Impact of the 'or natural' clause on environmental flow compliance when modelling future climate change scenarios

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Key Points

- Future climate conditions reduce the natural flows in a system.
- A lower natural flow can increase the environmental flow compliance in a system with an 'or natural' clause for future climate change scenarios.
- The resulting higher environmental flow compliance with the 'or natural' clause does not represent the potential increased ecological risks for future climate change scenarios.

Abstract

As part of environmental flow studies, flow compliance calculations are undertaken for a number of future climate conditions to determine the impact of climate change, as required by the Victorian FLOWS method (DEPI, 2013).

Environmental flow recommendations for low flows often include an 'or natural' clause, where the lesser of the unimpacted or 'natural' flow and the low flow recommended at the compliance point is required. As climate change impacts become more severe, the natural flow in the system also significantly reduces. Therefore, due to the 'or natural' clause, less water is required at a given environmental flow compliance point for environmental flow compliance under future climate conditions. This can mask the impact of climate change on environmental outcomes since the reduced natural flow may no longer meet the ecological need for which it was originally provided, for example a level of stream depth or bench inundation.

This investigation explores the true ecological impact of climate change on environmental flow compliance by allowing natural flow to be modelled retaining its characteristics under current climate, or by removing the 'or natural' clause entirely for some example catchments. The outcomes of this investigation were combined with reasonable low flow bounds necessary to achieve ecological outcomes to provide evidence to inform the future treatment of the 'or natural' clause when modelling environmental flow compliance under future climate conditions.

Keywords

Environmental flow compliance, water resource modelling, future climate change modelling

Introduction

Maintaining sufficient flow in the river is critical for the health of the river, the catchment and the values they support. The Victorian FLOWS method was first developed in 2002 and later refined in 2013 following the experiences of waterway management through the Millennium Drought (1997-2009). The original purpose of the method was to develop flow-dependent environmental objectives and the flow regime required to meet these objectives. Importantly, it was intended to maintain flow-dependent values 'at a low level of risk' (DEPI 2013). The method focused on understanding the minimum water requirements for key environmental values in the face of severe water scarcity, as well as water recovery needs.

In regulated systems the flow recommendations set out in a FLOWS study can be used to create stored environmental water entitlements. An environmental entitlement is a legal right to take water for the purposes of improving the environmental values and health of a waterway. In unregulated systems or systems where no

stored environmental entitlement is available, the flow recommendations can be used to test the degree to which environmental flow requirements are met under particular climate conditions, demand levels and operating rules (for example restriction triggers).

Flow compliance is an approach whereby performance of a waterway system is compared to environmental flow recommendations to assess the degree to which flow recommendations are met. In systems where stored environmental entitlements have been created, this gives a measure of whether the existing entitlement is sufficient or to highlight the need for additional water recovery. In systems where no stored environmental water is available this gives a measure of the degree to which demands and operating rules impact the ability to meet ecological objectives. The compliance analysis can include a range of future climate conditions and levels of development.

As climate change impacts become more severe, the natural flow in many catchments will likely significantly reduce. This investigation explores the potential ecological impact of climate change on environmental flow compliance by

a) modelling natural flow retaining its characteristics under current climate, or by

b) removing the 'or natural' clause entirely for three example catchments.

Environmental flow recommendations for low flows often include an 'or natural' clause, where the lesser of the unimpacted or 'natural' flow and the low flow recommended at the compliance point is required. Therefore, due to the 'or natural' clause, less water is required at the environmental flow compliance point for environmental flow compliance under future climate conditions. Originally the 'or natural' clause was included in FLOWS studies to prevent too much water being required when applying the recommendations compared to what would have naturally occurred. However, this can mask the severity of the impact of climate change on environmental outcomes since the reduced natural flow may no longer meet the ecological need for which it was originally provided, for example a level of stream depth or bench inundation.

Three case studies with differing environmental entitlement and share of storage availability have been tested as part of this investigation. These case studies have not been explicitly identified, but they represent typically dry catchments in western and eastern Victoria.

To determine the impact of the 'or natural' clause on environmental flow compliance, each water resource model has been set up as follows:

a) With the 'or natural' assumption changing for future climate conditions

b) With the 'or natural' assumption being set to current climate conditions for future climate scenarios

c) removing the 'or natural' clause.

