



OFFICIAL



**Climate resilience modelling of waterways
influenced by Barwon Downs borefield**

Scenario Forecast Modelling Report

Final

27/06/2025

Document status

Client	Barwon Water
Project	Climate resilience modelling of waterways influenced by Barwon Downs borefield
Report title	Scenario Forecast Modelling Report
Version	Final
Authors	Katherine Szabo
Project manager	Katherine Szabo
File name	BWA00017_RP_ClimateResilienceModelling_ScenarioForecastModellingReport_Final
Project number	BWA00017

Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
0.1	15/01/2025	K. Austin	K. Austin	W. McCance	Draft for review
0.2	05/02/2025	K. Austin	K. Austin	W. McCance	Revised draft to account for feedback
0.3	16/04/2025	K. Austin	K. Austin	W. McCance	Revised draft following presentation of results to the Remediation Reference Group
0.4	06/06/2025	K. Austin	K. Austin	W. McCance	Minor updates based on BW comments
Final	27/06/2025	K. Austin	K. Austin	W. McCance	Final version

Copyright and Limitation

This report has been produced by Hydrology and Risk Consulting Pty Ltd ACN 603 391 993 ("HARC") for Barwon Water. Unless otherwise indicated, the concepts, techniques, methods and information contained within the report are the intellectual property of HARC and may not be reproduced or used in any form by third parties without the express written consent of HARC and Barwon Water.

The report has been prepared based on the information and specifications provided to HARC by Barwon Water. HARC does not warrant this document as being complete, current or free from error and disclaims all liability for any loss, damage, costs or expenses (including consequential losses) relating from this report. It should only be used for its intended purpose by Barwon Water and should not be relied upon by third parties.

Copyright © Hydrology and Risk Consulting Pty Ltd ACN 603 391 993. All rights reserved.

Contents

1. Introduction	4
2. Scenario modelling assumptions	9
2.1 Climate change	9
2.2 Scenario modelling assumptions	10
2.2.1 Boundary Creek Supplementary Flows	10
2.2.2 Urban demands	11
2.2.3 Farm dam impacts	11
2.2.4 Full uptake of rural demands	12
3. Gellibrand system modelling results	14
3.1 Predicted response to future medium climate change projections	14
3.1.1 Water balance of system	15
3.1.2 Impact on flow at key locations	16
3.1.2.1 Full climate sequence	16
3.1.2.2 Typical wet and dry periods	23
3.2 Uncertainty in water availability under climate change	27
3.2.1 Water balance of system	27
3.2.2 Impact on flow at key locations	29
3.3 Impact of groundwater pumping on current surface water flow regime	32
3.3.1 Water balance of system	32
3.3.2 Impact on flow at key locations	33
3.4 Impact of full uptake of rural demands on system resilience under future climate	38
3.4.1 Water balance of system	38
3.4.2 Impact on flow at key locations	40
4. Boundary Creek system modelling results	41
4.1 Predicted response to future median climate change projections	41
4.1.1 Water balance of system	42
4.1.2 Supply of rural demands	43
4.1.3 Impact of flow on at key locations	44
4.1.3.1 Full climate sequence	44
4.1.3.2 Typical wet and dry periods	48
4.2 Uncertainty in water availability under climate change	52
4.2.1 Water balance of system	52
4.2.2 Supply of rural demands	54
4.2.3 Impact on flow at key locations	55
4.3 Impact of groundwater pumping on current surface water flow regime	58
4.3.1 Water balance of system	58
4.3.2 Supply of rural demands	59
4.3.3 Impact on flow at key locations	59



4.4	Impact of full uptake of rural demands on system resilience under future climate	61
4.4.1	Water balance of system	61
4.4.2	Supply of rural demands	63
4.4.3	Impact on flow at key locations	63
5.	Conclusions	65
6.	References	68
	Appendix A Scenario modelling results	69
A.1	Gellibrand River catchment	69
A.1.1	Water Balances	69
A.1.2	Average annual flows	73
A.1.3	Proportion of supplied demands	75
A.2	Boundary Creek catchment	76
A.2.1	Water Balances	76
A.2.2	Average annual flows	79
A.2.3	Proportion of supplied demands	81

Executive Summary

Between 1982 and 2016, Barwon Water intermittently extracted groundwater from the Barwon Downs borefield to supplement drinking water supplies during dry periods. The Barwon Downs borefield accessed water contained within the deep tertiary aged sediments, known as the Lower Tertiary Aquifer. These activities have led to hydraulic influences on select surface water features within the Gellibrand and Barwon River catchments that receive direct groundwater discharge from the Lower Tertiary Aquifer. The objective of this project is to:

- assess the resilience of these surface water systems under projected future climate scenarios,
- better understand the changes that are likely to occur in response to these climate related influences, and
- compare these changes to what is likely to have occurred if groundwater pumping never occurred.

This report documents the process and outcomes of scenario modelling. Scenario modelling has been undertaken to assess the current and future performance of Gellibrand and Boundary Creek catchments under various climate change and groundwater recovery scenarios. The scenarios have been developed to answer the following key questions:

- What is the predicted response of each catchment to future medium climate change projections?
- What is the uncertainty in water availability under climate change?
- What is likely to have occurred if groundwater pumping never occurred?
- What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?

A hydrological model was developed for Gellibrand River catchment down to Bunkers Hill and the Boundary Creek catchment. Key assumptions for deriving inputs to the hydrologic models, including catchment impacts, have been outlined in the model development report (BW and HARC, 2024). Scenario modelling has been undertaken using these models to assess the resilience of the surface water systems under project future climate and catchment impact scenarios. The following conclusions were made regarding the future climate resilience of these systems:

- All catchments are susceptible to future climate related impacts. With the highest percentage reduction in flows expected to occur within the Barwon River, irrespective of groundwater remediation.
- Under a medium climate change scenario:
 - Remediation actions are expected to reduce the impacts of climate change on Boundary Creek, at least for a short period of time, but in the longer-term term (beyond 2040) are unlikely to lead to any net improvement. This indicates that in the



future, climate related factors alone may result in conditions returning to what we see today.

- The increase in flows anticipated in Yahoo Creek due to recovery of groundwater discharge from the LTA is greater than the predicted climate related impacts, leading to a net increase in flows in 2040 and 2065 compared to the current state.
- Full uptake of rural demands has a negligible impact on the resilience of each catchment. However, under a remediated state, take and use licence holders along Boundary Creek are unlikely to be able to access their full entitlements in the absence of supplementary flows.
- Forecast climate related impacts could be 20-40% higher or 14-35% lower depending on the severity of climate change. The uncertainty in the impact of climate change on water availability was found to be similar, regardless of the subcatchment.



1. Introduction

Between 1982 and 2016, Barwon Water intermittently extracted groundwater from the Barwon Downs borefield to supplement drinking water supplies during dry periods. The Barwon Downs borefield accessed water contained within the deep tertiary aged sediments, known as the Lower Tertiary Aquifer. These activities have led to hydraulic influences on select surface water features that receive direct groundwater discharge from the Lower Tertiary Aquifer, including:

- Boundary Creek,
- Yahoo Creek, and
- The Gellibrand River.

The objective of this project is to:

- assess the resilience of these surface water systems under projected future climate scenarios,
- better understand the changes that are likely to occur in response to these climate related influences, and
- compare these changes to what is likely to have occurred if groundwater pumping never occurred.

This report documents the process and outcomes of scenario modelling. Scenario modelling has been undertaken to assess the current and future performance of Gellibrand and Boundary Creek catchments under various climate change and groundwater recovery scenarios. The scenarios have been developed to answer the following key questions:

- What is the predicted response of each catchment to future medium climate change projections?
- What is the uncertainty in water availability under climate change?
- What is likely to have occurred if groundwater pumping never occurred?
- What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?

The scenarios modelled are summarised in Table 1-1 and have been labelled as follows, noting that the labels in bold have been utilised in the scenario modelling results analysis:

- Scenario 1 - **No further groundwater recovery**: Current demand assumptions with no further groundwater level recovery in future (i.e., current groundwater pumping impacts apply in 2040 and 2065). This scenario provides a baseline for what can be expected if successful remediation cannot be achieved.
- Scenario 2 – **Remediated state**: This scenario assumes that in 2040 and 2065 groundwater discharge from the Lower Tertiary Aquifer into receiving waterways is nearing pre-pumping levels. This is indicative of what successful remediation would look like.



- **Scenario 3 - No pumping:** Current demand assumptions with no groundwater pumping impacts on the system. This is representative of what would have occurred if groundwater pumping from the Barwon Downs borefield never occurred (i.e. known impacts are added back in).
- **Scenario 4 - Full uptake:** This scenario is representative of what would occur post remediation if full update of rural licence volumes occurred in the future (in 2040 and 2065)

The RCP 8.5 2020 medium climate change projection has been assumed to be the base climate case. This allows the evaluation of climate change uncertainty by comparison with the low and high climate change projections, as well as assessment of performance of each system under future climate relative to the 2020 climate.

The subsequent sections of this report investigate the implications and results for each scenario. The full set of results for each scenario is available in Appendix A.



Table 1-1 Summary of scenarios

Scenarios	Purpose	Groundwater pumping assumption	Boundary Creek supplement ary flow status	Demand assumptions	RCP 8.5 2020 climate change scenario			RCP 8.5 2040 climate change scenario			RCP 8.5 2065 climate change scenario		
					Low	Med	High	Low	Med	High	Low	Med	High
1	No further groundwater recovery	To assess how the system may respond if successful remediation cannot be achieved	Current groundwater pumping impact assumptions for 2020, 2040 and 2065	On: 2020 Off: 2040, 2065	Current demands which represent the private diverter usage as at 2024 level of development. This is applied over the historic climate sequence of 1900 to 2021.	✓	Base Case	✓	✓	✓	✓	✓	✓
2	Remediated state	To assess how the system may respond if successful remediation is achieved	Current groundwater pumping impact assumptions used for 2020. Assumes that in 2040 and 2065 groundwater discharge from the Lower Tertiary Aquifer into receiving waterways is nearing pre-pumping levels.	Off: 2040, 2065 – as these would no longer be required	Current demands which represent the private diverter usage as at 2024 level of development. This is applied over the historic climate sequence of 1900 to 2021.				✓	✓	✓	✓	✓
3	No pumping scenario	To assess how the system would likely have responded if groundwater pumping never occurred	No groundwater pumping impacts for 2020, 2040 and 2065	Off for 2020, 2040 and 2065 as these would never have been required	Current demands which represent the private diverter usage as at 2024. This is applied over the historic climate sequence of 1900 to 2021.	✓	✓	✓	✓	✓	✓	✓	✓
4	Full entitlement scenario	To assess what is likely to occur if users access their full entitlements	Assumes groundwater levels have recovered to 90% of pre-pumping levels	On: 2020 Off: 2040, 2065	All take and use licence volumes in the catchments are fully utilised	✓	✓	✓	✓	✓	✓	✓	✓

2. Scenario modelling assumptions

2.1 Climate change

For future scenario modelling, climate change projections are required to determine the availability of water under 2020, 2040 and 2065 climate conditions. The historic climate and inflow inputs derived as outlined in the Model Development Report (BW and HARC, 2024) were adjusted to represent the following climate change projections, as recommended by the *Guidelines for Assessing the Impact of Climate Change in Water Availability in Victoria* (DELWP, 2020):

- Reference climate (pre-1975 data adjusted to match characteristics of post-1975 data)
- RCP 8.5 2020 low climate change projection
- RCP 8.5 2020 medium climate change projection
- RCP 8.5 2020 high climate change projection
- RCP 8.5 2040 low climate change projection
- RCP 8.5 2040 medium climate change projection
- RCP 8.5 2040 high climate change projection
- RCP 8.5 2065 low climate change projection
- RCP 8.5 2065 medium climate change projection
- RCP 8.5 2065 high climate change projection

For all projections the Representative Concentration Pathway (RCP8.5) has been adopted. The RCP8.5 case incorporates high rates of greenhouse gas emissions and is suitably precautionary for water supply planning applications. It considers global climate modelling uncertainty and uncertainty around future greenhouse gas emissions and concentrations. These projections (low, medium and high) represent the 10th, 50th and 90th percentile outcome from the 42 available global climate models (GCMs).

