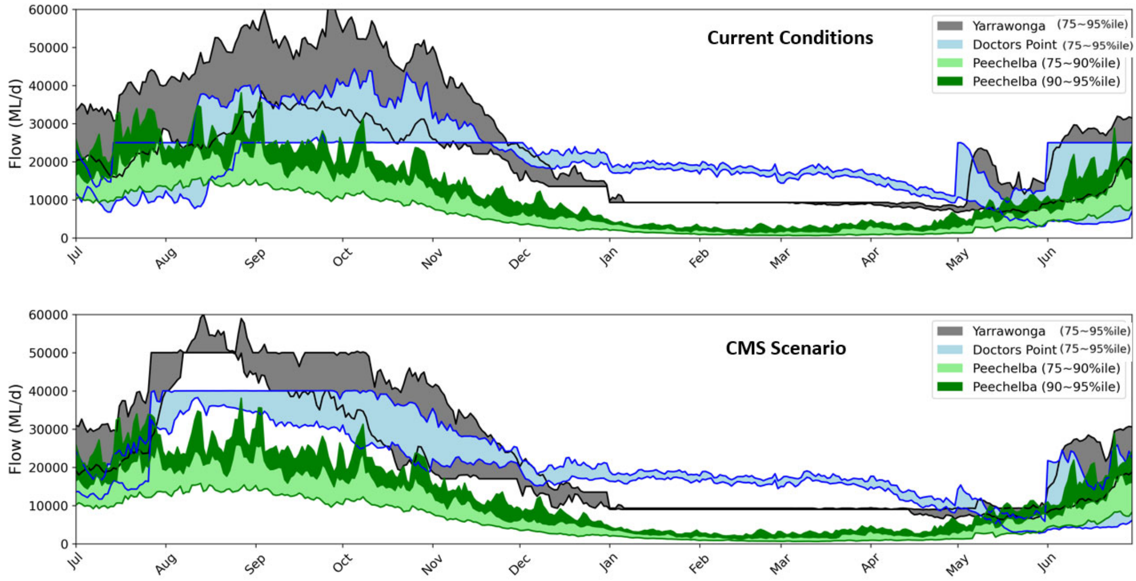

Figure 1: High flow frequency analysis for current conditions and constraints relaxed (CMS) scenarios

The analysis displayed in Figure 1 shows the relationship between high flows (75–95%ile) at Peechelba on the Ovens River and Doctors point and Yarrawonga Weir on the Murray River.

The analysis shows that flow events of 10,000 ML/d and above during winter or spring at Peechelba constitute events that provide an opportunity for enhancement with water for the environment. The higher the flow at Peechelba, the less held environmental water that will be required.

Element 1 Findings

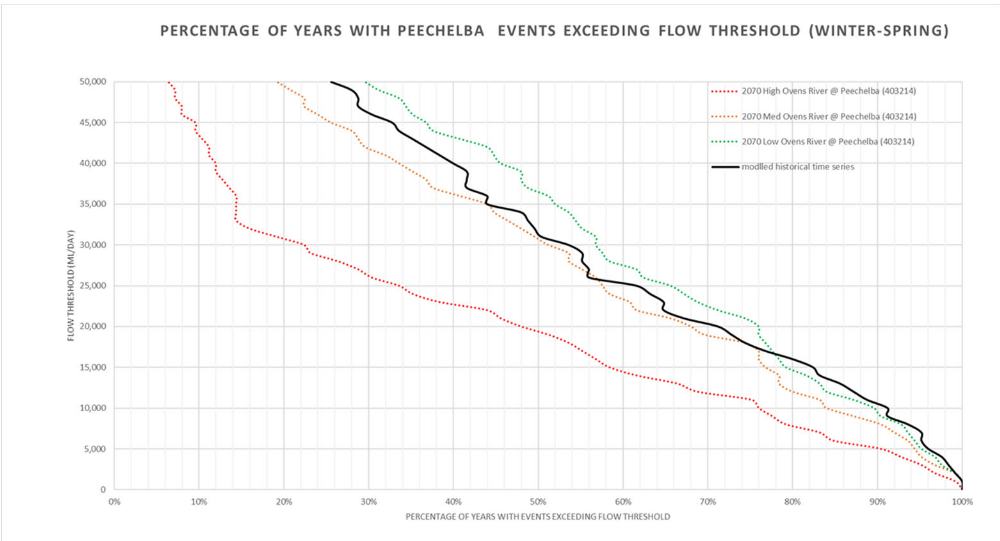

Figure 2: Projected changes in frequency of high flow events at Peechelba

Piggy-back opportunities are projected to reduce while remaining relatively frequent. However, it should be noted the range in projections is large. A majority of, but not all, projections investigated fall within the range identified in Figure 2. Under the 2070 medium projection, there will still be opportunities for environmental watering under relaxed constraints. Under a 2070 dry climate the frequency of opportunities will be further reduced, but it is likely that the relative importance of each opportunity will be greater due to the prevailing extreme climate impacts on the floodplains and wetlands of the southern Basin. Furthermore, there will be a plethora of significant challenges to managing water resources, meaning many of the assumptions inherent in the model scenarios will not hold.

Element 2 Findings

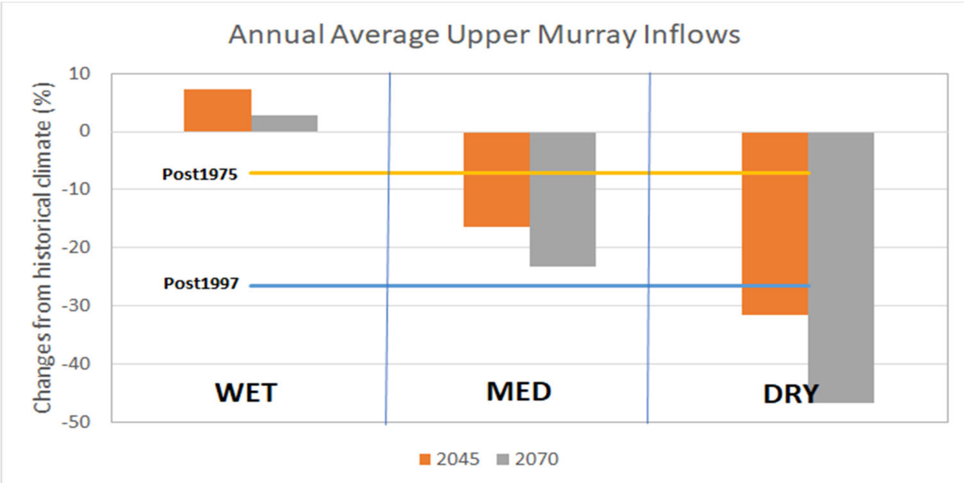

Figure 3: Projected Upper Murray Inflows compared to a historic climate

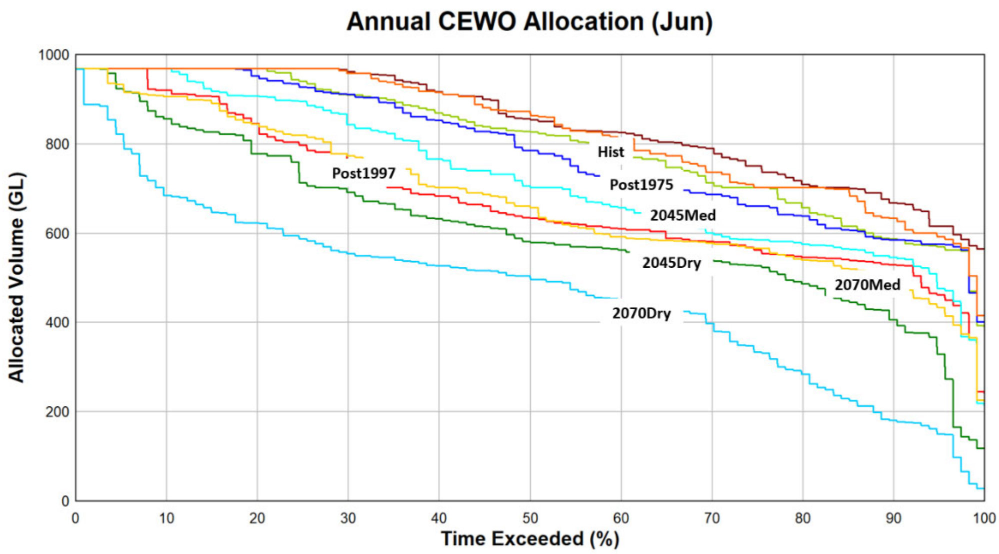

Figure 4: Storage volume exceedance curves

Environmental water availability is projected to reduce in comparison to the modelled long-term historic average but there will still be environmental water available to take piggy-back opportunities when they present. Medium projections are similar to post 1997 conditions.

Next Steps

While the analysis was able to confirm a projected direction of change for the two elements investigated, the scale of change is uncertain. Further work to represent the impact of a changing climate more robustly in the SMM is underway and will offer additional insights, particularly by representing constraints projects operating in unison across the Southern Connected Basin.

- Further analysis will not provide more precise information given the range in the projections
- Several assumptions and quick fixes have been included in this modelling and may not be suitable for other applications and interpretations beyond its development intent.
- Instead of a rapid analysis approach, focus should be on developing more technically robust solutions aligned with long-term goals
- The MDBA will continue working towards developing a robust Basin-wide approach for assessing the implications of climate change through its Climate Adaptation Program, working together with the Murray–Darling Water and Environment Research Program.

Introduction

The Basin Plan includes a mechanism to adjust sustainable diversion limits in the southern Basin – sustainable diversions limit adjustment mechanism (SDLAM). The mechanism requires a suite of projects to be implemented – some projects involve the relaxation of flow constraints. A 'constraint' is a technical term for anything that reduces the ability to deliver water to meet downstream demands. Constraints projects aim to overcome some of the operational barriers that impact delivering water for environment in the system and can include changes to physical features such as crossings and bridges. They can also change river operating practices and rules. They allow water managers more flexibility in releasing and moving water through the system. Sound scientific knowledge is needed to underpin implementation of these projects.

These SDLAM constraints projects are currently being assessed by the Murray–Darling Basin Authority (MDBA), together with the Basin States, to see how they fare under a future climate. This requires knowledge and analysis on environmental flow opportunities under relaxed constraints and how this could change under a future climate.

Future climate change projections, modelling of climate change impacts on catchment runoff and streamflow, and subsequent river system modelling incorporating the management and infrastructure options were needed to undertake this assessment.

The "Constraints under a future climate" project has been designed to be able to produce results within the required short timeframe, but to also inform and contribute to more rigorous investigations of the implications of changing climate on constraints projects in the future.

There were two main elements to consider:

- Piggy-back opportunities – taking advantage of unregulated flow events
- Held environmental water availability.

Prior to commencing any analysis, a review of existing model data and literature was undertaken as the initial component of the project.

Methods

Review of existing literature and data

A review of recent existing information was used to inform and guide the development of the following analysis elements. The literature reviewed comprised:

- BOM (2020) Short-duration, heavy rainfall is intensifying, but not everywhere, and not all the time – A literature review
- CSIRO & BOM (2020) State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/
- DELWP (2020). Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria. Final, November 2020, Department of Environment, Land, Water and Planning, Victoria
- Wasko C and Nathan R (2019) Influence of changes in rainfall and soil moisture on trends in flooding. Journal of Hydrology 575 (2019) 432-441
- Zhang, L, Zheng, HX, Teng, J, Chiew, FHS, and Post DA (2020). Plausible Hydroclimate Futures for the Murray–Darling Basin. A report for the Murray–Darling Basin Authority, CSIRO, Australia. 34pp.