The outcomes of this investigation can inform the future flow compliance assessments, and in particular the treatment of the 'or natural' clause when modelling environmental flow compliance under future climate conditions.

Impact on environmental flow compliance

To determine the impact of the 'or natural' clause on environmental flow compliance, three case studies have been tested using pre-existing daily water resource models. The Intergovernmental Panel on Climate Change (IPCC) future climate scenario, defined as Representative Concentration Pathway (RCP) 8.5 (referred to as RCP 8.5) was used. For each climate scenario, there are different options available, with a High Climate Scenario being the 95th percentile climate predictions under that given RCP. These scenarios were run for the climate conditions predicted in 2020, 2040 and 2065. As well, the post-1975 baseline and post-1997 step climate scenarios were modelled to be used as a benchmark. These two scenarios have been commonly used in water resource modelling in Victoria. The inputs to the water resource models were derived using the 2020 *Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria* (DELWP, 2020).

Environmental flow compliance has been tested for the warm and cool season low flow recommendations as defined for the given system in its corresponding FLOWS study, and a 100% tolerance has been assumed, i.e. the full low flow magnitude must be met for compliance and to meet the ecological needs of the system. Some studies apply a reduced tolerance, however for this comparison this added complexity was not included.

The following three case studies have been chosen to show the impact of the 'or natural' clause on environmental flow compliance in three different systems:

- A multi-year storage system that has water stored and available as an environmental entitlement that is greater than the annual low flow required. The low flow requirements for this system have been ordered for delivery in the reach directly downstream of storage.
- A multi-year storage system where environmental water is available for delivery based on allocations and carryover from the previous years usage. Allocations for environmental water deliverables are governed by the available water in the entire system.
- A run of river system that is unregulated where environmental flows are not able to be delivered using stored environmental entitlements, but where compliance can be impacted by changing demand characteristics (for example by converting direct irrigation entitlements to winterfill) and operating rules (for example by altering restriction triggers or passing flow requirements). The environmental flow compliance was calculated at a flow compliance point directly downstream of an urban offtake in the river.

Case study: Environmental share of storage, available environmental entitlement, and multi-year storage scenario.

The first case study analyses the impact of the 'or natural' clause for low flow requirements when the available environmental entitlement is large enough to supply the low flow volume and there is a share in storage available for the environment.

The warm season (December to March) and cool season (June to November) low flow compliance for each climate change scenario is shown in Table 1 when the low flow requirement without 'or natural' is delivered. The lowest compliance of 65% occurs for the summer low flow under the RCP 8.5 2065 High Climate Change Scenario. This shows that the environmental share in storage is limiting the delivery of the low flow requirement.

Table 1. Summer and winter low flow compliance for available Environmental Entitlement Scenario

Climate Change Scenario	Warm season low flow compliance			Cool season low flow compliance		
	No 'Or Natural'	With 'Or Natural'	% difference	No 'Or Natural'	With 'Or Natural'	% difference
Natural flow changing with future climate						
Post-1975 baseline climate	92%	100%	+8%	94%	100%	+6%
Post-1997 step climate	77%	100%	+23%	86%	100%	+14%
RCP 8.5 2020 High Climate Change	88%	100%	+12%	93%	100%	+7%
RCP 8.5 2040 High Climate Change	78%	100%	+22%	87%	100%	+13%
RCP 8.5 2065 High Climate Change	65%	98%	+33%	80%	92%	+12%
Natural flow set to current climate						
Post-1975 baseline climate	92%	100%	+8%	94%	100%	+6%
Post-1997 step climate	77%	99%	+22%	86%	100%	+14%
RCP 8.5 2020 High Climate Change	88%	100%	+12%	93%	100%	+7%
RCP 8.5 2040 High Climate Change	78%	100%	+22%	87%	99%	+12%
RCP 8.5 2065 High Climate Change	65%	98%	+33%	80%	92%	+12%

With the addition of the 'or natural' clause, low flow compliance increases to 100% for nearly all climate change scenarios, with the exception of the 2065 High Climate Change Scenario. As shown in Figure 1, the natural flow for each scenario is lower than the low flow requirement for 40-50% of the model run period. As the volume of environmental water being ordered with the 'or natural' clause is smaller than the low flow requirement, the environment share in storage is not drawn down as frequently and is able to provide the low

flow requirement (or natural) during the key drought periods (Figure 2). As well, the environmental water being ordered is the same as the natural flows upstream of the storage, so even when there is no environmental water available in storage, the natural flow can be passed and delivered to the environmental flow compliance location.