As outlined by DELWP (2020), the reference climate series is developed by applying seasonal decile scaling prior to 1975 to produce a stationary dataset that is representative of post 1975 climate behaviour. The seasonal scaling applied was for two seasons: warm (November to March) and cool (April to October). The climate change factors outlined in DELWP (2020) and summarised in Table 2-1 are then applied to the reference climate time series to produce the required climate change inputs.

Climate change factors were also applied to the inflow and climate inputs to the farm dam models developed in the Model Development Report and re-run under both future climate and with the future growth assumptions outlined in Section 2.2.

Table 2-1 Summary of climate change runoff factors adopted for Gellibrand (Otway Coast) and Boundary Creek (Barwon River) systems

RCP 8.5 climate change projection	Annual runoff scaling factors for climate change (%)	
	Otway Coast basin	Barwon River basin
2020 low	+3.6%	+9.0%
2020 med	-4.0%	-3.4%
2020 high	-14.1%	-18.4%
2040 low	+6.6%	+16.1%
2040 med	-7.2%	-6.1%
2040 high	-25.3%	-33.1%
2065 low	-4.7%	-0.8%
2065 med	-15.8%	-21.6%
2065 high	-41.9%	-47.6%

2.2 Scenario modelling assumptions

Scenario modelling has been undertaken using a long-term climate sequence (from 1900 to 2021) adjusted to represent either current or future climate conditions, as described in Section 2.1. These adjusted climate series are described as stationary as changes over time due to influences such as climate change have been removed. For each scenario these stationary climate series are paired with a stationary demand and groundwater pumping impact assumption. The demand and groundwater pumping impact assumptions for each scenario have been varied to provide a range of reference points that help understand what can be expected if remediation is successful, if recovery stagnates or if private diverter usage increases in response to a changing climate.

When stationary climate, demand and groundwater pumping impacts are used in a long-term model run this allows the reporting of long-term average annual impacts across a range of wet, average and dry sequences, as well reporting on the likelihood of particular system outcomes (e.g. restrictions or shortfalls), and the reporting of system performance under drought sequences.

2.2.1 Boundary Creek Supplementary Flows

As part of the historic licence renewal process, Barwon Water were required to release supplementary flows into the headwaters of Boundary Creek to offset potential groundwater pumping related impacts on Boundary Creek. Today, supplementary flows continue to be provided, where required, in accordance with the Boundary Creek and Big Swamp Remediation Plan (Barwon Water, 2024) to mitigate against prolonged cease to flow events. However, in line with the Remediation Plan, successful remediation includes the phasing out of these releases when the system has sufficiently recovered.

As such, supplementary flows would not have occurred under a no pumping scenario, and have also been switched off in the 2040 and 2065 scenarios based on the observed groundwater recovery following the cessation of groundwater pumping activities in 2016.

2.2.2 Urban demands

Flows in the Gellibrand and Barwon River catchments are impacted by urban extractions to supply Colac, Gellibrand and Geelong. Barwon Water's future surface water harvesting in 2040 and 2065 accounts for population growth and the impacts of climate change on BW storages. This remains below the maximum take limits outlined in BW's Bulk Entitlements.

As confirmed with Barwon Water (pers. comm C. McTaggart, 29/11/2024), it has been assumed that Gellibrand's current population of 73 grows by 4.1% in 2040 and 9.6% in 2065.

2.2.3 Farm dam impacts

Farm dams intercept and harvest catchment runoff, impacting the natural flow regime, particularly during dry periods.

Farm dam impacts have been modelled by determining the number and size of dams in each subcatchment and carrying out a water balance on each farm dam which includes net evaporation, usage and overflow, as shown in Figure 2-1.

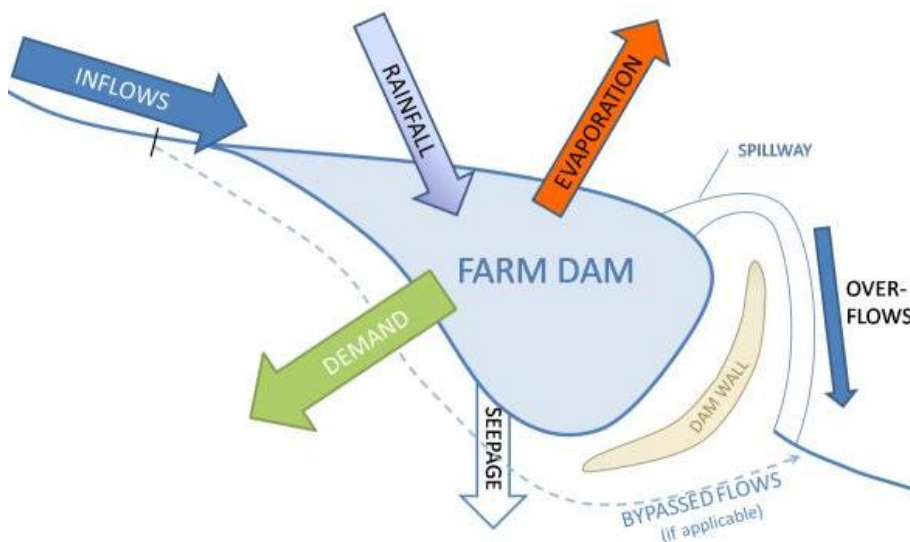


Figure 2-1 Schematic of farm dam water balance (Fowler et.al, 2012)

Farm dam impacts have been derived using the current distribution of farm dams in the Boundary Creek and Gellibrand River catchments, and their growth considered as part of future climate change scenarios.

Based on investigations carried out in HARC (2020) for 2040 and 2065, the impact of stock and domestic (<5 ML) farm dams was increased as per Table 2-2 across all Boundary Creek and Gellibrand River subcatchments. The resulting increase in average annual farm dam impacts for the Gellibrand River and Boundary Creek catchments is shown in Table 2-3.

The increase in demand from farm dams used for irrigation due to future climate has not been modelled. However, increases in irrigation demand by take and use licence holders (direct irrigation, onstream or offstream winterfill) has been captured by the full uptake scenario.

Table 2-2 Domestic and stock farm dam growth assumptions calculated in HARC (2020) and associated farm dam volumes in the Gellibrand and Boundary catchments

Level of development	% increase in stock and domestic farm dams per year ¹ in Love Creek	Total farm dam volumes (ML)	
		Gellibrand River catchment	Boundary Creek catchment
Current	0	562.7	309.5
2040	0.3%	580.8	317.6
2065	1.4%	685.9	364.5

increase every year from 2020 to 2040 and 2065

Table 2-3 Average annual farm dam impacts calculated from 1900 to 2021

Level of development	Average annual farm dam impact (ML/yr)	
	Gellibrand River catchment	Boundary Creek catchment
Current	417.9	245.9
2040	447.6	248.5
2065	554.8	293.8

2.2.4 Full uptake of rural demands

Rural demands in the Gellibrand and Barwon River systems include use by direct irrigation, commercial and industrial, domestic and stock, dairy and on-stream and off-stream winterfill take and use licence holders.

The full uptake scenario assumes that all take and use licences in the catchments are fully utilised. A summary of current level of development and full uptake demands can be found in Table 2-4, noting that the Gellibrand direct irrigation and private on-stream dam along Boundary Creek full uptake demands are calculated such that the maximum modelled usage year from 1900 to 2021 is equivalent to the licence volume.

There is no change to stock and domestic, dairy and commercial and industrial demand as the current level of development is equal to the licence volume. The full uptake scenario increases the total Gellibrand rural and irrigation demands to 376.5 ML/yr and 69.4 ML/yr for Boundary Creek upstream of Yeodene.

It is important to note that modelling does not factor in existing water rights holders along Boundary Creek downstream of Big Swamp as these are now supplied by Barwon Water's stock pipeline.



Table 2-4 Full uptake assumptions for the Gellibrand and Boundary catchments

	Current demand (ML/yr)	Licence Volume (ML/yr)	Full uptake demand (ML/yr)
Gellibrand River and Love Creek direct irrigation demands	0	168.4	90.2
Gellibrand River rural (S&D, dairy, C&I) demands	76.3	76.3	76.3
Gellibrand River onstream and off-stream winterfill demands	110.7	210	210
Total Gellibrand	187	454.7	376.5
Boundary Creek rural (S&D, Dairy, C&I) demands	7.5	7.5	7.5
Private on-stream dam demands	37.4	115	62
Total Boundary Creek upstream of Yeodene	44.9	122.5	69.4



3. Gellibrand system modelling results

This section outlines the scenario modelling results for the Gellibrand system. Each analysis has been undertaken to illustrate the differences in surface water availability due to different assumptions for groundwater pumping or climate change impacts. The following questions have been investigated:

- **What is the predicted response of each catchment to future medium climate change projection?**

The purpose of this analysis is to compare system behaviour under current climate and groundwater pumping conditions to system behaviour under future climate, with and without further groundwater recovery. The medium climate change projection is used for each time slice (2020, 2040 and 2065).

- **What is the uncertainty in water availability under climate change?**

The purpose of this analysis is to compare the impact on system behaviour of a more severe (RCP 8.5 High Climate Change) or less severe (RCP 8.5 Low Climate Change) climate change projection. The results show the uncertainty in modelling water availability under 2040 and 2065 climate, under the remediated state.

- **What is likely to have occurred if groundwater pumping never happened?**

The purpose of this analysis is to better understand the impact of groundwater pumping related reductions in groundwater discharge on the overall flow regime, and how this affects the resilience of the system.

- **What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?**

The purpose of this analysis is to identify any vulnerability in the system due to take and use licence holders fully utilising their entitlement. The analysis has been undertaken for future climate and assuming a remediated groundwater state for 2040 and 2065. Take and use demands are increased such that the current licenced volume is fully utilised.

The full suite of results for each scenario are included in Appendix A.1.

3.1 Predicted response to future medium climate change projections

This section analyses the performance of the Gellibrand system under medium future climate change projections with and without groundwater recovery by utilising outputs from Scenario 1 (no further recovery) and Scenario 2 (remediated state).

The purpose of this section is to explore the question:

What is the predicted response of each catchment to future median climate change projections?



3.1.1 Water balance of system

A water balance summarises the inputs to and extractions from each system. Comparison of water balances across scenarios allows differences to be readily highlighted.

Water balances of the Gellibrand system down to Bunkers Hill shows the impact of future climate on demands and inflows assuming there is no further groundwater recovery (Table 3-1- Scenario 1) and with future groundwater recovery (Table 3-2- Scenario 2).

In comparing the two scenarios, there is less than 0.5% difference between the outflow at Gellibrand River at Bunkers Hill in 2040 and 2065 between the no further recovery and remediated state scenario, indicating that the forecast reduction of streamflow in the future (between 3.2 and 13%) is driven almost entirely by climate change.

Table 3-1 Water balance for Gellibrand River under the no further groundwater recovery scenario

Average annual water availability calculated for the full climate sequence (ML/yr)					
	Base Case (current pumping impacts)	No further recovery 2040 Med	% diff to BC	No further recovery 2065 Med	% diff to BC
Inflows	91,690	88,636	-3.3%	80,451	-12%
Catchment Inflows	91,474	88,425	-3.3%	80,230	-12%
Farm Dam inflows	216	211	-2.3%	221	+2.3%
Demands	5,248	5,260	+0.2%	5,185	-1.2%
BW extractions to Colac	4,400	4,386	-0.3%	4,192	-4.7%
Rural Demands	186	186	0.0%	185	-0.5%
Farm Dam impacts	644	669	+3.9%	789	23%
Urban demands	18	19	+5.6%	20	+11%
Losses	1,557	1,574	+1.1%	1,590	-0.5%
Groundwater Impacts	397	397	0.0%	395	-0.5%
River losses	1,279	1,283	+0.3%	1,285	+0.5%
Net Evaporation	-120	-106	-12%	-90	-25%
Outflow	84,901	81,821	-3.6%	73,690	-13%
Gellibrand River at Bunkers Hill	84,899	81,819	-3.6%	73,688	-13%
Change in storage	2	2		2	
Balance error (%)	0%	0%		0%	

Table 3-2 Water balance for Gellibrand River under the remediated state scenario

Average annual water availability calculated for the full climate sequence (ML/yr)					
	Base Case (current pumping impacts)	Remediated state 2040 Med	% diff to BC	Remediated state 2065 Med	% diff to BC
Inflows	91,690	88,636	-3.3%	80,451	-12%
Catchment Inflows	91,474	88,425	-3.3%	80,230	-12%
Farm Dam inflows	216	211	-2.3%	221	+2.3%
Demands	5,248	5,260	0.2%	5,186	-1.2%
BW extractions to Colac	4,400	4,386	-0.3%	4,192	-4.7%
Rural Demands	186	186	0.0%	185	-0.5%
Farm Dam impacts	644	669	+3.9%	789	+23%
Urban demands	18	19	+5.6%	20	+11%
Losses	1,557	1,225	-21%	1,245	-20%
Groundwater Impacts	397	40	-90%	40	-90%
River losses	1,279	1,291	+0.9%	1,295	+1.3%
Net Evaporation	-120	-106	-12%	-90	-25%
Outflow	84,901	82,169	-3.2%	74,035	-13%
Gellibrand River at Bunkers Hill	84,899	82,166	-3.2%	74,033	-13%
Change in storage	2	2		2	
Balance error (%)	0%	0%		0%	

3.1.2 Impact on flow at key locations

The flow at key locations has been analysed over the full model run period from 1900 to 2021 and for a low flow and typical wet period.