An analysis of existing modelling was used to interrogate what type of flows constitute a trigger for the operation of constraints projects. This analysis was confined to the model scenarios detailed in Table 1.

Table 1: Model scenarios reviewed

Source Murray Model (SMM) Scenario	Description
Without Development	SMM run over the historic climate sequence without the operation of any water management infrastructure or extractions.
Current Conditions	SMM run over the historic climate sequence with development at current levels with the operation of current constraints. Commonwealth Environmental Water Holder (CEWH) water is delivered up to 15,000 ML/d.
CMS	SMM run over the historic climate sequence with constraints projects implemented as specified in their business cases. Environmental demands are delivered to meet NSW Long Term Watering Plan targets downstream of Yarrawonga.

It is not known how to directly scale inflows to represent the projected impact of climate change on high flow events relevant to the relaxation of flow delivery constraints. As such, projected inflows need to be acquired from hydrologic models driven by rainfall inputs that represent climate change projections. Undertaking this approach across multiple catchments is a very time-consuming process so a 'proxy' analysis was required.

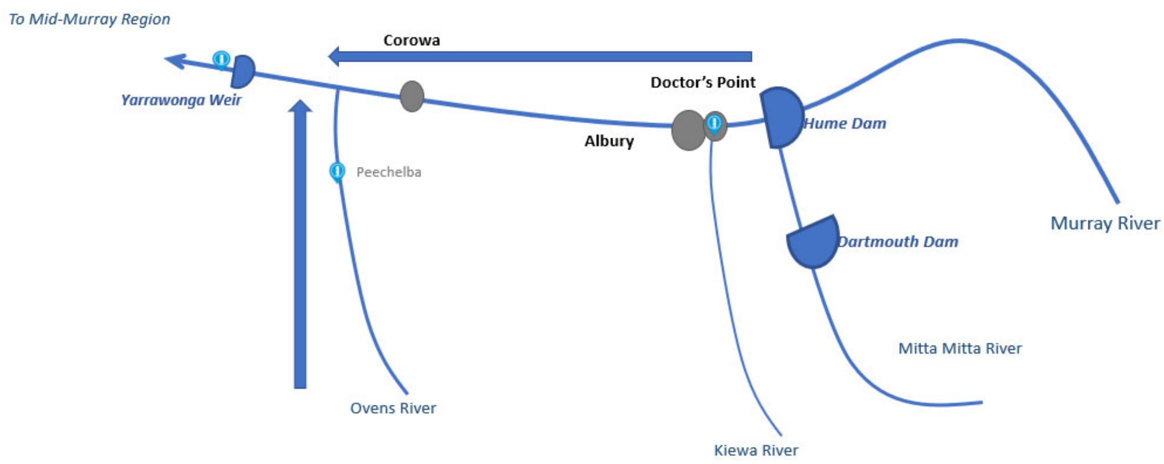

Figure 5: Stylised diagram of location investigated

Given the time available, downstream of Yarrawonga weir was designated to the be the most appropriate location for this analysis because two main constraint levels in the Murray system can be assessed and heavily influenced by nearby unregulated systems (Kiewa and Ovens). A robust representation of flows from the unregulated systems is important and hence multiple approaches were tested. Inflows to regulating structures are not likely impacted by different scaling methods, therefore an inflow scaling approach was the only method used to assess water availability.

This is the only site where analysis was undertaken, the site can be considered as a proxy for climate change impacts on other constraints projects. However, this indirect analysis means factors such as the interaction between different constraints relaxation reaches were not considered.

There are two elements to be investigated to elucidate the impact of a changing climate on delivering flows relevant to constraints relaxation downstream of Yarrawonga weir:

- Changes in opportunities to piggy-back on unregulated flows from the Ovens River
- Changes in held environmental water availability.

These two elements are represented by the two arrows in Figure 5.

Sensitivity Analysis of Ovens Flows – Piggy-back Opportunities Element

Unregulated flows from the Oven's catchment constitute a trigger for environmental water holders to piggy-back environmental water releases on existing flows to operate above current constraint levels.

Projecting climate change impacts is a complex task. Large-scale, long-term indicators (such as temperature) can be tracked against a future emissions pathway with a good degree of confidence. However, there is a higher degree of uncertainty tied to other climate factors, such as rainfall, runoff, and river inflows. It is expected that climate change will have an impact on the size, timing, and frequency of these flows, but there are many different approaches that can be used to better understand these impacts, and each can provide differing pictures of the future. As such a variety of methods were investigated to test the sensitivity of these flows to a changing climate and explore a range of plausible futures.

CSIRO was contracted to produce the data required to inform this element, as outlined in Table 2. The investigation focused only on the potential climate change impact on catchment runoff (or streamflow); specifically, the different methods for developing future climate series and subsequent modelling of catchment runoff. These include:

- Scaling the historical daily rainfall time series by the change signal (at the annual, seasonal, and/or daily level) in the global climate models (GCMs) or dynamic downscaling models (also referred to as regional climate model, RCMs)
- Bias correcting the future daily rainfall time series from the RCMs (i.e., mapping/relating the RCM and observed historical daily rainfall distribution, and then using this relationship to convert the raw future RCM daily rainfall series to catchment future daily rainfall series).

These future climate time series were then used as inputs into rainfall-runoff models, and the results analysed to interpret the implications of the methods, including on the high (overbank) flows important for floodplain inundation. Many catchments were investigated so insights could be gained into the consistency (or inconsistency) of the projected changes to headwater catchment flows.

Table 2: Task specification provided to CSIRO

Task	Specifications
1. Calibrate/parameterise rainfall-runoff models across the Murray–Darling Basin	1 and 2 are highest priority, 3-5 are lower priority 1. Ovens flow at Peechelba East a. AWRC No: 403241 b. Lat/Long: -36.163/146.235 c. Catchment area: 6239 km2 2. Kiewa flow at Bandiana a. AWRC No: 402205 b. Lat/Long: -36.138/146.95 c. Catchment area: 1655 km2 3. Indigo Creek flow at D/S Creamery Bridge a. AWRC No: 403248

Task	Specifications
	4. Mitta Mitta flow at Hinnomunjie a. AWRC No: 401203 b. Lat/Long: -36.948/147.605 c. Catchment area: 1533 km2 5. Black Dog Creek flow at U/S Dugays Bridge a. AWRC No: 403247 If time permits other catchments may be investigated including Ovens at Myrtleford (403210) and the largest unregulated catchments in the Goulburn, Broken and Campaspe.
2. Develop future climate flow series	For the sites listed above: modelled catchment runoff (averages and high flow characteristics) using future time series developed from different methods and projections products, assess one future time period (20-year period centred on 2065) relative to a historical time period (1986–2005) for the RCP8.5 scenario: – scaling the historical data by the change signal in the 42 CMIP5 GCMs, 4 NARCliM WRF product and 6 VCP19 CCAM product (daily scaling rescaled to seasonal change and then annual change, and seasonal scaling rescaled to annual change) – bias correction of daily outputs from the 4 NARCliM WRF product and 6 VCP19 CCAM product (without rescaling to the annual change).
3. Run the future climate series through the rainfall-runoff models and report on the modelled change in future long-term average runoff and the high flow characteristics	The precise high flow characteristics (e.g. days above Q_{99} or Q_{95}) reported on will be informed by analysis of a Murray model constraints relaxed scenario e.g. the flows at Peechelba East that correspond with (or trigger) delivery of constraints level flows in the Murray.
4. Deliver salient datasets and report on the results, and together with the MDBA and Basin States, discuss and interpret the implications on environmental flow opportunities with relaxed constraints under a future climate	To be informed by a workshop with MDBA and representatives from Basin States.

All flow time series generated as part of the environmental water availability analysis element were also contrasted with historical Peechelba event frequency for completeness. This was to better understand the range of possible results and to test if the findings from alternate analytical techniques are commensurate.

Available Environmental Water Account Estimation Element

For the analysis of future water availability inflows to the Murray system were modified to represent a future climate by applying an inflow scaling method based on the Victorian guidelines for assessing Climate Change (DEWLP, 2020).

Source Murray Model Scenarios

Table 3 details the various Source Murray model (SMM) scenarios produced.

Table 3: Source Murray Model (SMM) model scenarios

Scenario Title	Short description
Current conditions	Based on a latest water resource plan (WRP) version of model with following changes to represent environmental water holder behaviours: – Commonwealth water recovered as of 2020 – Model's representation of current environmental water delivery practices with the current constraint levels (i.e. Yarrawonga flows are targeted up to 15,000 ML/d).
CMS Historical	From the current condition scenario, the current constraint levels are changed to the notified flow rates with model's representation of environmental water holder behaviours to use the relaxed constraint levels.
Post1975 historic reference	CMS scenario with 1975 – 2019 climate conditions which are extended to cover 124-year sequence using a decile probability exceedance approach. It is used as a base case to derive future climate projects.
Post1997 historic reference	Step change scenario with 1997 – 2019 climate conditions extended to cover 124-year sequence using a decile probability exceedance approach.
2045 Wet	CMS scenario with modified climate sequence to represent a low impact climate scenario centred at 2045.
2045 Med	CMS scenario with modified climate sequence to represent a medium impact climate scenario centred at 2045.
2045 Dry	CMS scenario with modified climate sequence to represent a high impact climate scenario centred at 2045.
2070 Wet	CMS scenario with modified climate sequence to represent a low impact climate scenario centred at 2070.

Scenario Title	Short description
2070 Med	CMS scenario with modified climate sequence to represent a medium impact climate scenario centred at 2070.
2070 Dry	CMS scenario with modified climate sequence to represent a high impact climate scenario centred at 2070

Developing projected end of system flows using all tributary models and scaled inflow sequences was not feasible in the required timeframe. A combination of approaches was applied as detailed in Table 4.

Table 4: Treatments to represent a future climate in SMM scenarios

Tributary	Treatment
Murrumbidgee flow at Balranald	Scaled end-of-system flows
Inflow to Menindee	Scaled end-of-system flows
Goulburn flow at McCoys Bridge	Scaled inflows
Campaspe flow at Rochester	Scaled inflows
Loddon flow at South Appin	Scaled inflows
Murray inflows upstream of Doctors Point	Scaled end-of-system flows
Snowy release	Scaled end-of-system flows

It should be noted that the scaling method applied may be applicable for deriving runoff from unregulated catchments. However, there is a high likelihood that this approach does not produce a scientifically sound result for estimating the end of system flows from regulated systems which include flows at Balranald, inflows to the Menindee lakes and Snowy scheme releases. This caveat does not impact the work described in this report, but it will limit the applicability of this approach to understanding climate change impacts on other parts of the river system.

Potential impacts from the Murrumbidgee and Lower Darling systems of using the scaling method to modify their inflows to the Murray system are not highly material as the current analysis is limited to the upper Murray system. However, the assumptions around Snowy releases are likely more significant. How the Snowy scheme would behave in a drier and hotter climate is uncertain, and this uncertainty is compounded by the Snowy 2.0 project. It is beyond the scope of the current study to forecast future Snowy scheme releases and therefore the current approach is treated as best available until an improved approach or knowledge becomes available.

In addition to the inflow treatments, climatic data is also scaled similarly. The SMM uses announced allocation levels and spills from headwater storages in each tributary to estimate environmental watering behaviours. For the Victorian tributaries, these are developed from the Victorian models.

However, it is assumed that there are no changes from the current conditions for the Murrumbidgee catchment.

Results

Review of Existing Data

There is a scientific consensus that the future climate will be hotter than the historic record. The impacts on rainfall, both in terms of the amount and the patterns in space and time it falls is less certain. As climate models become more sophisticated and finer scale, more certainty in projected impacts on rainfall are expected to emerge. However, the range of rainfall projections will remain much larger than temperature projections.