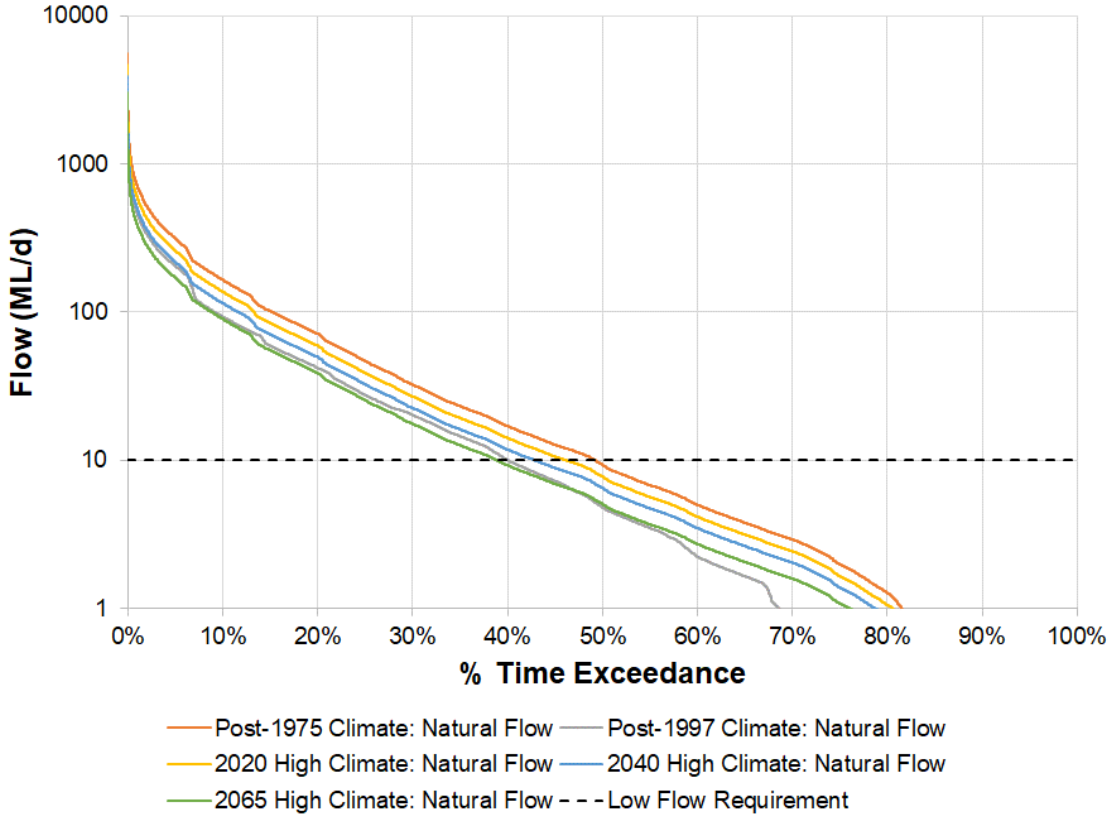

Figure 1. Flow duration comparison of the low flow requirement and the natural flow for each climate change scenario