3.1.2.1 Full climate sequence

The average annual flow over the full climate sequence compared back to the base case has been summarised for each gauge location in Table 3-3.

The outputs from this analysis show that under future climate change, further reductions in flow are anticipated to occur in Love Creek and Gellibrand River, regardless of groundwater remediation. In Yahoo Creek however, the recovery of groundwater discharge from the LTA leads to a net increase in streamflows in 2040 and 2065 compared to the current conditions.

Flow duration curves have been plotted for Yahoo Creek at Kawarren, Love Creek at Kawarren and Gellibrand River at Bunkers Hill for each scenario annually, for the warm season (November to March) and for the cool season (April to October) for 2040 and 2065 medium climate change scenarios.



In Yahoo Creek, the recovery of groundwater discharge from the LTA is forecast to reduce the frequency and duration of low flow periods (Figure 3-1 to Figure 3-3), and reduce the impacts of climate change despite having minimal effect on flows >2 ML/day. This has a positive flow on effect on the flows in Love Creek, but does not lead to significant improvement in overall flows in Love Creek (Figure 3-4 to Figure 3-6).

Over the entire model run period for Gellibrand River at Bunkers Hill, there are negligible changes in the flow duration curves for the annual (Figure 3-7), warm season (Figure 3-8) and cool season (Figure 3-9) between the two scenarios.



Table 3-3 Average annual flow calculated over the full climate sequence at key flow locations compared to the base case

	235227 Gellibrand River at Bunkers Hill	235231 Gellibrand River at Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kawarren
2040 climate change projections				
No further recovery	3.6% reduction in flow (average of 3,080 ML/yr)	3.8% reduction in flow (average of 1,327 ML/yr)	3.9% reduction in flow (average of 304 ML/yr)	4.0% reduction in flow (average of 48 ML/yr)
Remediated state	3.2% reduction in flow (average of 2,732 ML/yr)	3.3% reduction in flow (average of 1,173 ML/yr)	1.3% reduction in flow (average of 102 ML/yr)	13% increase in flow (average of 154 ML/yr)
2065 climate change projections				
No further recovery	13.2% reduction in flow (average of 11,211 ML/yr)	13.4% reduction in flow (average of 4,734 ML/yr)	14.5% reduction in flow (average of 1,129 ML/yr)	14.8% reduction in flow (average of 178 ML/yr)
Remediated state	12.8% reduction in flow (average of 10,866 ML/yr)	13.0% reduction in flow (average of 4,579 ML/yr)	11.9% reduction in flow (average of 929 ML/yr)	1.8% increase in flow (average of 22 ML/yr)

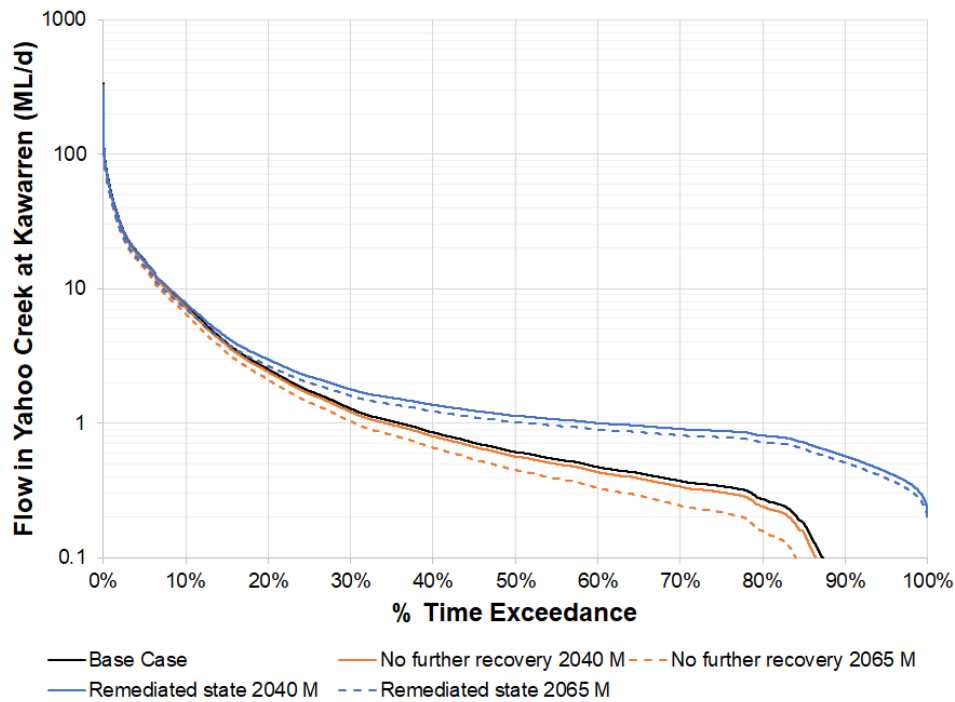


Figure 3-1 Flow duration curve comparison calculated across full climate sequence for future performance scenarios in Yahoo Creek at Kawarren

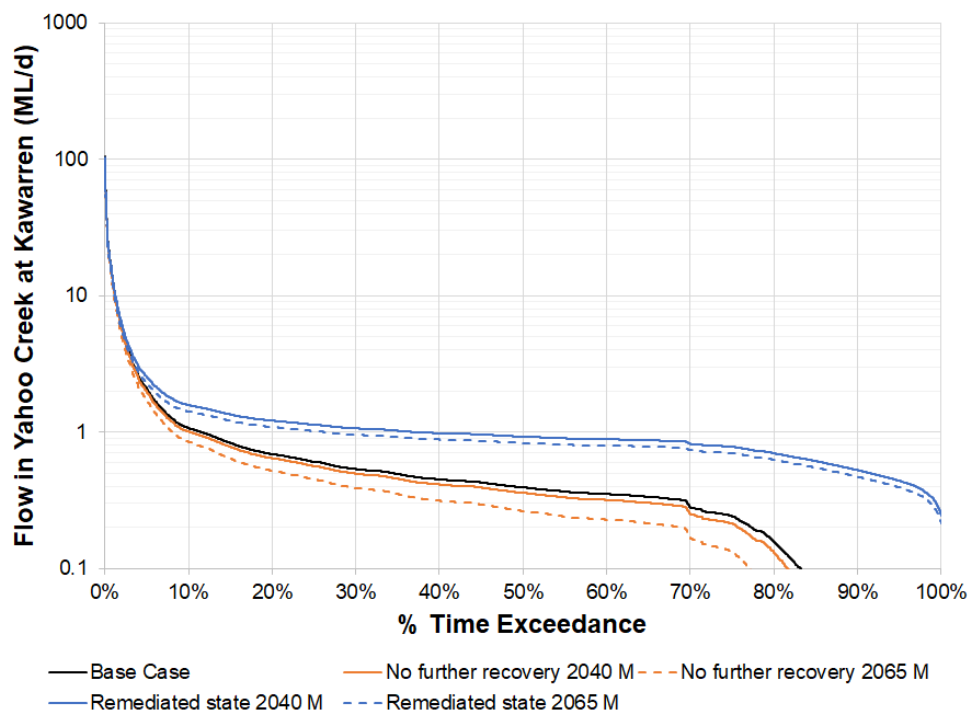


Figure 3-2 Flow duration curve comparison calculated for warm seasons (November to March) across full climate sequence for future performance scenarios in Yahoo Creek at Kawarren

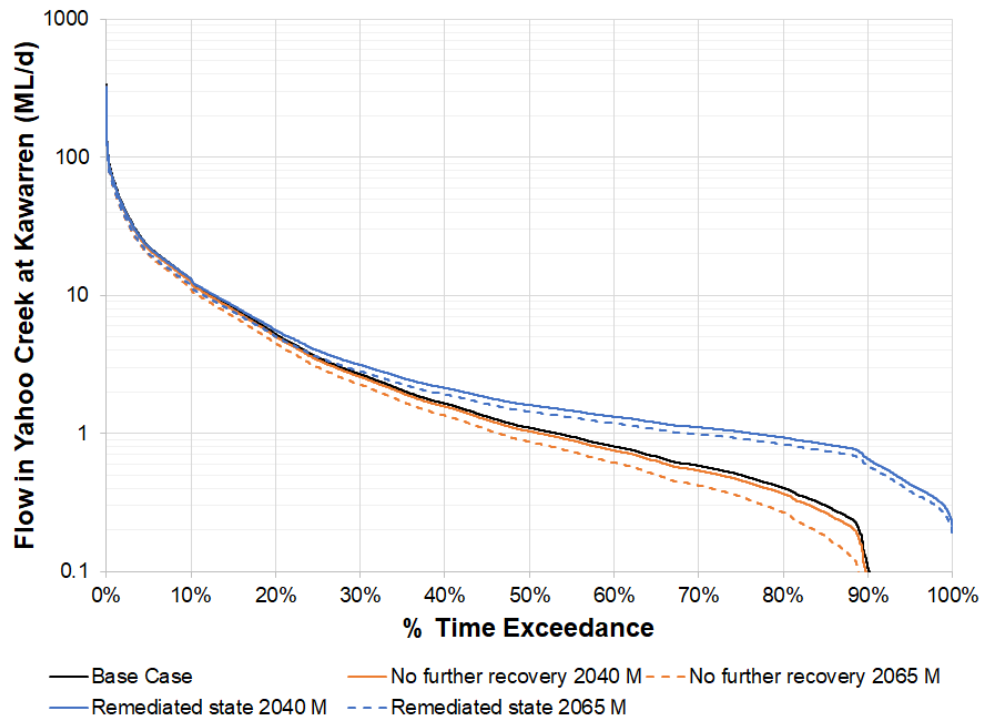


Figure 3-3 Flow duration curve comparison calculated for cool seasons (April to October) across full climate sequence for future performance scenarios in Yahoo Creek at Kwarren

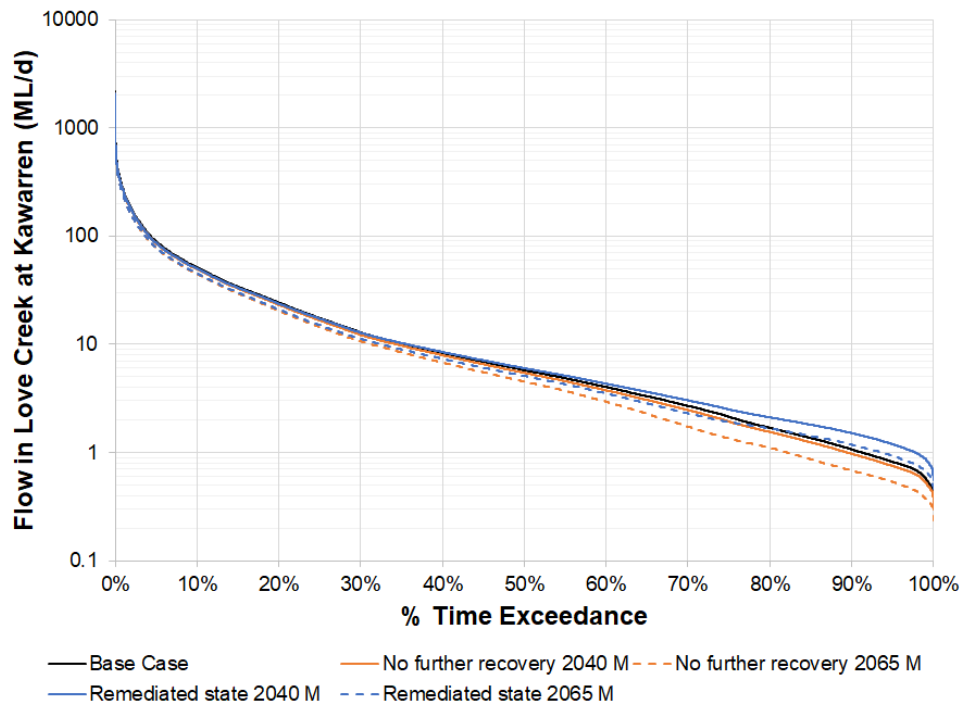


Figure 3-4 Flow duration curve comparison calculated across full climate sequence for future performance scenarios in Love Creek at Kwarren