Existing model data review

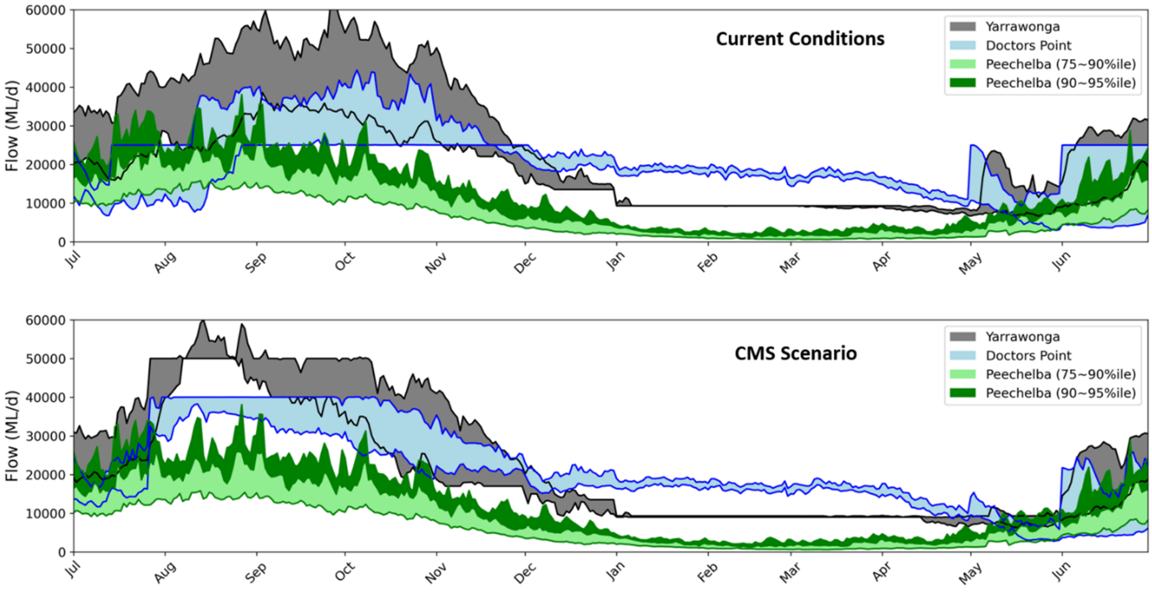

Figure 6: Existing SMM scenario flow frequency analysis

Analysis of existing model scenarios presented in Figure 6 suggests flows at Peechelba between 10,000 ML/d and 40,0000 ML/d in the winter and spring constitute an opportunity to operate constraints projects by delivering environmental water from Hume Dam. A flow of any duration has been considered in this analysis as this provides an opportunity for environmental water holders to enhance either the duration or peak of an event to meet their objectives.

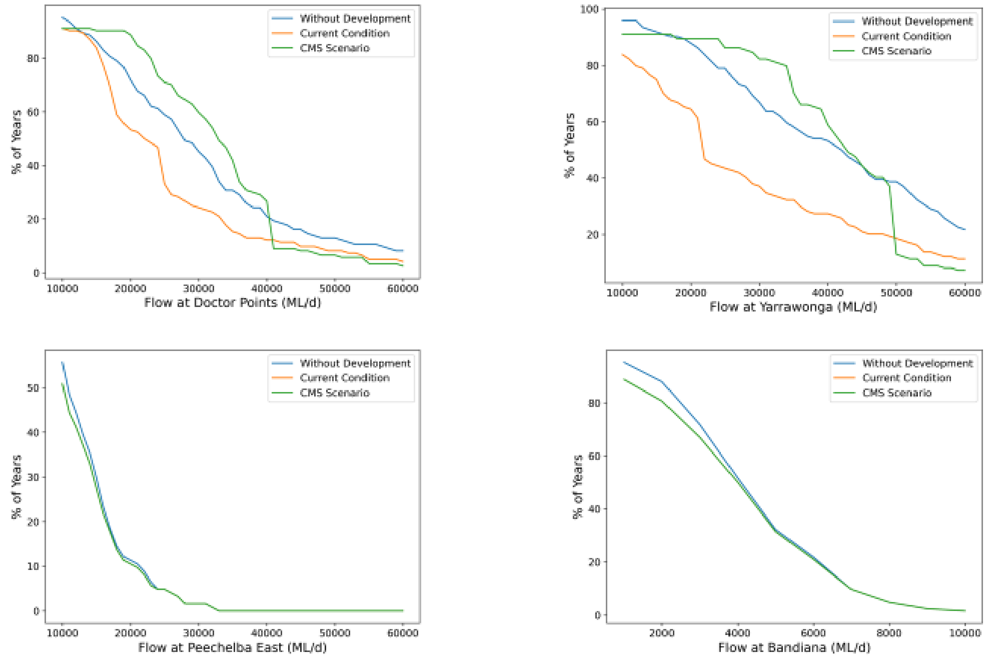

Figure 7: Annual flow exceedance curves for key SMM scenarios

This estimate is reinforced by analysis presented in Figure 7 that shows a divergence between the current conditions and CMS scenarios for flows between approximately 10,000 ML/d and 40,000 ML/d at Doctors Point. It can also be seen in Figure 7 that flows from The Kiewa River (at Bandiana) are insignificant in comparison to flows from the Ovens of the same annual frequency.

Literature Review

The impacts of a changing climate are already being felt and the projected impacts of climate change are becoming increasingly clear. The future will be warmer and is likely to be drier with more severe droughts (Zhang et. al., 2020). There are several changes that can be anticipated with a high level of confidence. Of most relevance to constraints projects are the anticipated cool season rainfall decline and increase in the intensity of heavy rainfall.

Reductions in rainfall

- The observed long-term reduction in rainfall across many parts of southern Australia, including the Murray–Darling Basin has led to reduced streamflow (CSIRO & BOM, 2020)
- Australia is projected to see a continued decrease in cool season rainfall across many regions of southern and eastern Australia, likely leading to more time in drought (CSIRO & BOM, 2020)
- In the near future (2030) natural variability is projected to predominate over trends due to greenhouse gas emissions (CSIRO & BOM,2020).

Increases in high intensity rainfall

- Observations show that there has been an increase in the intensity of heavy rainfall events in Australia. The intensity of short-duration (hourly) extreme rainfall events have increased by around 10 per cent or more in some regions in recent decades (CSIRO & BOM, 2020)
- Even though mean annual rainfall is projected to decline, heavy rainfall intensity is projected to increase, with high confidence (CSIRO & BOM, 2020)
- As the climate warms, heavy rainfall events are expected to continue to become more intense. Storms in summer are expected to become more intense. Storms in autumn and winter might see little change (DELWP, 2020).

Implications for Constraints Projects

In the context of constraints projects, these two projections pose a question: *Is the frequency of constraints relevant flows likely to decrease because of reduced rainfall or increase because of more frequent high intensity rainfall events?*

Previous studies have found that when increased rainfall intensities for rare events are modelled in conjunction with reductions in average annual rainfall, the magnitude of frequently occurring floods will decline, while the magnitude of rarer floods will increase (DELWP, 2020).

This is consistent with recent observations —indicating that drier antecedent conditions are modulating the impact of increasing rainfall intensities in the historic record — for frequently occurring rural floods (Wasko and Nathan, 2019).

Indications are that, particularly for large rural catchments, the overall reductions in rainfall will have more impact on the flows than the increase in rainfall intensity.

The literature reviewed suggests that flows relevant to the operation of constraints projects will decline in frequency.

Sensitivity Analysis of Ovens Flows – Piggy-back Opportunities Element

Analysis produced by the CSIRO is presented in Figures 9–12. Data was generated from phase 5 of the Coupled Model Intercomparison Project (CMIP5), NSW and ACT Regional Climate Modelling (NARCliM) and Conformal Cubic Atmospheric Model (CCAM) regional climate models.

Flow projections

The locations of the catchments investigated are displayed in Figure 8. The results from analysing changes in rainfall, runoff, and high flow days of these projected flow time series are shown in Figure 9 Figure 10 and Figure 11 respectively. The key site of the Ovens at Peechelba (403241) is displayed at the top right.

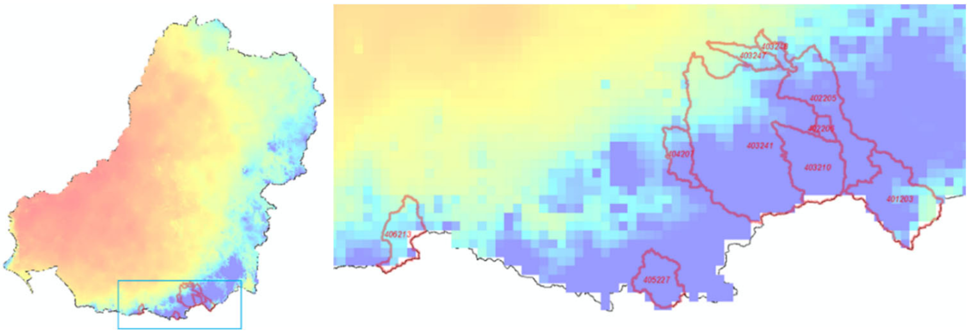

Figure 8: Sub-catchments investigated and their location within the Murray–Darling Basin (CSIRO)

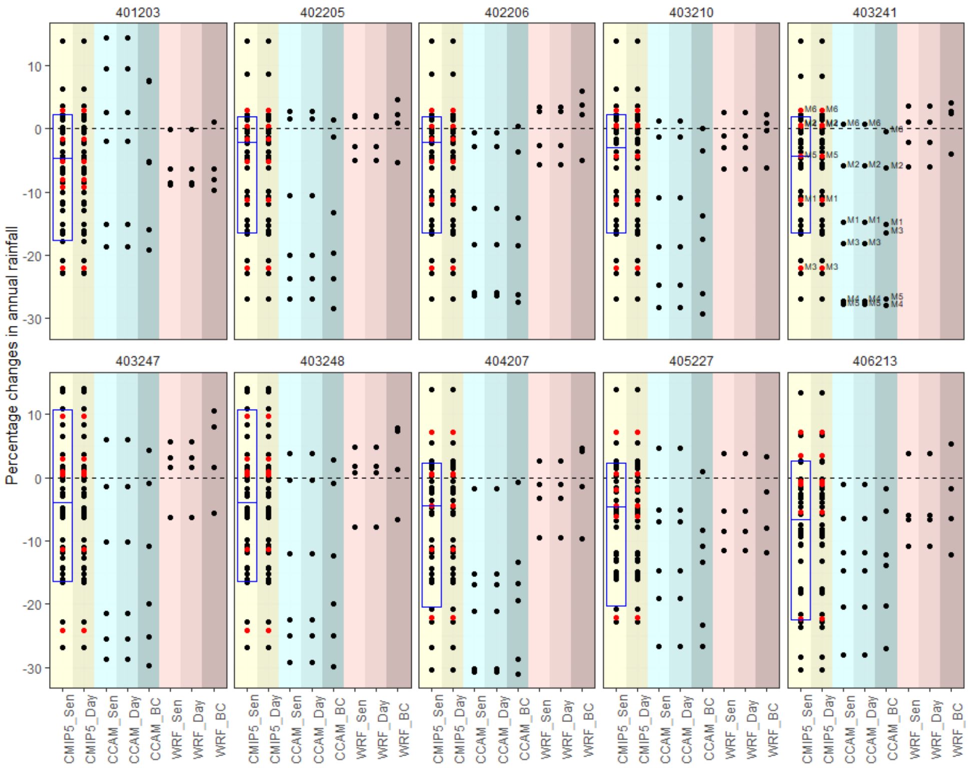

Figure 9: Projected percentage change in annual rainfall (CSIRO)