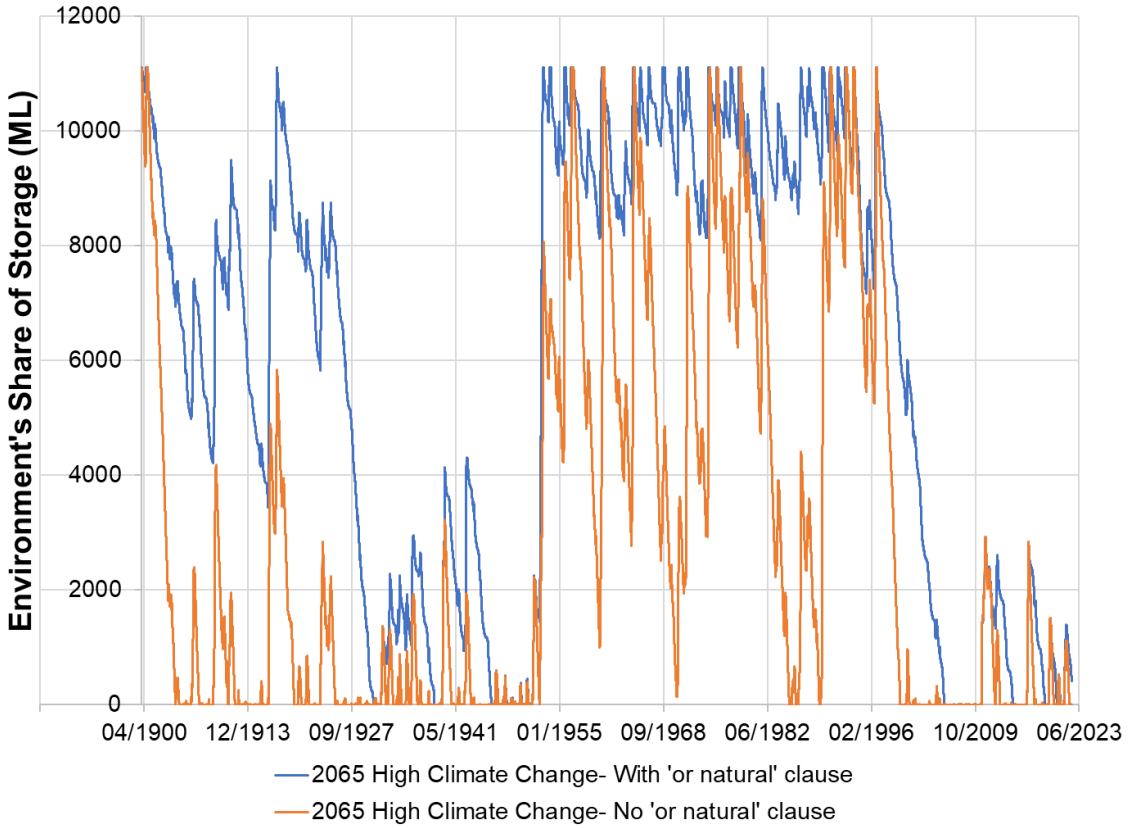

Figure 2. Comparison of environmental share of storage with and without the 'or natural' clause for 2065 High Climate Change Scenario

The natural flow for each future climate change scenario was then set to the natural flow under current climate, and it was found that the environmental entitlement and water available in storage was enough to deliver the required environmental flow (Table 1).

Results show that using natural flows under future climate masks the impact of flows reduced due to climate change on meeting environmental objectives. In this case the results using natural flows under current climate shows there is still reasonable compliance with low flow objectives under future climate.

Case study: Multi-year storage scenario where environmental water delivery is based on available allocation.

This case study investigates a multi-year storage system in Western Victoria where environmental water is available to be ordered and delivered based on the available allocation in a given month. The environmental water can be carried over from year to year. Delivery of low flows requires the available allocation for a given month to be greater than the minimum flow required in the river.

As shown in Table 2, there is poor warm (November to April) and cool (May to October) season low flow compliance without the 'or natural' clause under future climate in 2040 and 2065 showing less than 40% compliance over the model run period. The inclusion of the 'or natural' clause resulted in a significant increase in warm and cool season low flow compliance, with the natural flow required being substantially lower than the minimum flow requirement. All low flow compliance is above 95% and 90% for the warm season and cool season low flow recommendations respectively.

Table 2. Summer and winter low flow compliance for no share in storage but available environmental entitlement scenario

Climate Change Scenario	Warm season low flow compliance			Cool season low flow compliance		
	No 'Or Natural'	With 'Or Natural'	% difference	No 'Or Natural'	With 'Or Natural'	% difference

Natural flow changing with future climate						
Post-1975 baseline climate	69%	98%	+29%	74%	97%	+24%
Post-1997 step climate	46%	98%	+52%	62%	96%	+34%
RCP 8.5 2020 High Climate Change	51%	98%	+47%	66%	95%	+29%
RCP 8.5 2040 High Climate Change	33%	97%	+64%	59%	93%	+34%
RCP 8.5 2065 High Climate Change	10%	97%	+87%	46%	90%	+44%
Natural flow set to current climate						
Post-1975 baseline climate	69%	98%	+29%	74%	98%	+24%
Post-1997 step climate	46%	92%	+46%	62%	87%	+25%
RCP 8.5 2020 High Climate Change	51%	92%	+41%	66%	94%	+28%
RCP 8.5 2040 High Climate Change	33%	45%	+12%	59%	74%	+15%
RCP 8.5 2065 High Climate Change	10%	14%	+4%	46%	47%	+1%