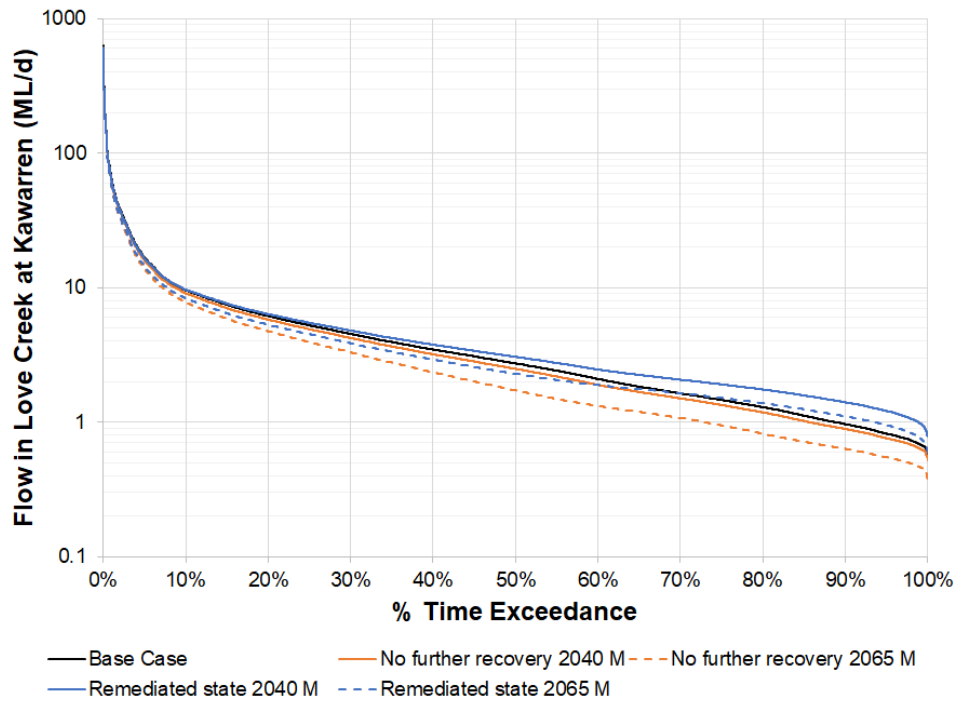


Figure 3-5 Flow duration curve comparison calculated for warm seasons (November to March) across full climate sequence for future performance scenarios in Love Creek at Kwararren

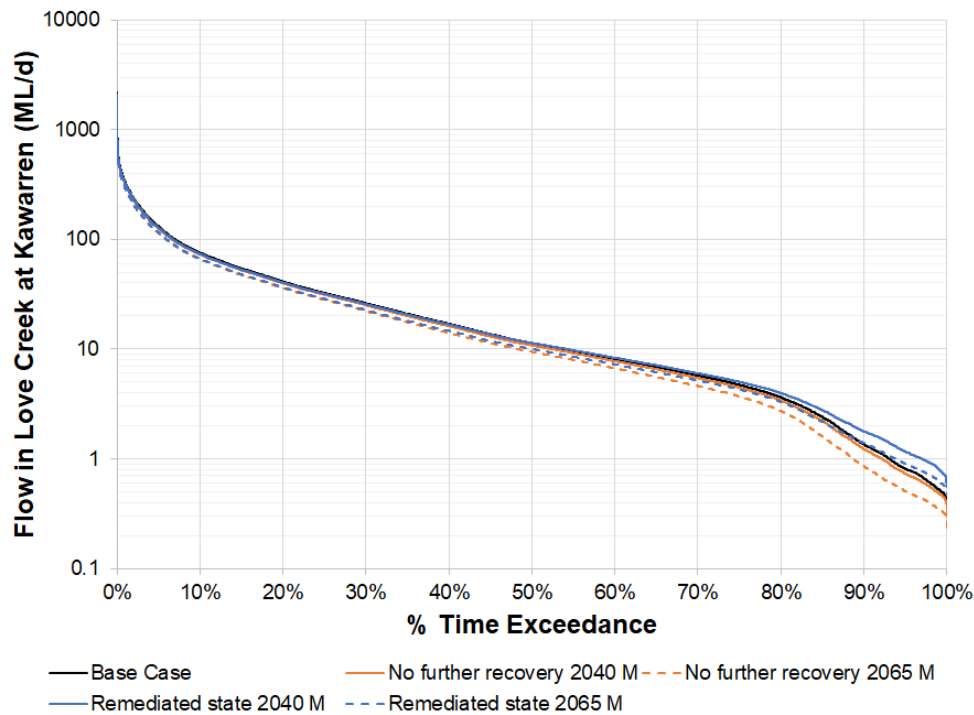


Figure 3-6 Flow duration curve comparison calculated for cool seasons (April to October) across full climate sequence for future performance scenarios in Love Creek at Kwararren

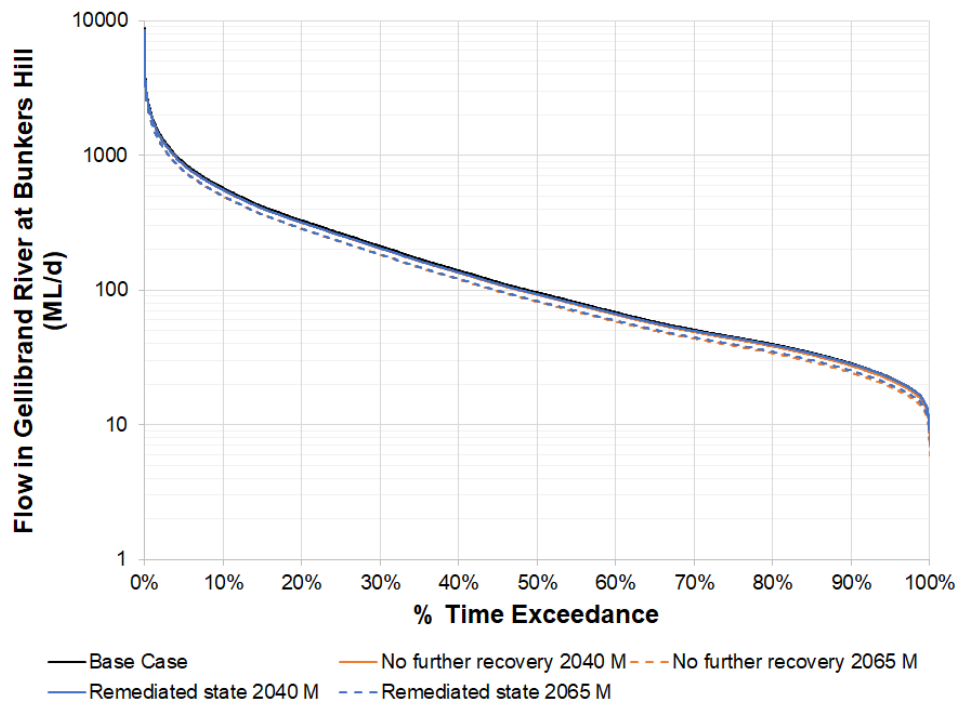


Figure 3-7 Flow duration curve comparison calculated across full climate sequence for future performance scenarios in Gellibrand River at Bunkers Hill

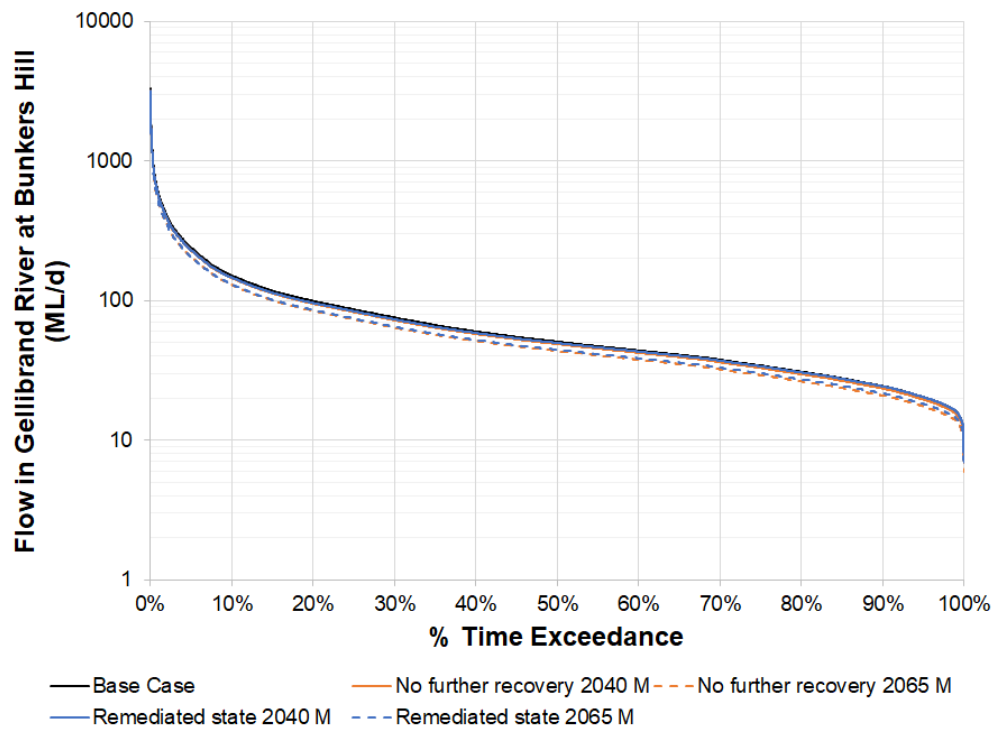


Figure 3-8 Flow duration curve comparison calculated for warm seasons (November to March) across full climate sequence for future performance scenarios in Gellibrand River at Bunkers Hill

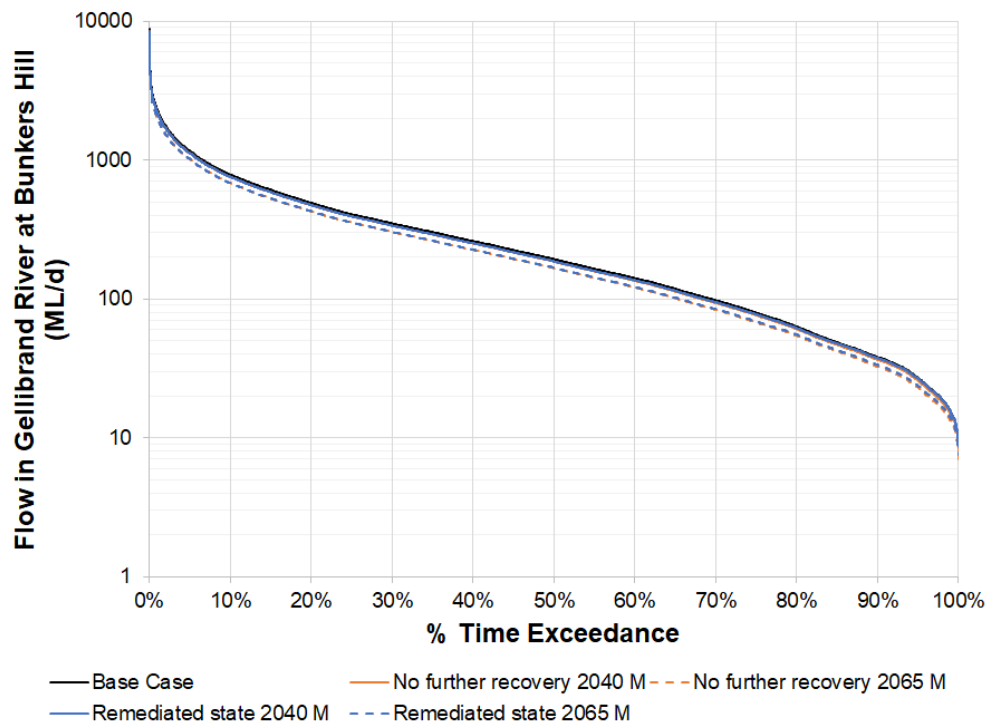


Figure 3-9 Flow duration curve comparison calculated for cool seasons (April to October) across full climate sequence for future performance scenarios in Gellibrand River at Bunkers Hill

3.1.2.2 Typical wet and dry periods

In addition to analysis of system performance over the predicted future climate sequence, the impacts of a future typical low flow and typical wet period have also been investigated to determine how the system may respond under these flow conditions.