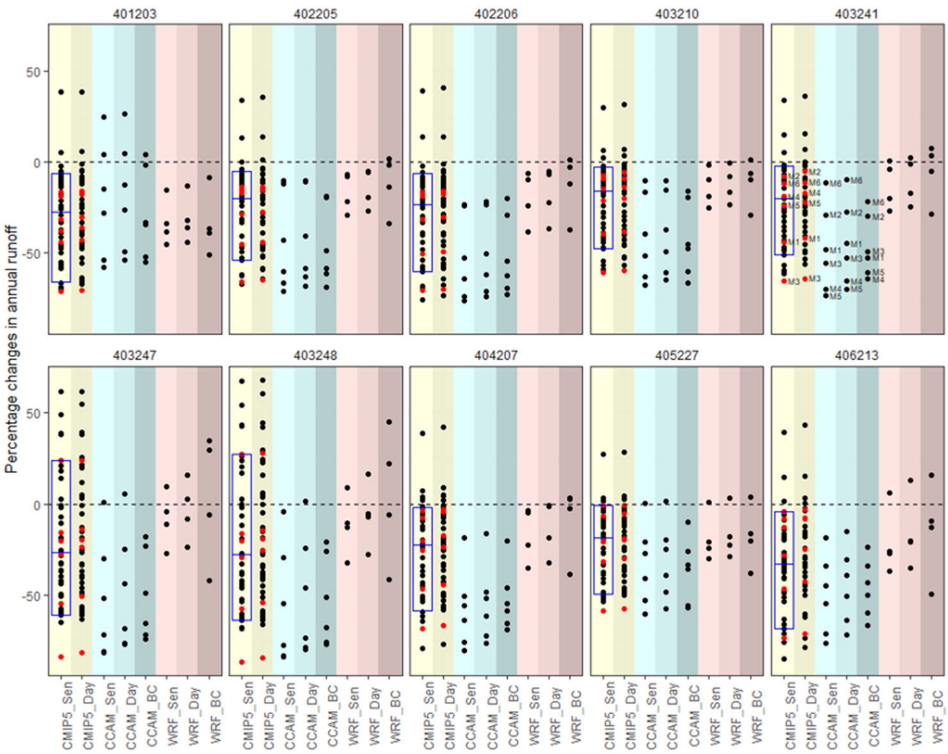

Figure 10: Projected percentage change in annual runoff (CSIRO)

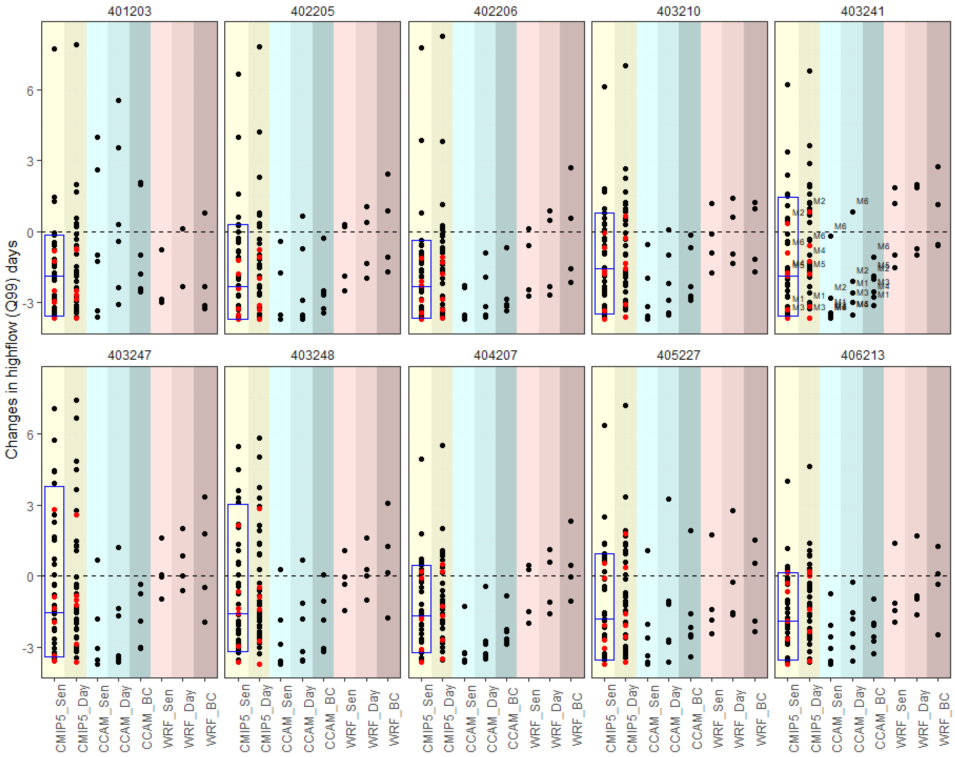

Figure 11: Projected change in high flow days (CSIRO)

Flow projections displayed above show that while the different model products and techniques produce a wide range of results (CMIP5 being the widest), the results are reasonably consistent across the ten catchments investigated. In general, CCAM predicts drier climates while NARCliM indicates wetter conditions.

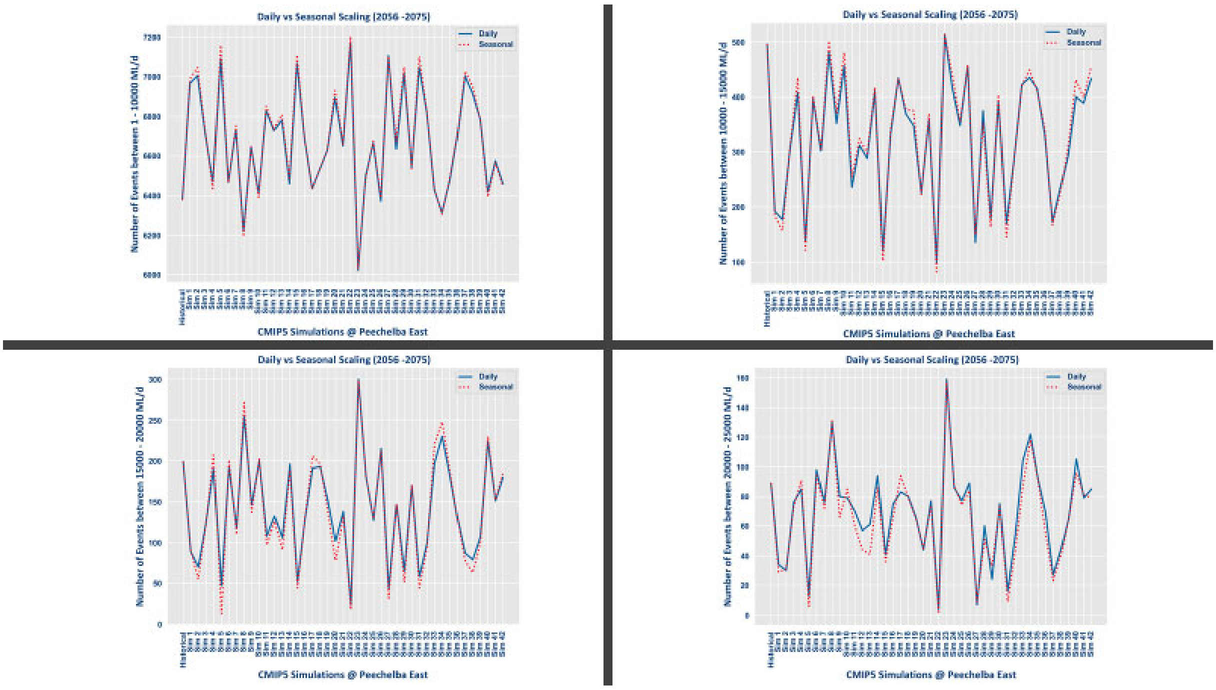

Figure 12 Comparison between daily and seasonal scaling techniques

Figure 13: Comparison between daily and seasonal scaling techniques

The differences between scaling techniques and model products for projected Peechelba flows were investigated as displayed in the Figure 12 and Figure 13. It can be seen that differences between model products far exceed the differences between daily and seasonal scaling techniques.

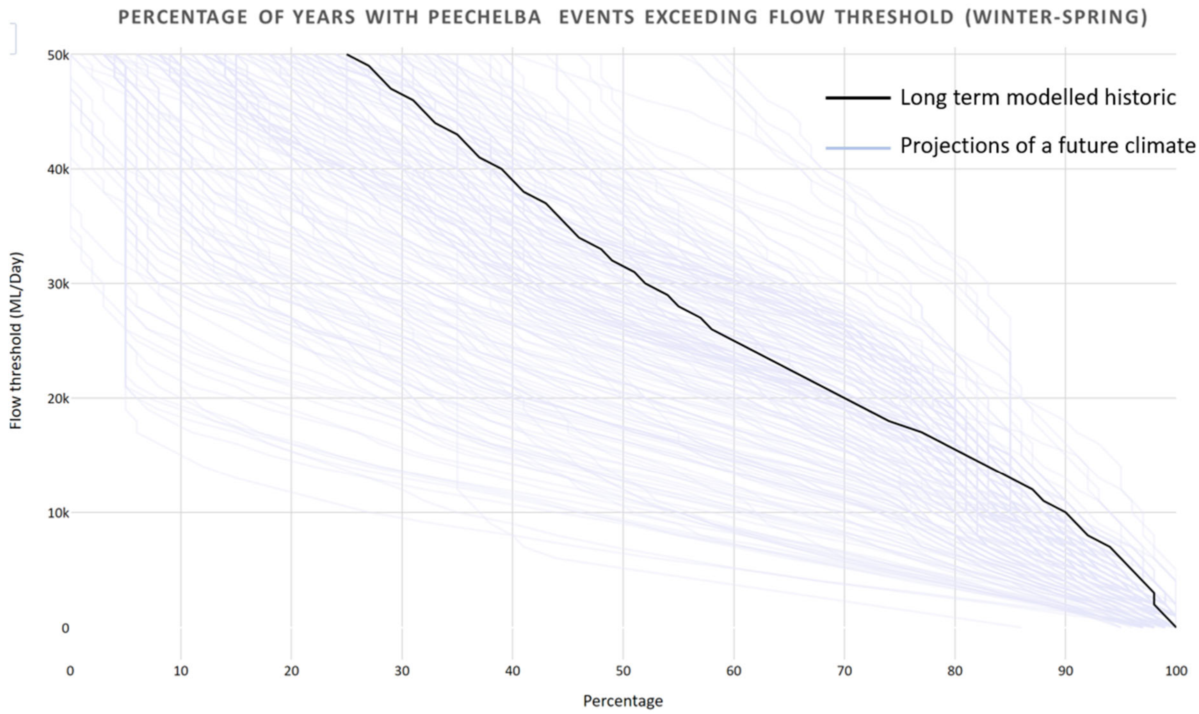

Figure 14: All Ovens flow projections plotted as annual flow exceedance curves (constructed using projected rainfall runoff model data)