An additional set of scenarios were run to investigate setting the natural flow to current climate conditions (post-1975 baseline natural flow) for all future climate change scenarios. As shown in Table 2, whilst there is significant improvement for the post-1997 and 2020 High Climate Change Scenarios that is similar to using the future climate natural flow, the impact of using current climate natural flow is shown in the drier climate change scenarios, where there is only 4% and 1% improvement in warm season and cool season low flow compliance for the 2065 High Climate Change Scenario. In comparison, using the 2065 High Climate Change natural flow would result in an 87% improvement in warm season low flow compliance when compared to the scenario without an 'or natural' clause.

The results show that using natural flows under future climate masks the impact of flows that are significantly reduced by climate change on meeting environmental objectives. In this case the results using natural flows under current climate shows there is still reasonable compliance with low flow objectives for the post-1975 baseline, post-1997 and 2020 climate change cases, but not under 2040 and 2065 high climate change.

Case study: No environmental entitlement and run of river system scenario.

The third case study analyses a run of river system that is unregulated, so environmental water cannot be ordered from storage but where compliance can be impacted by demand characteristics and operating rules. The unregulated system relies on the natural inflows to the system and is therefore vulnerable to the 'or natural' clause when describing environmental flow compliance of the system.

The change in low flow compliance with and without the 'or natural' clause in place is lower when compared to the systems with stored environmental water, however, there is still up to a 30% difference (Table 3) in low flow compliance for the future climate change scenarios with an 'or natural' clause.

Table 3. Summer and winter low flow compliance for no environmental entitlement scenario

Climate Change Scenario	Warm season low flow compliance			Cool season low flow compliance		
	No 'Or Natural'	With 'Or Natural'	% difference	No 'Or Natural'	With 'Or Natural'	% difference
Natural flow changing with future climate						
Post-1975 baseline climate	75%	86%	+11%	83%	96%	+13%
Post-1997 step climate	73%	87%	+14%	80%	97%	+17%
RCP 8.5 2020 High Climate Change	70%	87%	+17%	77%	96%	+29%
RCP 8.5 2040 High Climate Change	64%	87%	+23%	72%	95%	+23%
RCP 8.5 2065 High Climate Change	56%	84%	+28%	62%	92%	+30%
Natural flow set to current climate						
Post-1975 baseline climate	75%	86%	+11%	83%	96%	+13%
Post-1997 step climate	73%	84%	+11%	80%	92%	+12%
RCP 8.5 2020 High Climate Change	70%	79%	+9%	77%	87%	+10%
RCP 8.5 2040 High Climate Change	64%	72%	+8%	72%	77%	+5%
RCP 8.5 2065 High Climate Change	56%	64%	+8%	62%	65%	+3%

When the natural flow is set to the current climate case (post-1975 baseline climate), the improvement in environmental flow compliance is less than when the natural flow is changing with climate. For the RCP 8.5

2065 High Climate Change Scenario, this improvement in flow compliance for the warm season reduces from 28% to 8% by setting the natural flow to current climate.

These results show that the ecological intent of the environmental flow recommendations including the "or natural" clause under current climate is not met under future climate, and that the inclusion of the or natural clause with changing natural flows masks the reduction in low flow compliance under increasing climate change.

Impact on ecological risks

Flow recommendations often include an 'or natural' clause to account for the fact that some waterways have periods of naturally low flow which can be below the value specified in the flow recommendations. The 'or natural' clause means that flows many still be deemed to be compliant when the predicted natural flows at the compliance point are 'naturally' providing less than the recommended magnitude, frequency, or duration, provided that the flow, frequency and/or duration at the compliance point is equal to or greater than the predicted natural flow. These 'or natural' flow requirements have been developed in the context of current flow conditions. The consequence of the 'or natural' clause is that there can be very low flows at certain times of year that are considered natural in reference to flows under current climate. These periods of extreme low flow will become more frequent and severe under future climate and will potentially no longer reflect natural flows under current climate and their associated ecological outcomes.