Similar to the full climate sequence (refer section 3.1.2.1), the recovery of groundwater discharge from the LTA is not forecast to lead to any change in typical low flow and wet period flows at Gellibrand River at Bunkers Hill (Figure 3-14 and Figure 3-15).

For Yahoo Creek, the recovery of groundwater discharge from the LTA is forecast to lead to improvements in typical low flow conditions of around 0.2-0.4 ML/day (Figure 3-10). However, has minimal impact on the typical winter flows in Yahoo Creek, as shown in Figure 3-11. Given the relationship between Yahoo Creek and Love Creek, the modelling also suggests that any improvement in low flow conditions in Yahoo Creek would lead to similar improvements in flows in Love Creek (Figure 3-12 and Figure 3-13).

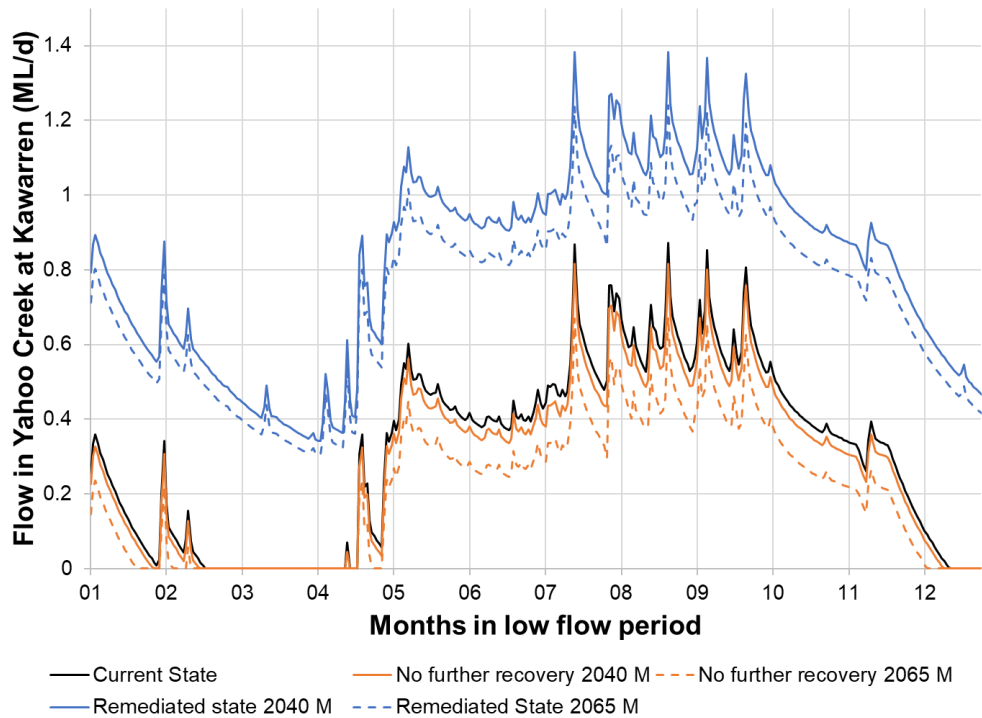


Figure 3-10 Comparison of flow during a dry period for Yahoo Creek at Kwarren

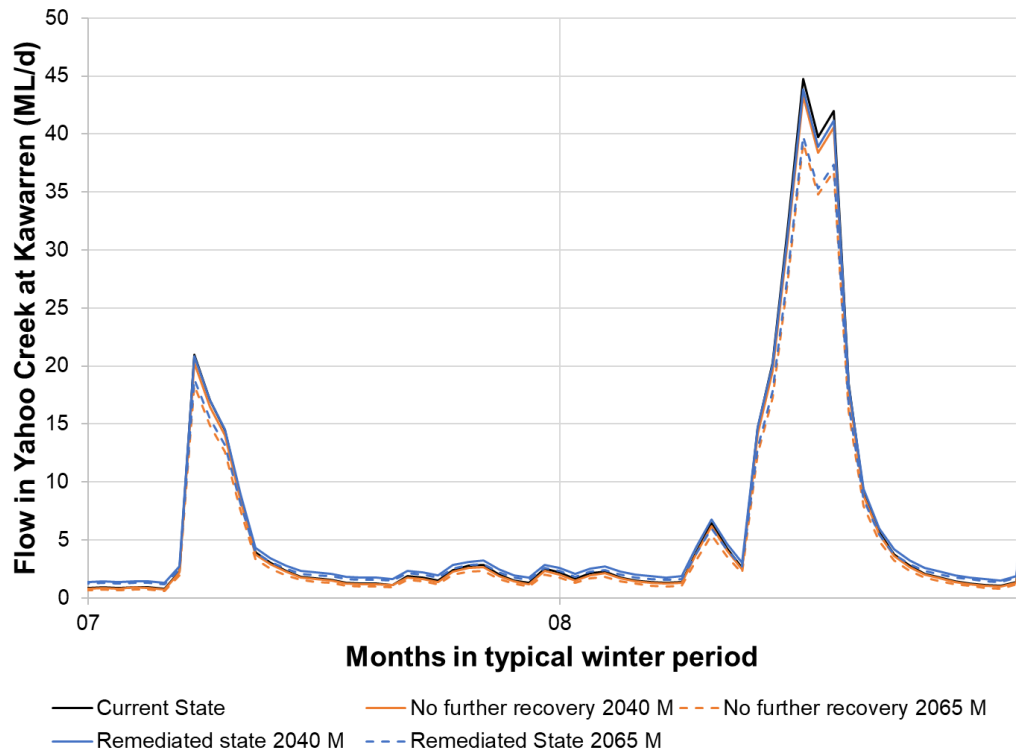


Figure 3-11 Comparison of flow during a typical winter period for Yahoo Creek at Kwarren

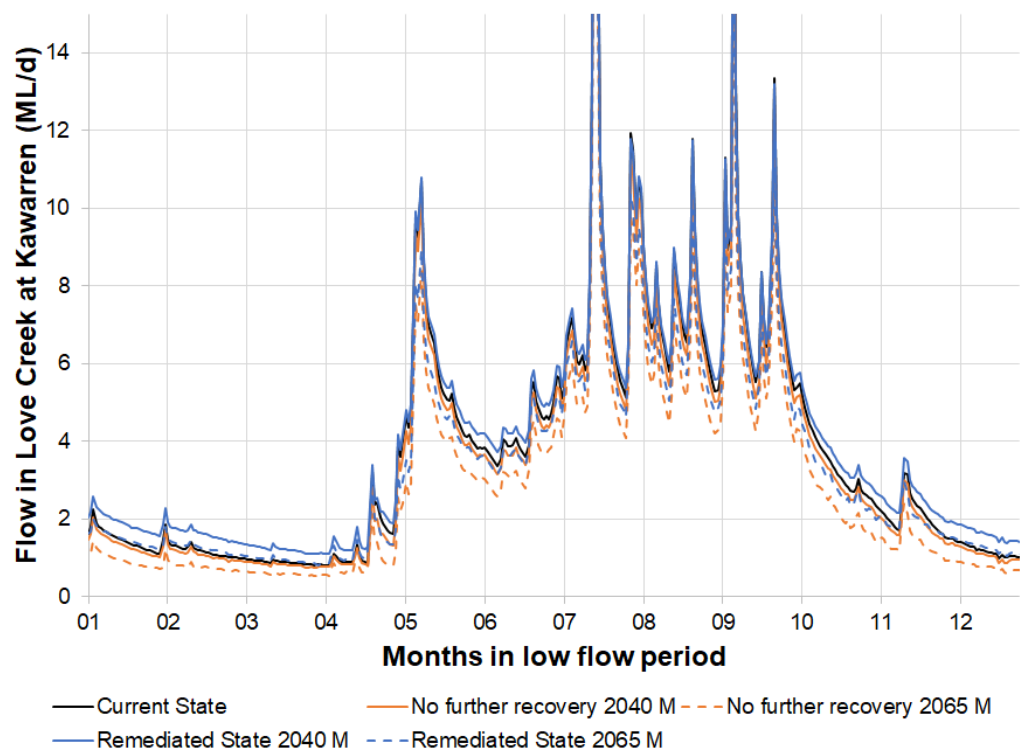


Figure 3-12 Comparison of flow during a dry period for Love Creek at Kwararren

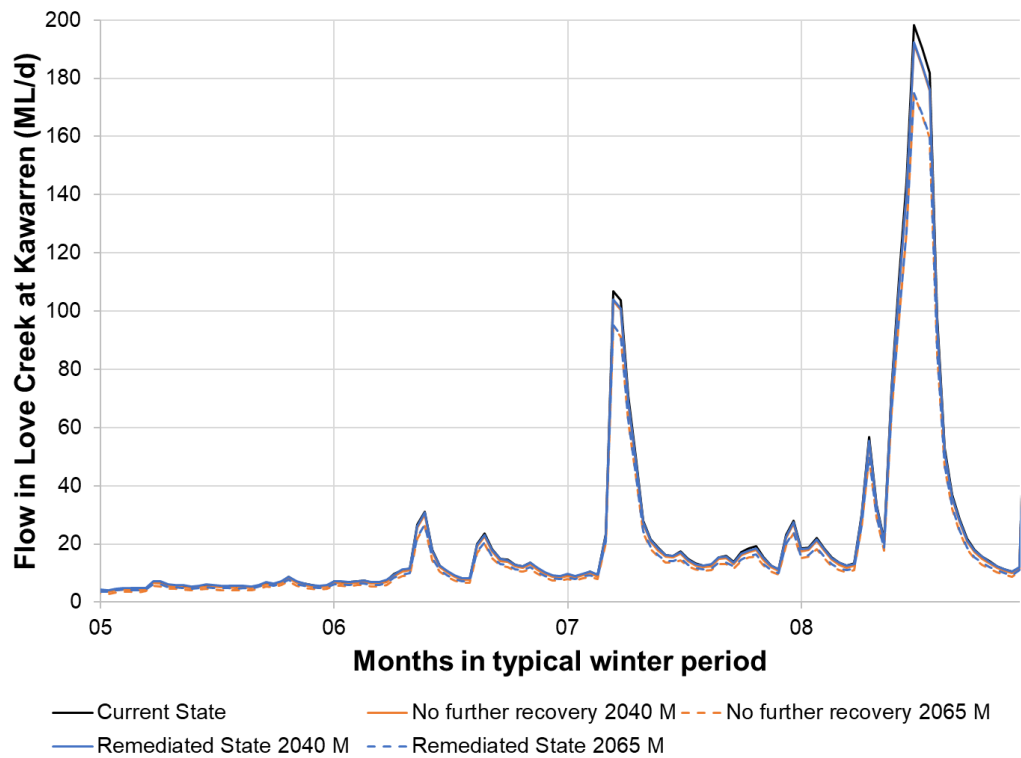


Figure 3-13 Comparison of flow during a typical wet period for Love Creek at Kwararren