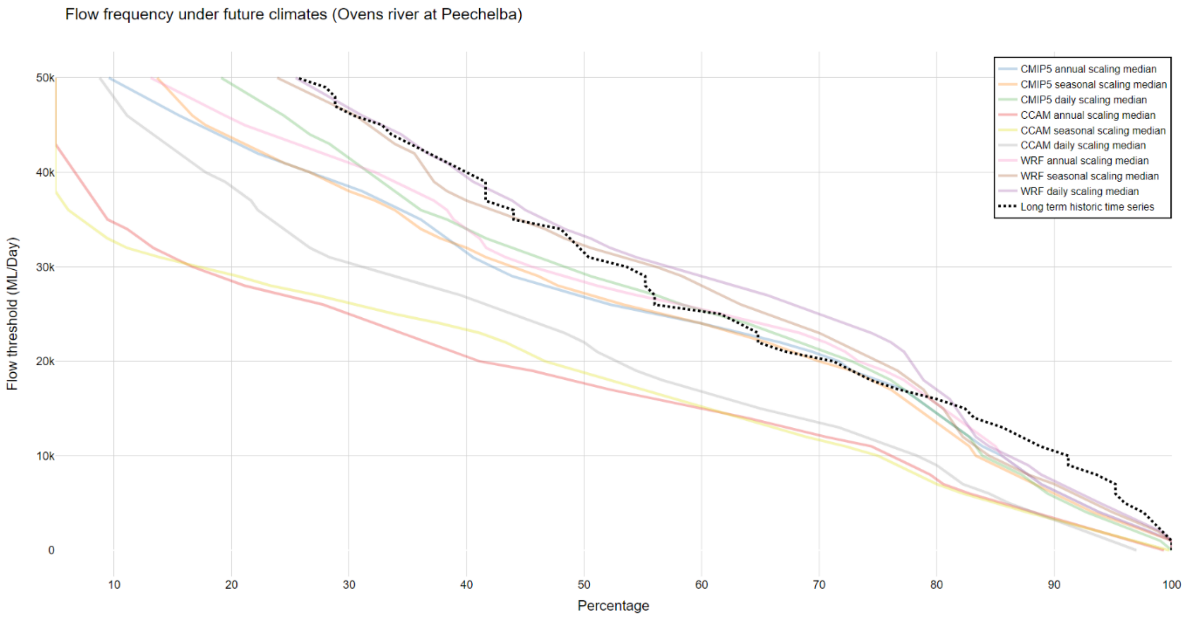

Figure 15: Percentage of years with flow threshold exceeded at Peechelba:- ensemble averages

Figure 15 shows the average series for model ensembles where the same techniques are applied. All series show a projected reduction in frequency apart from the NARCliM products that produce results similar to the long-term historic data apart from an increase in frequency of events between approximately 15,000 and 30,000 ML/d. Generally, the CCAM result show the largest decline in frequency, the NARCliM products show results closer to historic conditions with global climate model results (CMIP5) falling somewhere in between.

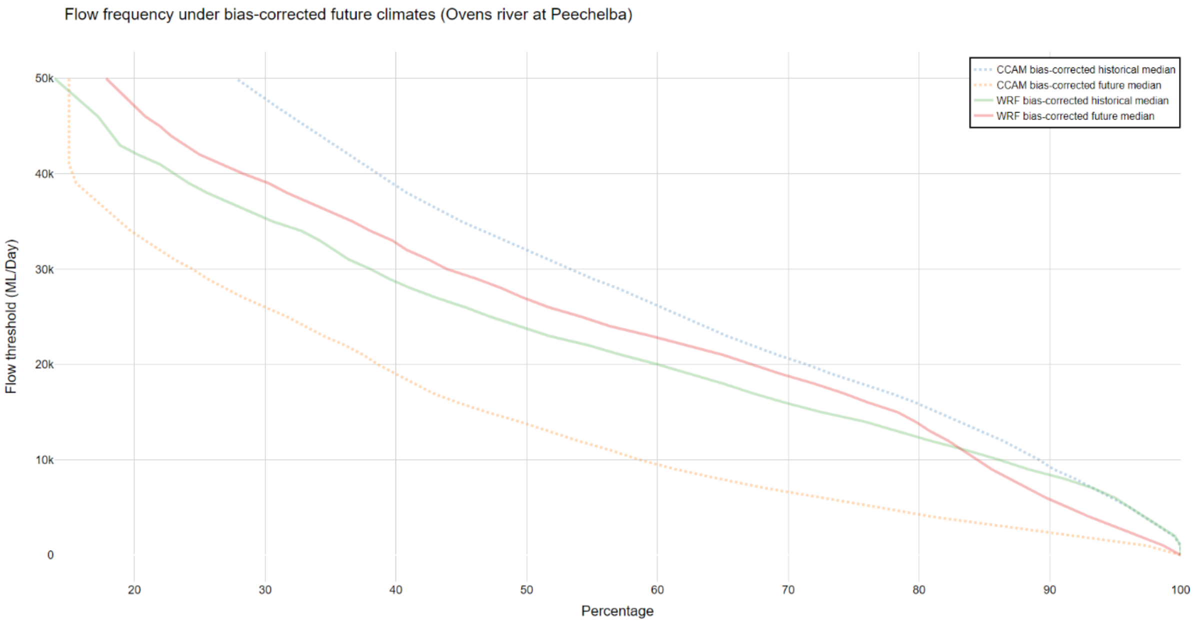

Figure 16: Percentage of years with flow threshold exceeded at Peechelba:- bias corrected series averages

Figure 16 again confirms the trend seen with other scaling techniques that CCAM results are consistently drier than NARCliM results. NARCliM results show an increase for event frequencies of flows above approximately 10,000 ML/d while CCAM results show a much larger difference in the other direction.

Comparison with inflow scaling techniques

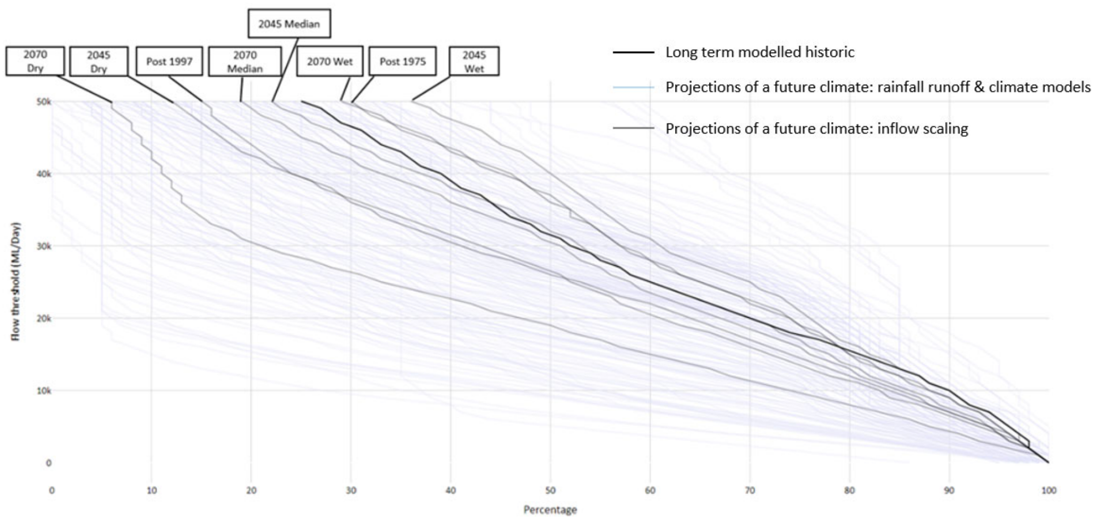

Figure 17: Comparison of Ovens flows at Peechelba derived from CSIRO's rainfall-runoff study and an inflow scaling method

Figure 17 presents Ovens flows at Peechelba for different climate projections developed by the rainfall-runoff modelling approach which are compared against those derived using the scaling method described in DELWP (2020). As described in DELWP (2020), the scaling method is based on projected outcomes of 42 GCMs after excluding 10% of extreme ends. If all possible results are included, changes would be bounded by a much wider range. It shows a consistent message indicating that either approach can be used to estimate a projected inflow sequence in this catchment. This figure shows a wide range with the median scenarios (centre of the range) indicating a slight reduction in flow frequency across the 10,000 – 40,000 ML/d range.

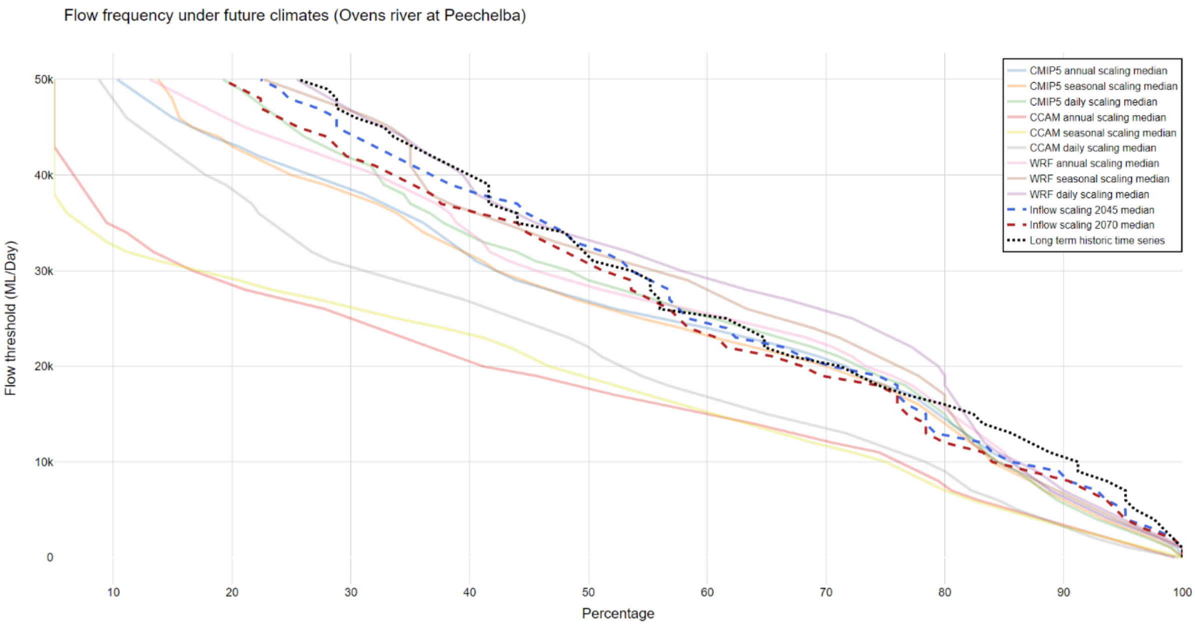

Figure 18: Percentage of years with flow threshold exceeded at Peechelba:- ensemble averages compared to median impact scenarios developed by inflow scaling

While the method outlined in the DEWLP guidelines does not directly capture the projected increase in high intensity rainfall events the results are similar when taken in light of the large range of uncertainty.

During the literature review it was identified that this would be the most likely result for large lowland and rural catchments like the Ovens. In the headwaters of more urbanised catchments (i.e. with large areas of impervious surfaces) this effect would be more pronounced. In this case, regulating structures will dampen the variability in a system like the Upper Murray catchment.

Key findings from the sensitivity analysis of Ovens flows – piggy-back opportunities element:

- Climate model selection has a bigger impact on results than scaling techniques.
- Different techniques produce different results however the scaling method outlined in the DEWLP guidelines gave commensurate results to those garnered from linked climate and rainfall-runoff models.
- The annual frequency of events between 10,000 ML/d – 40,000 ML/d during winter/spring is anticipated to decline but the range of projections are large (i.e. larger than the difference between historical conditions and any of the projected futures investigated).

Available Environmental Water Account Estimation Element

An analysis of allocations in the various model scenarios produced using input data set developed based on the Victorian guidelines (DEWLP, 2020) are displayed below.