The inclusion of an 'or natural' clause under future climate conditions introduces unintended consequences in assessments of whether ecological outcomes are at risk under climate change. In the future climate scenarios for many (if not all) Victorian catchments, there is a general reduction in flows, which can be particularly evident in summer low flows. If compliance with flow recommendations adopts the 'or natural' value from the future scenario, then essentially it is accepting that these lower flows are ecologically sustainable and therefore compliant with the recommendations. However, the inclusion of the 'or natural' clause assumed a stationary climate and the low flow conditions in future climate scenarios may in fact be too shallow or of such an extended duration that the system is ecologically "stressed" rather than naturally able to cope.

For example, in some systems there are short 'cease to flow' periods under current conditions and in the historical record. However, under future climate the duration of these 'cease to flow' periods can be substantially extended. If the 'or natural' clause is adopted then these periods may be deemed to comply when in fact the extended duration of cease to flow would likely result in disconnection along the waterway, fragmentation into pools, and poor water quality in some of those pools. The outcome may be the loss of ecological values.

In some systems, environmental flow recommendations also vary depending on whether conditions in that year are categorized as wet, average, dry or drought. In Victoria, these categories are used to develop seasonal watering plans, where the conditions are defined as:

- Drought: no or negligible contributions from unregulated flows; waterways may stop flowing at times, more likely in summer or autumn
- Dry: minor contributions from unregulated reaches and tributaries, more likely in winter and spring
- Average: unregulated flows provided extended low flows and multiple freshes, more likely in winter and spring; minor storage spills may occur.
- Wet: extended unregulated high flows, multiple large storage spills and overbank flooding, more likely in winter and spring but possible any time of the year

The hydrologic thresholds related to these different climatic conditions are not explicitly defined, however they are generally relatable to annual flow volume percentiles. For example, a threshold of the lowest 5th percentile of annual flow volumes was used to define drought years in a recent FLOWS study on the Glenelg and Ovens rivers (Streamology, 2024a and b). However, if a hydrologic threshold is used to define these categories (e.g. drought years are the lowest 5th percentile annual flow volume years), and this does not vary by future climate scenario, it is likely that under for example a 2065 high climate change scenario, many more years will be

classified as dry or in drought. This was indeed the case for the recent Lower Ovens and Glenelg River FLOWS studies (Streamology 2024a and b) where the frequency of years that would be considered "drought" under natural conditions increased by 283% and 433% respectively in these systems by 2065. In turn, this can result in reduced environmental water requirements if fewer flow components are recommended for dry or drought years compared with average or wet years. If hydrological indicators or environmental flow shortfall approaches are then used to assess ecological outcomes, high compliance metrics and low shortfall volumes may mask that environmental assets are being stressed because there are more 'dry' and 'drought' years under the projected climate change scenario.

Conclusions

The inclusion of the 'or natural' clause in cool and warm season low flow requirements increases low flow compliance under future climate conditions. This is due to the reduction of natural flow as climate change impacts become more severe, requiring less water to be delivered to the environmental flow compliance point. Of the three case studies examined, it was found that the system with no environmental storage available was most impacted by the inclusion of a changing 'or natural' clause. The case study where environmental storage is available showed that environmental flow compliance was less impacted by a current or future 'or natural' clause as stored water was available to provide both scenarios.

Whilst inclusion of the 'or natural' clause either changing with future climate scenario or set to current climate significantly improved the low flow compliance for each case study, the degree to which it improved was based on the availability of stored environmental water in the system. The run of river system improved less than a system with stored water available as the inclusion of the 'or natural' clause allowed environmental water to be retained in storage for drier periods.

The increase in low flow compliance due to the 'or natural' clause under future climate masks the potential severity of the impact of climate change on environmental outcomes since more frequent and severe low flow conditions may no longer meet the ecological needs that were met by natural flows under current climate; for example, reduced frequency of inundation of instream benches, longer periods of very low flows and potentially flow disconnection within a system. Under future climate there is also an increase in what is currently defined as 'dry' to 'drought' years, and if environmental flows suitable for these dry or drought conditions are provided more frequently, then there is likely to be a negative impact on ecological values and the ability of ecological systems to adapt to changes in climate.

It is concluded that for analysis of environmental flow compliance under future climate the natural flow thresholds defined for current climate conditions provide a better indication of ecological outcomes. Alternatively, reprioritising the ecological assets supported when less water is available in the future may be possible through developing climate ready ecological flow objectives. More generally, it is recommended that the impact of future climate on the 'or natural' clause be taken into account in FLOWS studies undertaken in future, and for future FLOWS method reviews.

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