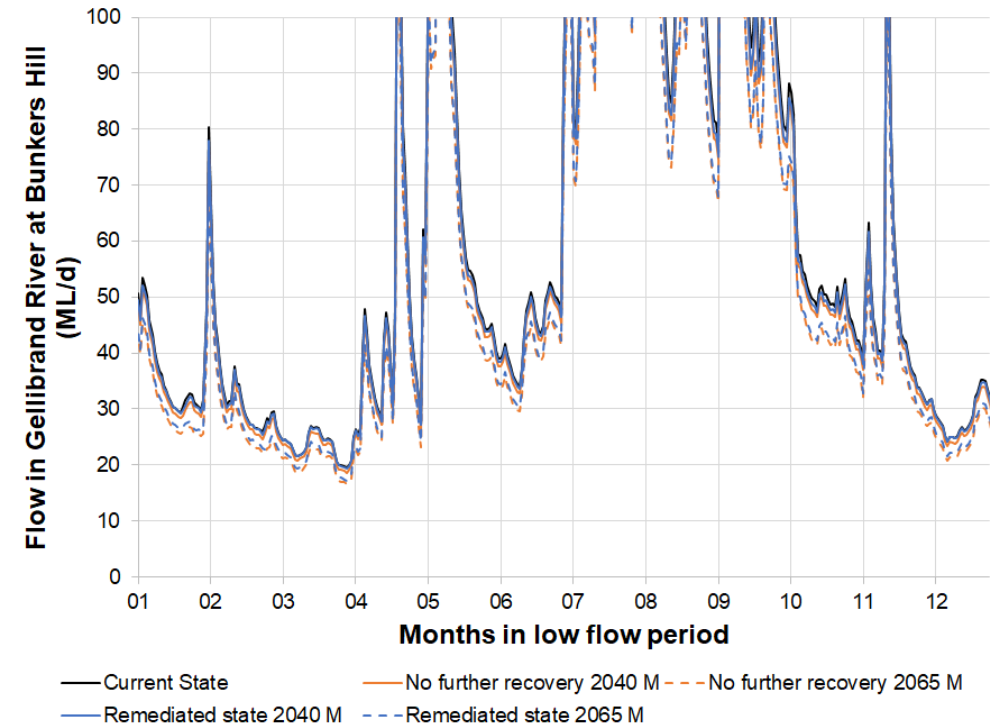


Figure 3-14 Comparison of flow during a dry period for Gellibrand River at Bunkers Hill

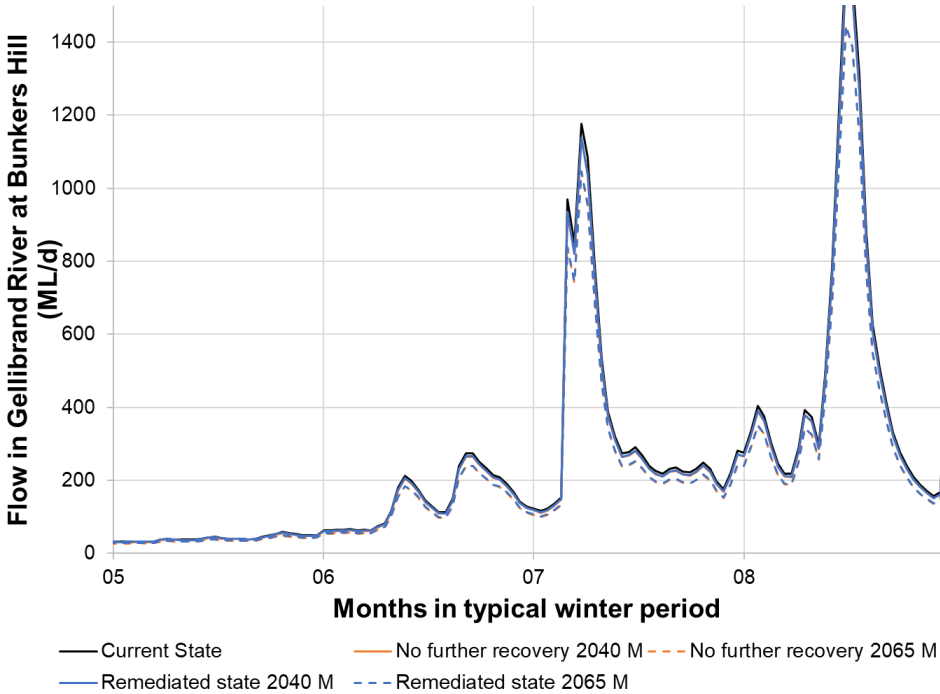


Figure 3-15 Comparison of flow during a typical winter period for Gellibrand River at Bunkers Hill



3.2 Uncertainty in water availability under climate change

In the DELWP 2020 climate change guidelines (DELWP, 2020) low, medium and high values are published for 2020, 2040 and 2065 climate change. The low, medium and high values correspond to the 10th, 50th and 90th percentile results from the suite of 42 available GCMs used to make the climate change projection.

The purpose of this analysis is to compare the impact on system behaviour of a more severe (RCP 8.5 High Climate Change) or less severe (RCP 8.5 Low Climate Change) climate change projection is to occur. The results will show the uncertainty in modelling water availability under 2040 and 2065 climate change projections under a remediated state.

This section explores the question:

What is the uncertainty in water availability under climate change?

3.2.1 Water balance of system

The water balance of the Gellibrand River catchment shows the impact on demands and inflows for 2040 low, medium and high climate change projections (Table 3-4) and 2065 low, medium and high climate change projections (Table 3-5).

In 2040, the low climate change projection results in 15-16% more inflows and outflows compared to the medium climate change projection, whilst the 2040 high climate change projection results in inflows and outflows 20-21% lower when compared to the medium climate change scenario.

The difference in inflow and outflow due to the high 2065 climate change projection increases to 31-33% when compared to medium climate change, as shown in Table 3-5. The low climate change projection results in 13-14% more inflows and outflows when compared to medium climate change.



Table 3-4 Water balance for Gellibrand River down to Bunkers Hill for the different 2040 climate change projections under a remediated state

Average annual water availability calculated over the full climate sequence (ML/yr)					
	Medium climate change scenario	Low climate change scenario	% diff to Med	High climate change scenario	% diff to Med
Inflows	88,636	101,785	+15%	71,389	-20%
Catchment Inflows	88,425	101,574	+15%	71,178	-20%
Farm Dam inflows	211	211	0.0%	211	0.0%
Demands	5,260	5,449	+3.6%	4,894	-7.0%
BW extractions to Colac	4,386	4,574	+4.3%	4,023	-8.3%
Rural Demands	186	187	+0.5%	184	-1.1%
Farm Dam impacts	669	669	0.0%	669	0.0%
Urban demands	19	19	0.0%	19	0.0%
Losses	1,225	1,172	-4.3%	1,276	+4.2%
Groundwater Impacts	40	40	0.0%	40	0.0%
River losses	1,291	1,271	-1.5%	1,302	+0.9%
Net Evaporation	-106	-139	+31%	-66	-38%
Outflow	82,169	95,192	+16%	65,231	-21%
Gellibrand River at Bunkers Hill	82,166	95,190	+16%	65,228	-21%
Change in storage	2	2		2	
Balance error (%)	0%	0%		0%	

Table 3-5 Water balance for Gellibrand River down to Bunkers Hill at for the different 2065 climate change projections under a remediated state

Average annual water availability calculated over the full climate sequence (ML/yr)					
	Medium climate change scenario	Low climate change scenario	% diff to Med	High climate change scenario	% diff to Med
Inflows	80,451	91,028	+13%	55,582	-31%
Catchment Inflows	80,230	90,807	+13%	55,361	-31%
Farm Dam inflows	221	221	0.0%	221	0.0%
Demands	5,186	5,435	+4.8%	4,680	-9.8%
BW extractions to Colac	4,192	4,440	+5.9%	3,692	-12%
Rural Demands	185	186	+0.5%	179	-3.2%
Farm Dam impacts	789	789	0.0%	789	0.0%
Urban demands	20	20	0.0%	20	0.0%
Losses	1,245	1,200	-3.6%	1,304	+4.7%
Groundwater Impacts	40	40	0.0%	40	0.0%
River losses	1,295	1,285	-0.8%	1,282	-1.0%
Net Evaporation	-90	-125	+39%	-18	-80%
Outflow	74,035	84,419	+14%	49,614	-33%
Gellibrand River at Bunkers Hill	74,033	84,417	+14%	49,611	-33%
Change in storage	2	2		2	
Balance error (%)	0%	0%		0%	

3.2.2 Impact on flow at key locations

The flow at key locations has been analysed over the full climate sequence and has been summarised for each gauge location in Table 3-6. Compared to medium climate change, the low climate change projection produces flow at key gauge locations that are 15-16% higher in 2040 and 14-15% higher in 2065. By comparison, the high climate change results in flow at key gauge locations 20-21% lower in 2040 and 32-34% lower in 2065 compared to the medium climate change projection.

Given that the climate change adjustments have been made using an annual scaling factor, only the annual flow duration curve has been compared for 2040 and for 2065. As shown in Figure 3-16, flows under 2040 high climate change are lower than under medium and low climate change. This is also observed for the 2065 in Figure 3-17.

Note that the uncertainty in the impact of climate change on water availability is similar regardless of the subcatchment.



Table 3-6 Average annual flow calculated across the full climate sequence at key flow locations under a remediated state compared to the medium climate change scenario

Average annual flow compared to the medium climate change projection calculated over the full climate sequence				
	235227 Gellibrand River at Bunkers Hill	235231 Gellibrand River at Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kawarren
2040 climate change projections				
Low climate change	16% higher flow (average of 13,023 ML/yr)	16% higher flow (average of 5,573 ML/yr)	16% higher flow (average of 1,252 ML/yr)	15% higher flow (average of 207 ML/yr)
High climate change	21% lower flow (average of 16,939 ML/yr)	21% lower flow (average of 7,184 ML/yr)	21% lower flow (average of 1,650 ML/yr)	20% lower flow (average of 272 ML/yr)
2065 climate change projections				
Low climate change	14% higher flow (average of 10,384 ML/yr)	14% higher flow (average of 4,398 ML/yr)	15% higher flow (average of 1,013 ML/yr)	14% higher flow (average of 166 ML/yr)
High climate change	33% lower flow (average of 24,422 ML/yr)	34% lower flow (average of 10,386 ML/yr)	34% lower flow (average of 2,364 ML/yr)	32% lower flow (average of 392 ML/yr)

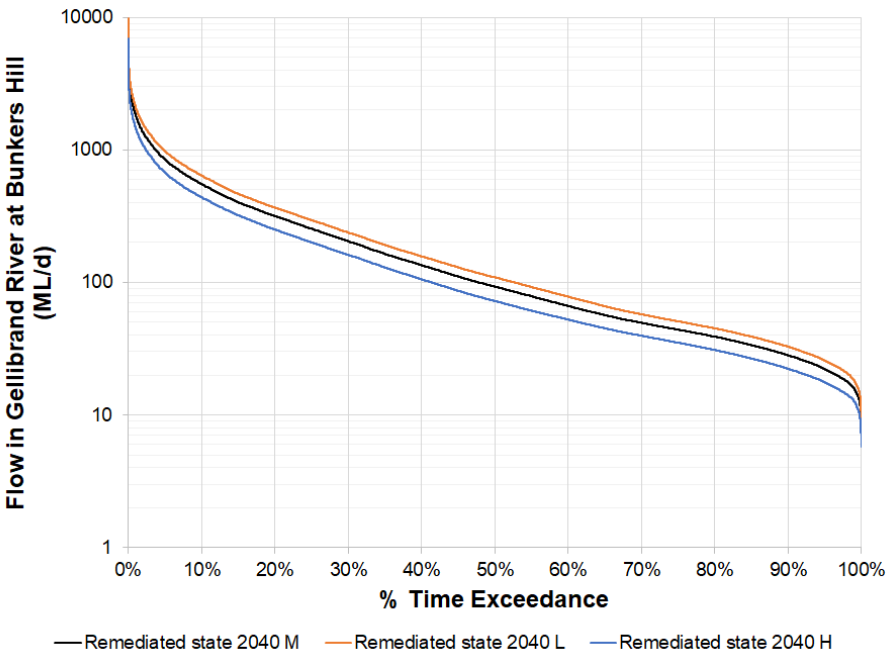


Figure 3-16 Flow duration curve comparison calculated across full climate sequence for future performance scenarios in Gellibrand River at Bunkers Hill for 2040 climate change scenarios