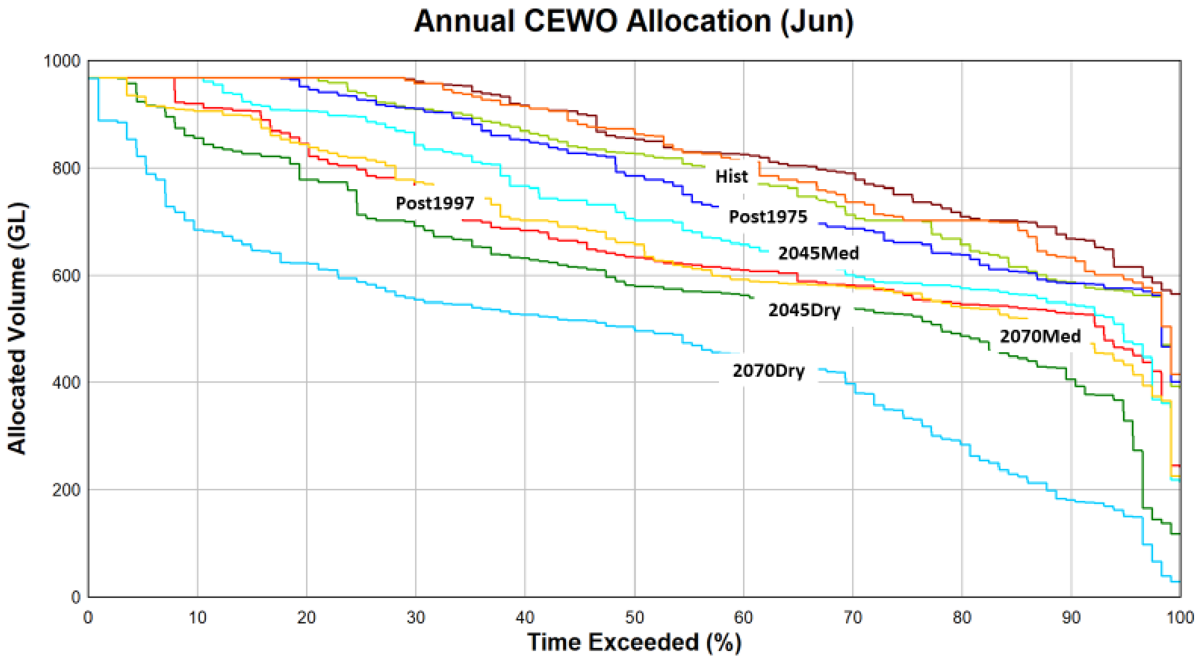

Figure 19: Projected Commonwealth Environmental Water Holder allocation curves – June

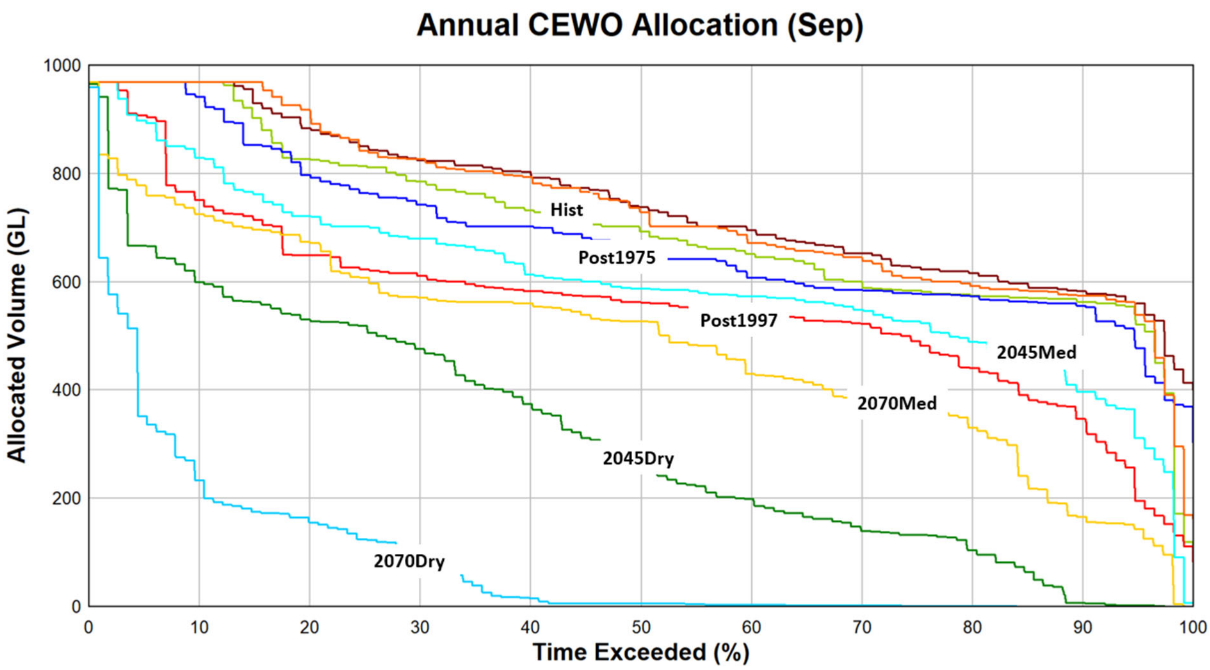

Figure 20: Projected Commonwealth Environmental Water Holder allocation curves – September

Figure 19and Figure 20 show allocation reductions can be expected but only the dry (high impact) climate change scenarios show allocation that would severely limit environmental watering. Even though the outcomes are highly subject to how environmental water holders react to future climate, the median (medium impact) scenarios are similar to the post-1997 historic reference period. This means that recently experienced water availability is likely to continue or slightly worse in future.

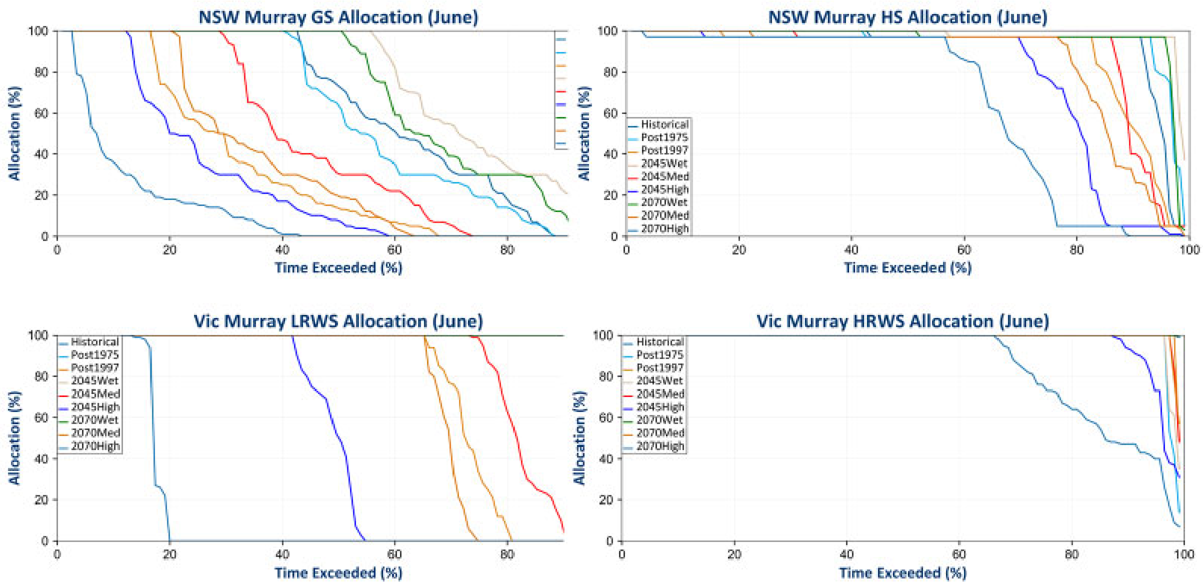

Figure 21: Projected allocation curves for New South Wales Murray General Security entitlements (GS), New South Wales Murray High Security entitlements (HS), Victorian High Reliability Water Shares (HRWS) & Victorian Low Reliability Water Shares (LRWS) – June

Key findings from the available environmental water account estimation element:

- Water allocations are projected to decline
- The range of projections is large
- The worst-case scenarios presented here would have significant implications for water management arrangements beyond the operation of constraints projects and would likely result in a fundamental re-examination of the over-arching water management framework
- Even with the declined trend for future projections, the median scenarios indicate that a considerable amount of water will be available for the environment. It will be further increased if other environmental water accounts such as The Living Murray are made available in addition to the CEWO account. Also, the current carryover provisions may lead to improved circumstances when a piggy-backing opportunity arises.

Discussion

Piggy-back opportunities downstream of Yarrawonga weir are projected to reduce while remaining relatively frequent. However, it should be noted the range in projections is large. A comparison of results produced by linking climate and rainfall runoff models and the seasonal inflow scaling techniques (from DELWP guidelines) showed that they are generally commensurate. This analysis has not sought to identify the most appropriate technique for projecting flow time series.

At Peechelba the projected increase in the intensity of rainfall events does not lead to increased high flow frequencies but rather is counteracted by the overall decrease in rainfall and increase in temperatures. All techniques investigated showed a projected decrease in frequency of piggy-back opportunities to deliver environmental water above existing flow constraints.

Under the 2070 medium projection, there will still be ample opportunities for environmental watering under relaxed constraints. Under 2070 dry, there will be fewer opportunities, however if this scenario plays out there will be significant challenges to managing water resources beyond constraints projects invalidating some of the assumption made in this analysis.

Environmental water availability is projected to reduce in comparison to the modelled long-term historic average but there will still be environmental water available to take piggy-back opportunities when they present. Medium projections are similar to post 1997 conditions.

The ambiguity around the response of environmental water holders and water managers more broadly to future climate conditions adds additional uncertainty to the analysis presented in this report. The modelled simulations assume behaviour remains consistent in the face of changed climate conditions while in reality this is unlikely to be the case.

Existing Refinements

While the information generated in this analysis does provide useful insights it has not fully met the information needs of decision makers as demonstrated by Victoria assessing the work as not being sufficient to meet the gateway investment requirements for their projects.

After initial results were presented to the Constraints Management Working Group, Victoria has extended the analysis to consider a broader range of potential triggers (piggy-back opportunities) for constraints operation and developed a list of additional information that would be required to fully elucidate the value proposition of the constraints management program under a future climate (summarised in Table 5).

Table 5: Additional information and potential pathways to acquire it

Additional Information Desired	Acquisition Pathway
Future environmental water behaviour	Requires input from environmental water holders
Projected Peechelba event frequency changes of 7- and 14-day events	Complete, can be seen in Appendix A
Sequencing of events over different climate sequences	Requires additional analysis, best undertaken with whole of system modelling
Whole of system outcomes	Requires whole of system modelling

This additional analysis is presented in Appendix A. By extending the analysis to consider 7- and 14-day events a trend has been made clear that as the event duration is extended the projected impacted of climate change increases. This is to say, for longer duration events the projected decrease in event frequency is larger.

Future Refinements

More sophisticated analysis of existing data will not produce more precise information given the large range in projections and is highly unlikely to change the overarching messages. Developing more robust SMM scenarios offers the best avenue to develop additional insights into the implications of future climate projections. Pre-existing work towards an appropriate representation of SDLAM projects and the impacts of a changing climate in the SMM continues and is anticipated to progressively provide more robust information over the next 24 months.

Key additional information required on top of the initial analysis identified by Victoria has been summarised in Table 5.

The short time frames and limited resources available to design and undertake this body of work required the most expedient rather than the most robust techniques and assumptions to be applied.

Undertaking complex analytical work in a ‘sprint’ style or as a series of short ‘sprint’ efforts produces information of limited utility and diverts the limited resources available to do such work away from existing priorities. River system modelling capacity has proved difficult to surge sufficiently to meet quickly shifting and expanding priorities.