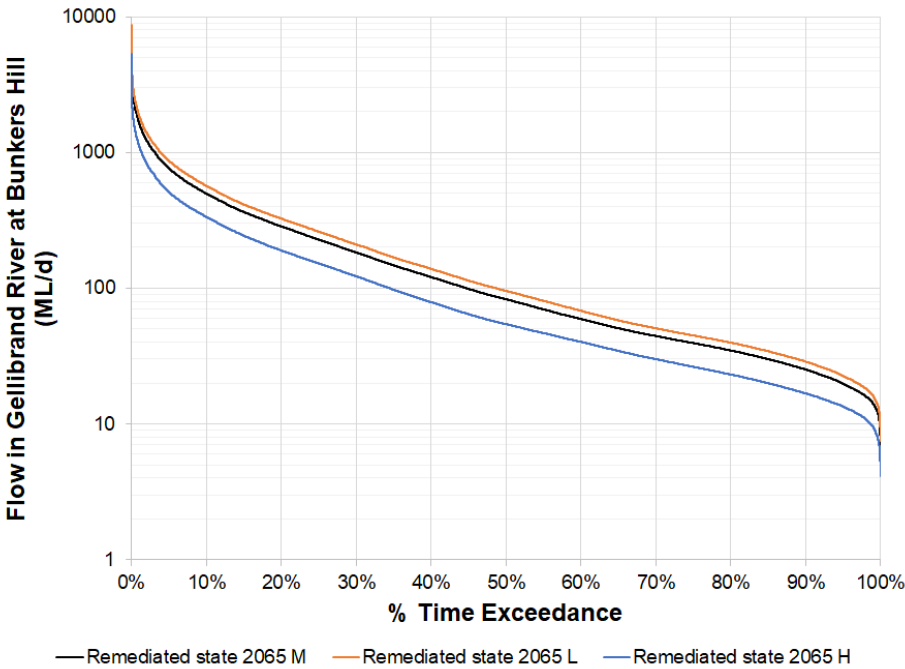


Figure 3-17 Flow duration curve comparison calculated across full climate sequence for future performance scenarios in Gellibrand River at Bunkers Hill for 2065 climate change scenarios



3.3 Impact of groundwater pumping on current surface water flow regime

The purpose of this section is to show the difference in surface water availability with and without groundwater pumping, assuming current climate conditions and demand levels. This section does not consider any impacts of future climate and is intended to only look at changes in system behaviour driven by current groundwater pumping impacts.

This section explores the question:

What is likely to have occurred if groundwater pumping never happened?

3.3.1 Water balance of system

The water balance of the Gellibrand system (refer Table 3-7) shows that groundwater pumping has had a very minimal impact on the average annual water availability of the Gellibrand system. Specifically, there is a 0.5% higher flow in the Gellibrand River at Bunkers Hill under a no groundwater pumping scenario as compared to the current situation with groundwater pumping derived reductions in baseflow. There is also a small difference (1 ML/yr) in rural demands between the two scenarios. This small difference is driven by the timing of rural restrictions triggers in the Gellibrand catchment, with less restrictions triggered when losses are reduced.

Table 3-7 Water balance for Gellibrand system at current assuming with and without groundwater pumping impacts (current climate)

	Average annual water availability calculated from 1900 to 2021 (ML/yr)		% diff between no pumping and no further recovery scenarios
	Pumping scenario	No pumping scenario	
Inflows	91,690	91,690	0.0%
Catchment Inflows	91,474	91,474	0.0%
Farm Dam inflows	216	216	0.0%
Demands	5,248	5,248	0.0%
BW extractions to Colac	4,400	4,400	0.0%
Rural Demands	186	187	+0.5%
Farm Dam impacts	644	644	0.0%
Urban demands	18	18	0.0%
Losses	1,557	1,168	-25%
Groundwater Impacts	397	0	-100%
River losses	1,279	1,288	+0.7%
Net Evaporation	-120	-120	0.0%
Outflow	84,901	85,290	+0.5%
Gellibrand River at Bunkers Hill	84,899	85,288	+0.5%
Change in storage	2	2	
Balance error (%)	0%	0%	



3.3.2 Impact on flow at key locations

The flow at key locations under a pumping and no pumping scenario has been analysed over the full climate sequence and has been summarised for each gauge location in Table 3-8.

This analysis shows that if groundwater pumping never occurred, average annual flows are expected to be 19% higher in Yahoo Creek and 3% higher in Love Creek. Only minor variations of 0.5% were evident for locations along the Gellibrand River between the no pumping and current situation with groundwater pumping derived reductions in baseflow. This shows that the localised groundwater pumping impacts in Yahoo Creek and to a lesser extent, Love Creek have little effect on the Gellibrand catchment overall.

Table 3-8 Average annual flow calculated across the full climate sequence at key flow locations

Scenario	Average annual flow at key gauge locations calculated from 1900 to 2021 (ML/yr)			
	235227 Gellibrand River at Bunkers Hill	235231 Gellibrand River at Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kawarren
No pumping scenario	85,288	35,459	8,032	1,427
Pumping scenario	84,899	35,287	7,806	1,201
% difference comparing the pumping scenario to the no pumping scenario	-0.5%	-0.5%	-2.8%	-16%

Flow duration curves have been plotted for Yahoo Creek at Kawarren, Love Creek at Kawarren and Gellibrand River at Bunkers Hill for each scenario annually, for the warm season (November to March) and for the cool season (April to October).

Unsurprisingly, if pumping never occurred modelling suggests that Yahoo Creek would not have experienced as many cease to flow periods, both annually (Figure 3-18) and in the warm season (Figure 3-19). A cease to flow event has been defined as flow measured below 0.1 ML/d. However, improvements are expected to be less significant for flows greater than 3 or 4 ML/day, and during the cool season (Figure 3-20). Whilst differences can also be observed in Love Creek, these are not as significant as Yahoo Creek given the additional inputs to Love Creek from other tributaries.

For Gellibrand River at Bunkers Hill negligible changes in the flow duration curves for the annual (Figure 3-24), warm season (Figure 3-25) and cool season (Figure 3-26) are evident between the pumping and non-pumping scenario.

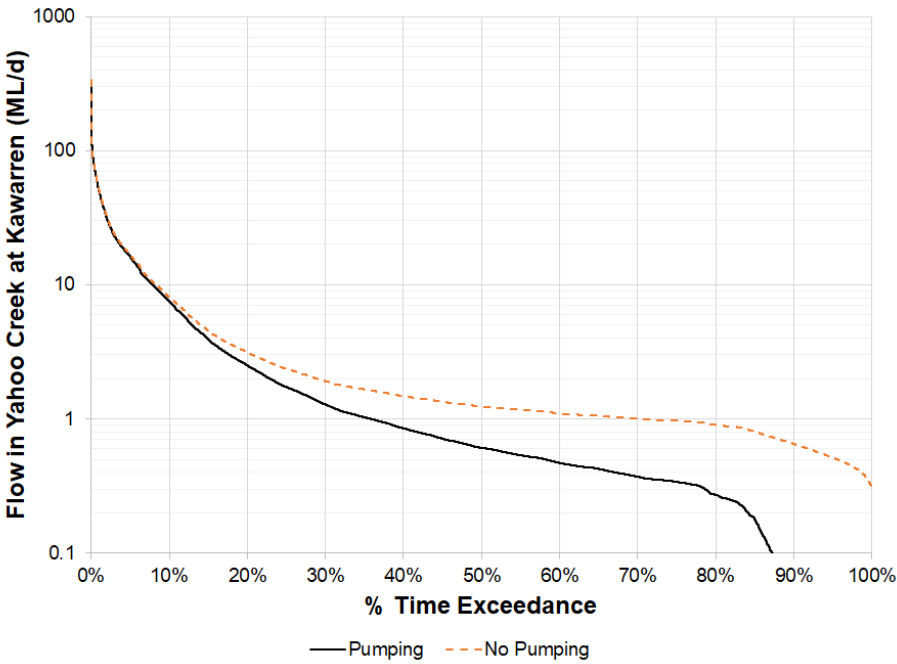


Figure 3-18 Flow duration curve comparison calculated over full climate sequence for current groundwater pumping impacts in at Yahoo Creek at Kwarren

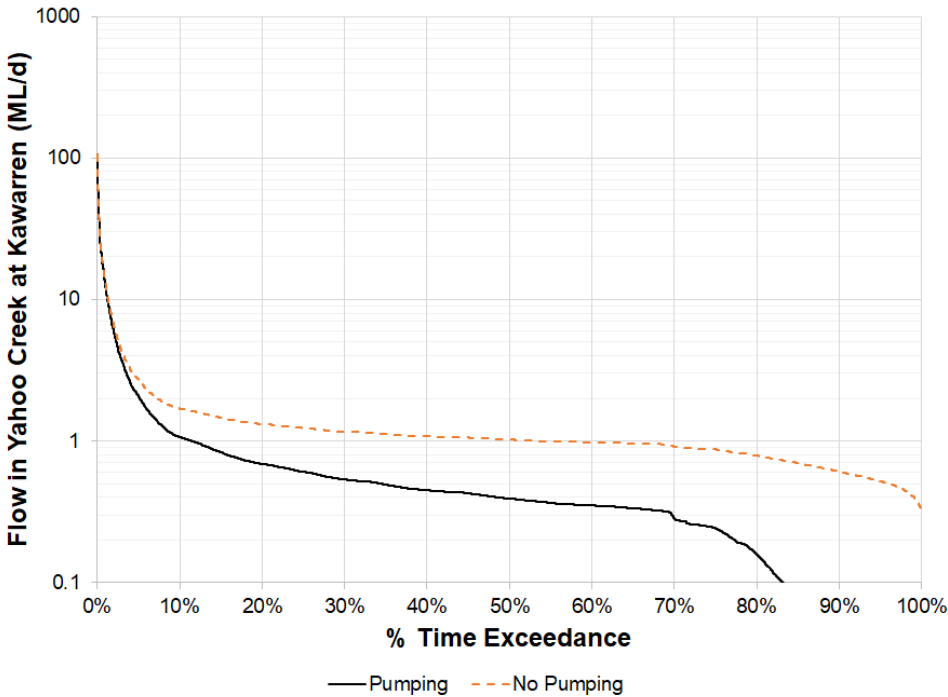


Figure 3-19 Flow duration curve comparison calculated for warm seasons (November to March) over full climate sequence for current groundwater pumping impacts in Yahoo Creek at Kwarren

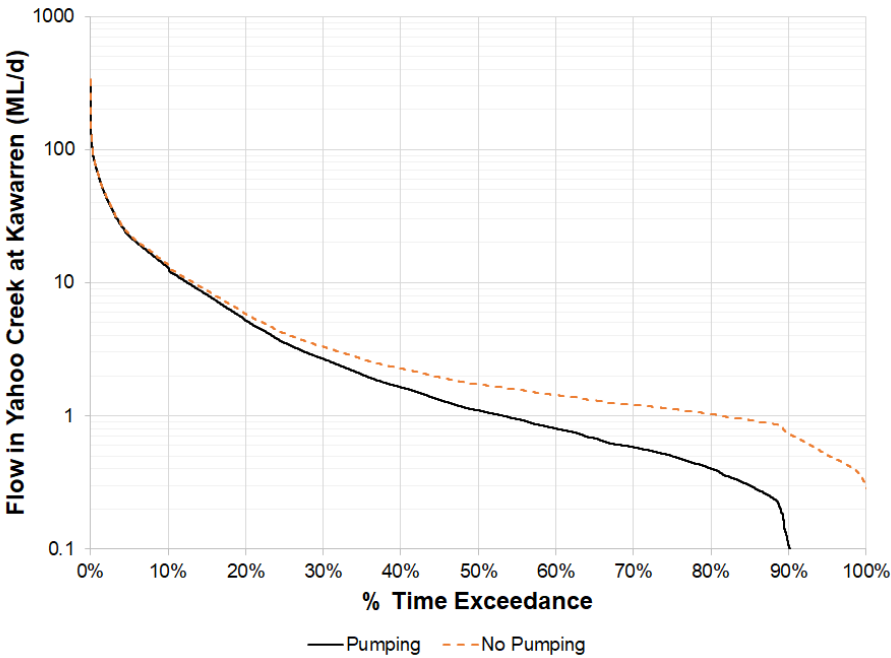


Figure 3-20 Flow duration curve comparison calculated for cool seasons (April to October) over full climate sequence for current groundwater pumping impacts in Yahoo Creek at Kwararren