Conclusion

The constraints under a future climate analysis has been designed to produce results within the required timeframe, but to also inform and contribute to more rigorous investigations of the implications of changing climate on constraints projects in the future.

While the analysis was able to confirm a projected direction of change for the two elements investigated, the scale of change is uncertain. Further work to represent the impact of a changing climate more robustly in the Source Murray Model is underway and will offer additional insights, particularly by representing constraints projects operating in unison across the Southern Connected Basin.

References

BOM (2020) Short-duration, heavy rainfall is intensifying, but not everywhere, and not all the time – A literature review

CSIRO & BOM (2020) State of the Climate 2020, http://www.bom.gov.au/state-of-the-climate/

DELWP (2020). Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria. Final, November 2020, Department of Environment, Land, Water and Planning, Victoria.

Wasko C and Nathan R (2019) Influence of changes in rainfall and soil moisture on trends in flooding. Journal of Hydrology 575 (2019) 432-441. https://doi.org/10.1016/j.jhydrol.2019.05.054

Zhang, L, Zheng, HX, Teng, J, Chiew, FHS, and Post DA (2020). Plausible Hydroclimate Futures for the Murray–Darling Basin. A report for the Murray–Darling Basin Authority, CSIRO, Australia. 34pp.

Appendix A

Analysis extension to consider longer duration events

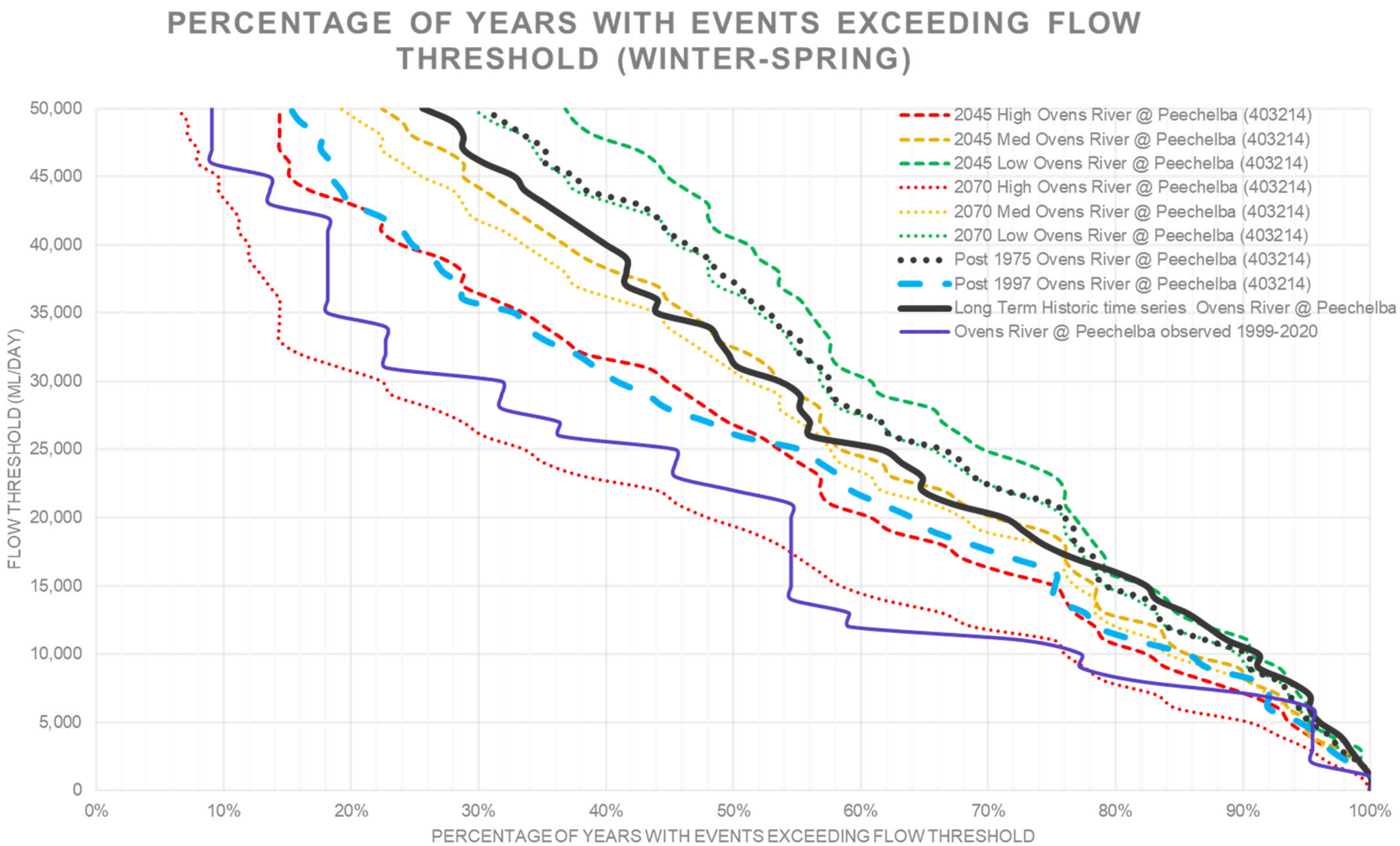

Figure 22: All SMM time series:- 1 day event duration

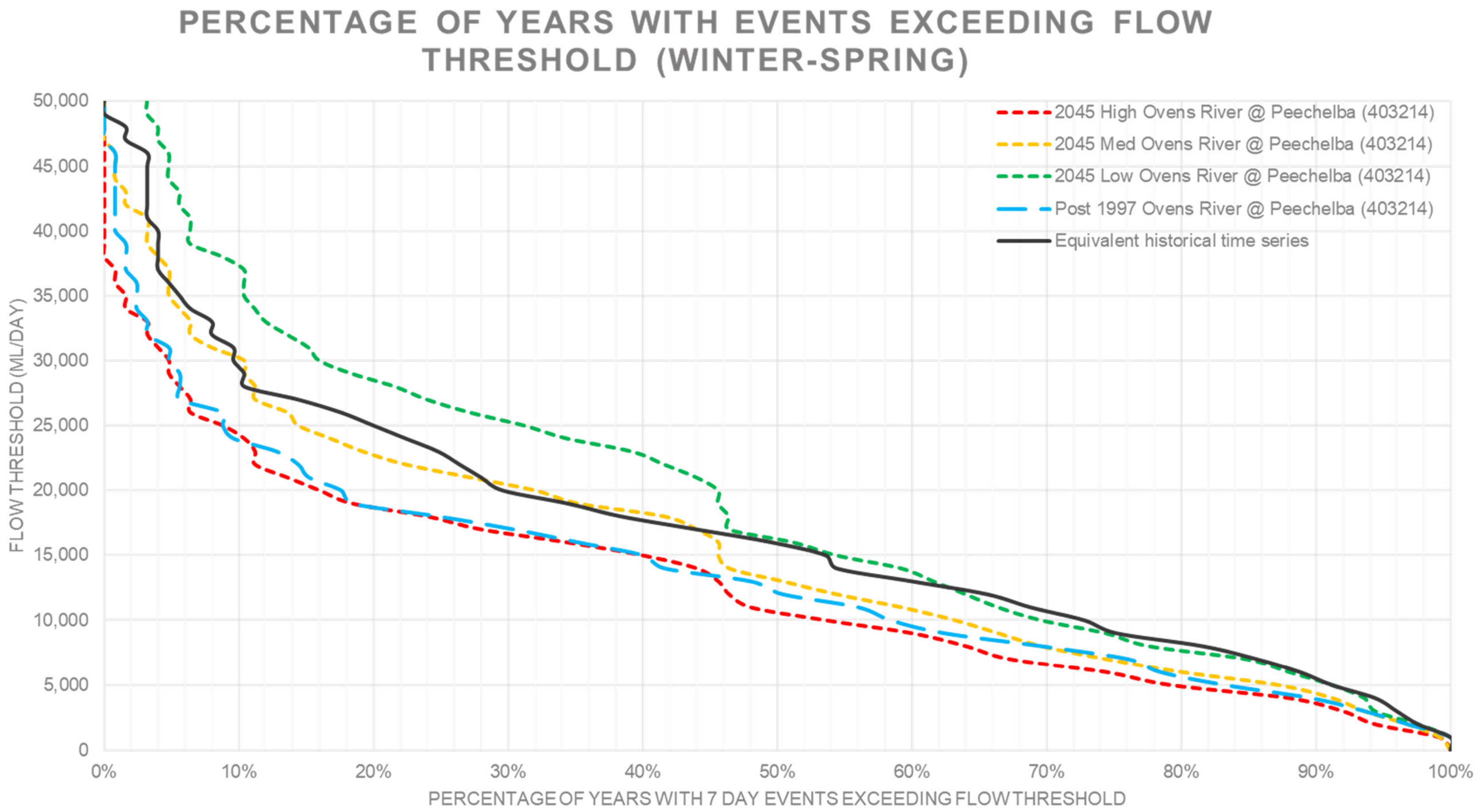

Figure 23: 7 day duration – 2045 Climate scenario

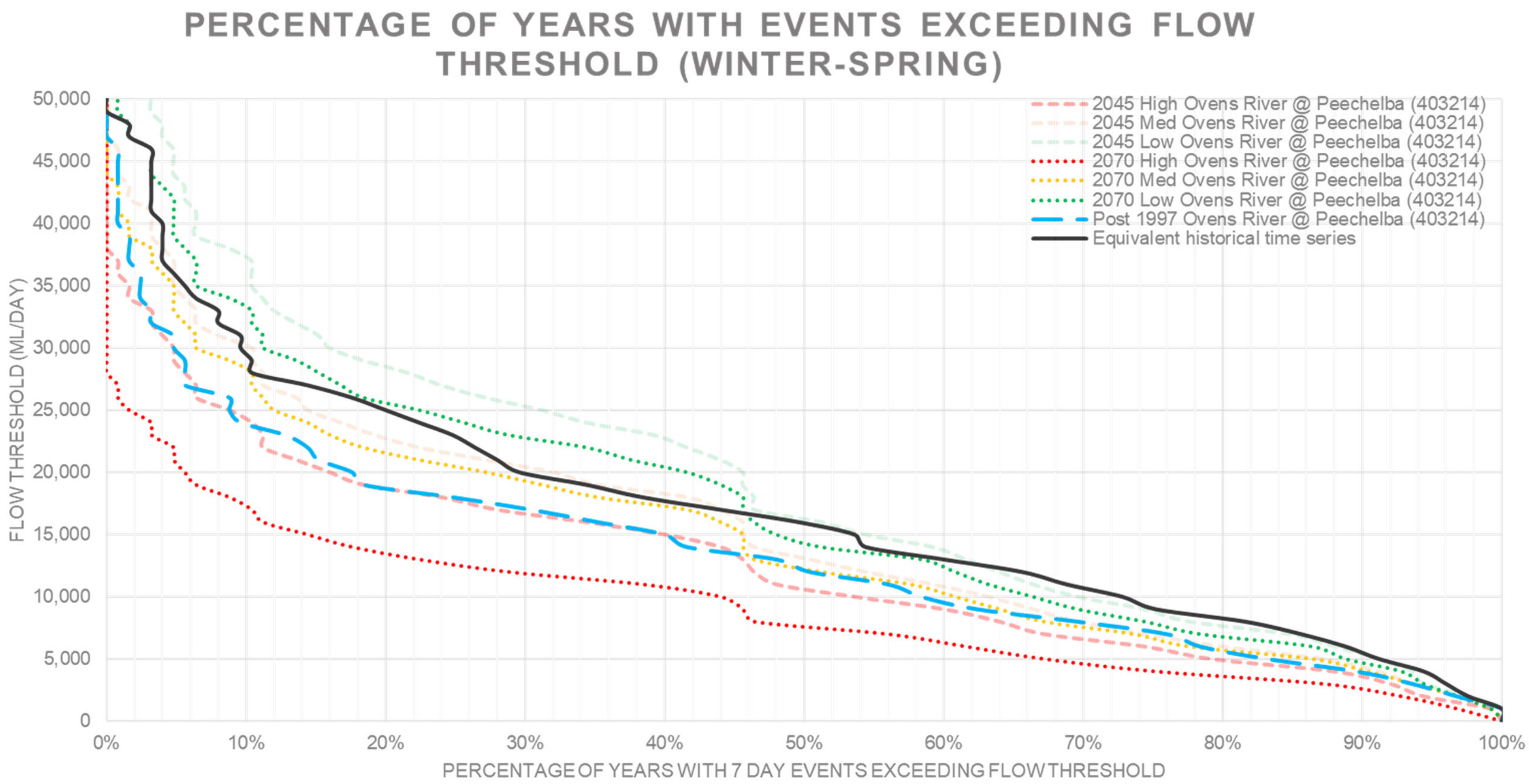

Figure 24: 7 day duration – 2070 & 2045 Climate scenarios

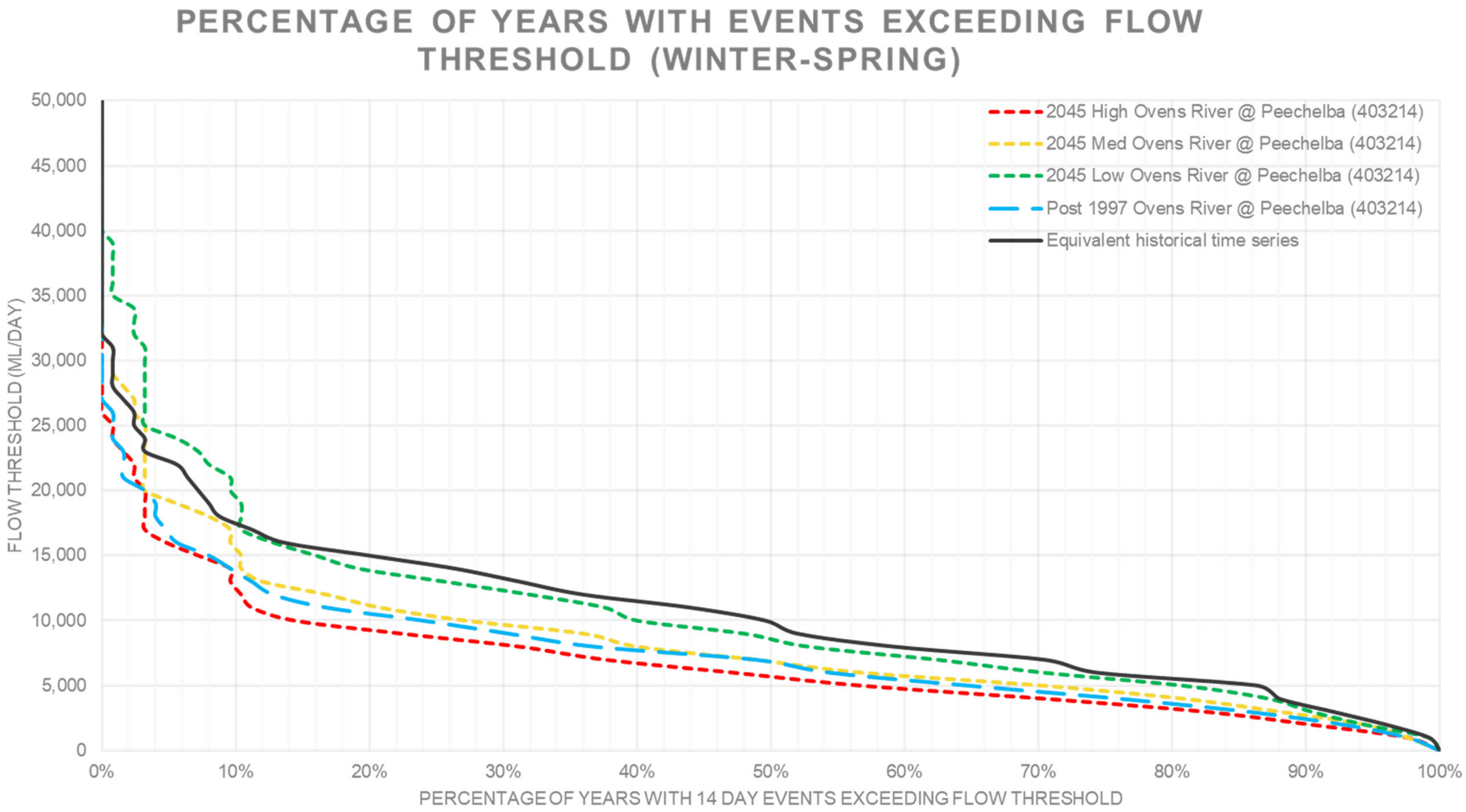

Figure 25: 14 day event duration – 2045 climate scenario

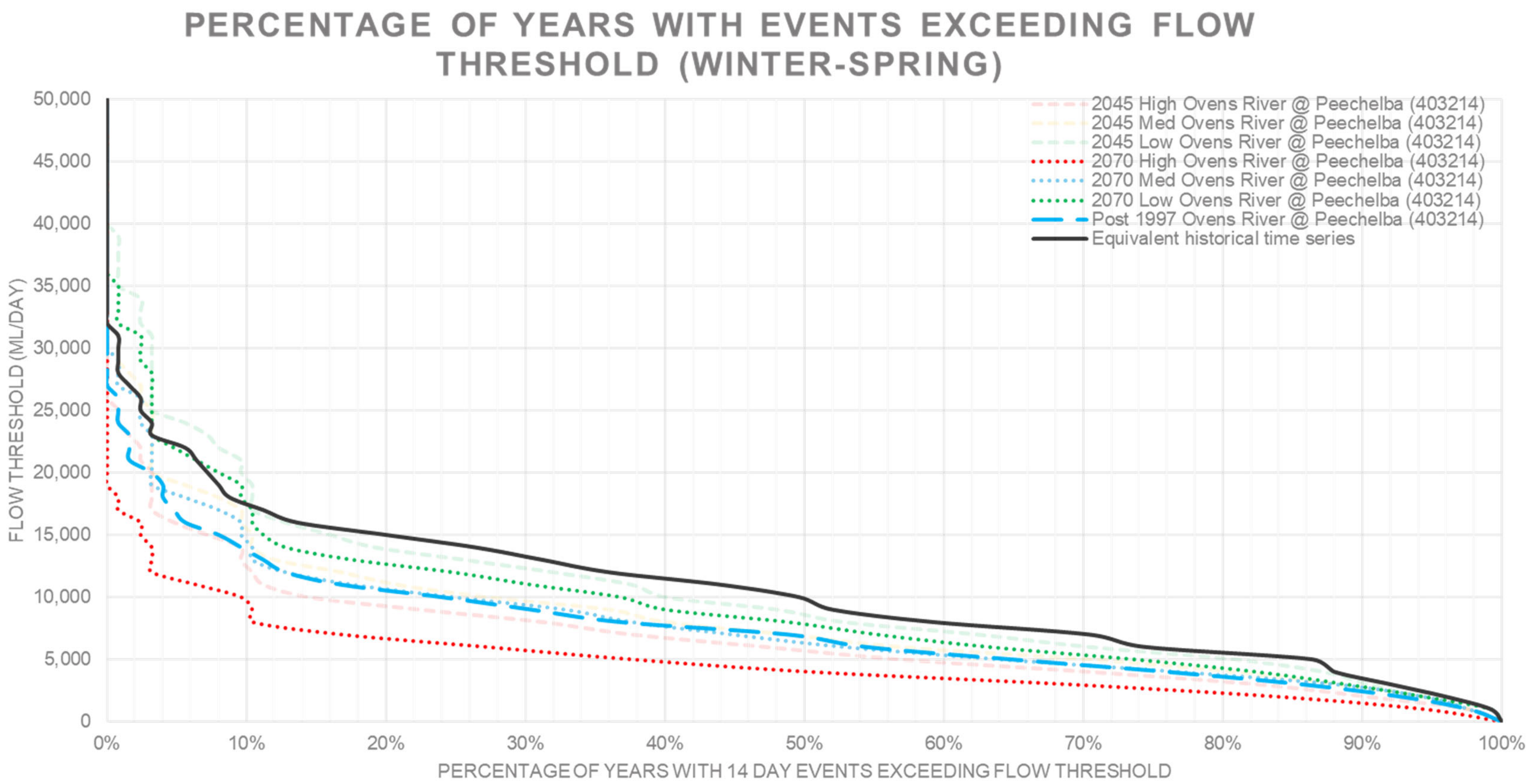

Figure 26: 14 day event duration – 2045 & 2070 climate scenarios

Table 6: Medium impact climate scenario figures

Flow rate (climate record)	1-day threshold (% of years)	7-day threshold (% of years)	14-day threshold (% of years)
10,000ML/d (historic) (2045 med) (2070 med)	91.2 85.6 (-5.6) 84 (-7.2)	72.8 63.2 (-9.6) 60.8 (-12)	49.6 27.2 (-22.4) 24.8 (-24.8)
15,000ML/d (historic) (2045 med) (2070 med)	82.4 78.4 (-4.0) 76.8 (-5.6)	53.6 45.6 (-8.0) 45.6 (-8.0)	20 10.4 (-9.6) 9.6 (-10.4)
20,000ML/d (historic) (2045 med) (2070 med)	71.2 70.4 (-0.8) 68 (-3.2)	29.6 32 (+3.6) 27.2 (-2.4)	7.2 3.2 (-4.0) 3.2 (-4.0)
25,000ML/d (historic) (2045 med) (2070 med)	61.6 58.4 (-3.2) 57.6 (-5)	20 14.4 (-5.6) 12 (-8.0)	2.4 3.2 (-1.6) 2.4 (-0.0)

Table 7: High impact climate scenario figures

Flow rate (climate record)	1-day threshold (% of years)	7-day threshold (% of years)	14-day threshold (% of years)
10,000ML/d (historic) (2045 high) (2070 high)	91.2 82.4 (-8.8) 76 (-15.2)	72.8 53.6 (-19.2) 44 (-38.8)	49.6 14.4 (-35.2) 9.6 (-40)
15,000ML/d (historic) (2045 high) (2070 high)	82.4 75.2 (-7.2) 58.4 (-24.0)	53.6 40 (-13.6) 14.4 (-39.2)	20 7.2 (-12.8) 2.4 (-17.6)
20,000ML/d (historic) (2045 high) (2070 high)	71.2 60.8 (-10.4) 48 (-23.2)	29.6 16 (-13.6) 5.6 (-24)	7.2 3.2 (-4.0) 0 (-7.2)
25,000ML/d (historic) (2045 high) (2070 high)	61.6 53.6 (-8.0) 33.6 (-38.0)	20 8.8 (-11.2) 1.6 (-18.4)	2.4 0.8 (-1.6) 0 (-2.4)

Office locations – *First Nations Country*
Adelaide – *Kaurna Country*
Canberra – *Ngunnawal Country*
Goondiwindi – *Bigambul Country*
Griffith – *Wiradjuri Country*
Mildura – *Latji Latji Country*
Murray Bridge – *Ngarrindjeri Country*
Toowoomba – *Jarowair and Wakka Wakka Country*
Wodonga – *Dhudhuroa Country*

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