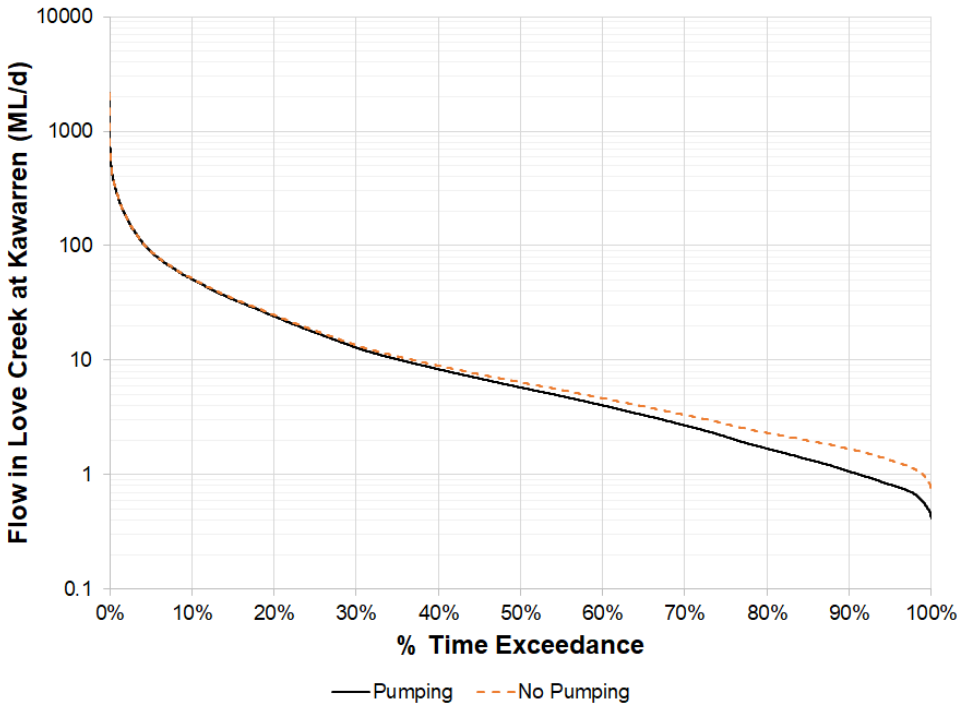


Figure 3-21 Flow duration curve comparison calculated over full climate sequence for current groundwater pumping impacts in Love Creek at Kwararren

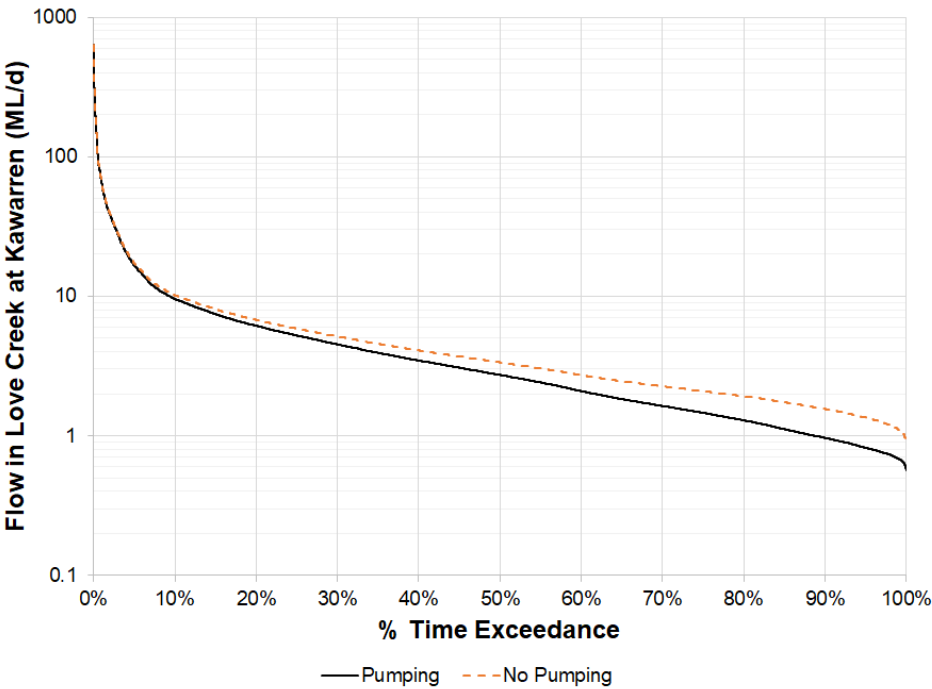


Figure 3-22 Flow duration curve comparison calculated for warm seasons (November to March) over full climate sequence for current groundwater pumping impacts in Love Creek at Kwararren

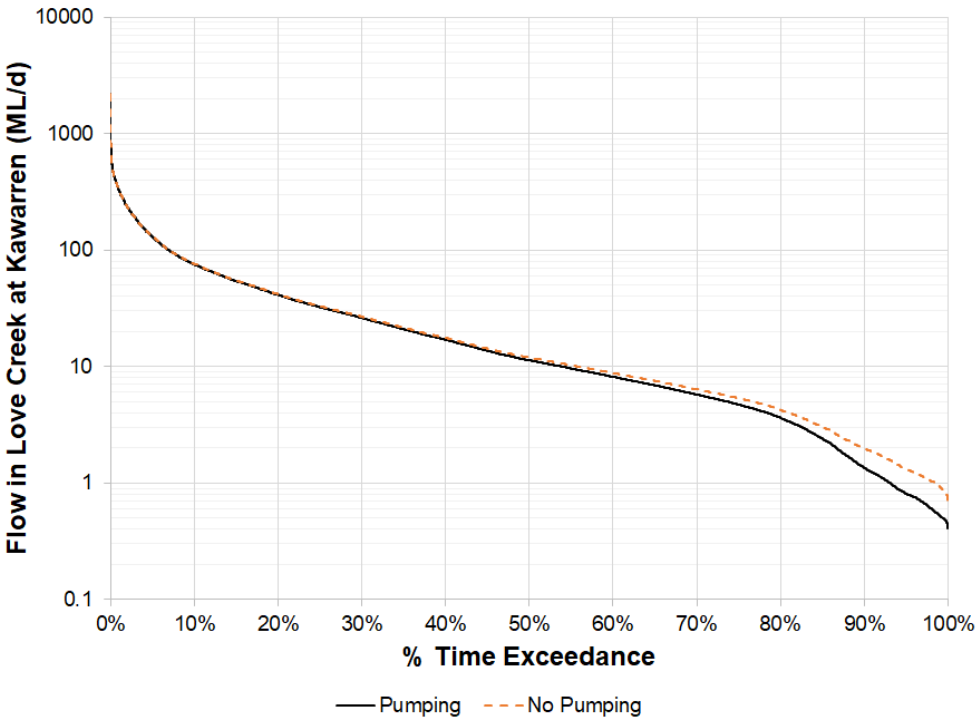


Figure 3-23 Flow duration curve comparison calculated for cool seasons (April to October) over full climate sequence for current groundwater pumping impacts in Love Creek at Kwararren

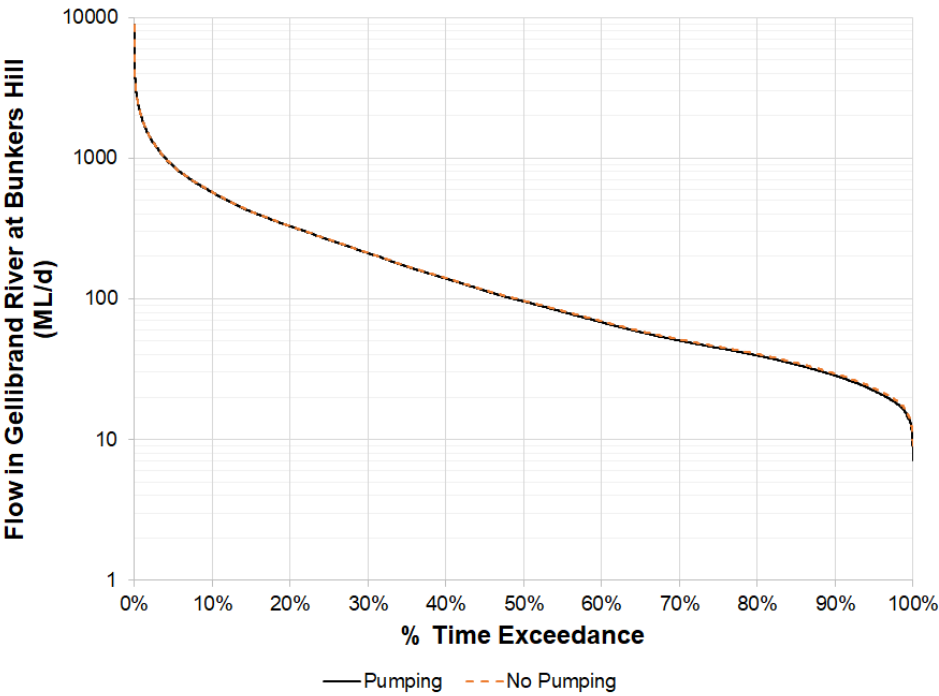


Figure 3-24 Flow duration curve comparison calculated over full climate sequence for current groundwater pumping impacts in Gellibrand River at Bunkers Hill

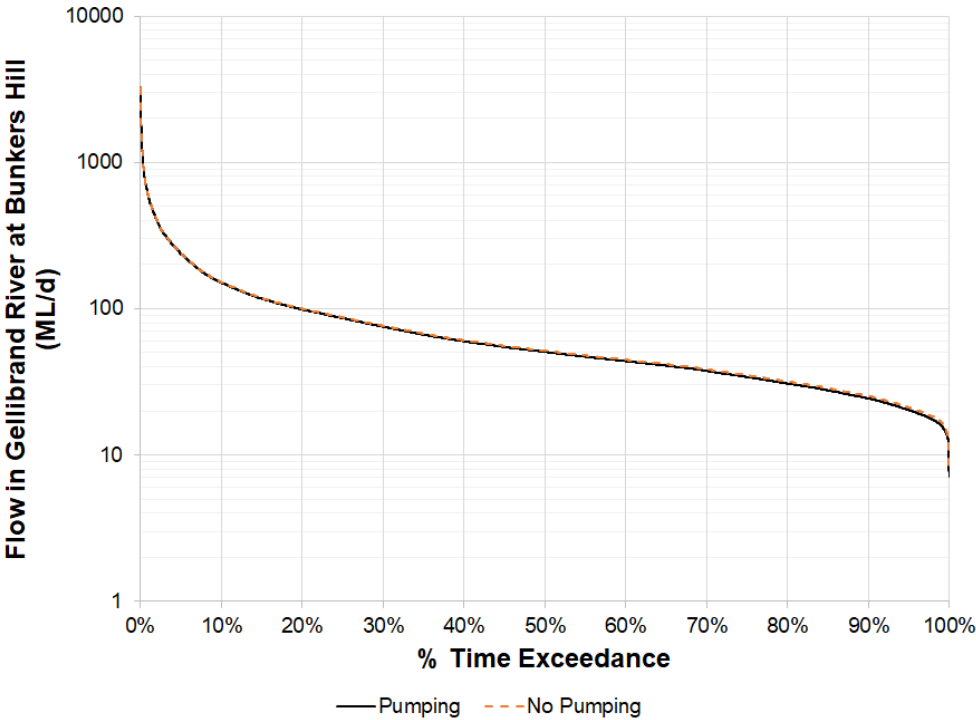


Figure 3-25 Flow duration curve comparison calculated for warm seasons (November to March) over full climate sequence for current groundwater pumping impacts in Gellibrand River at Bunkers Hill

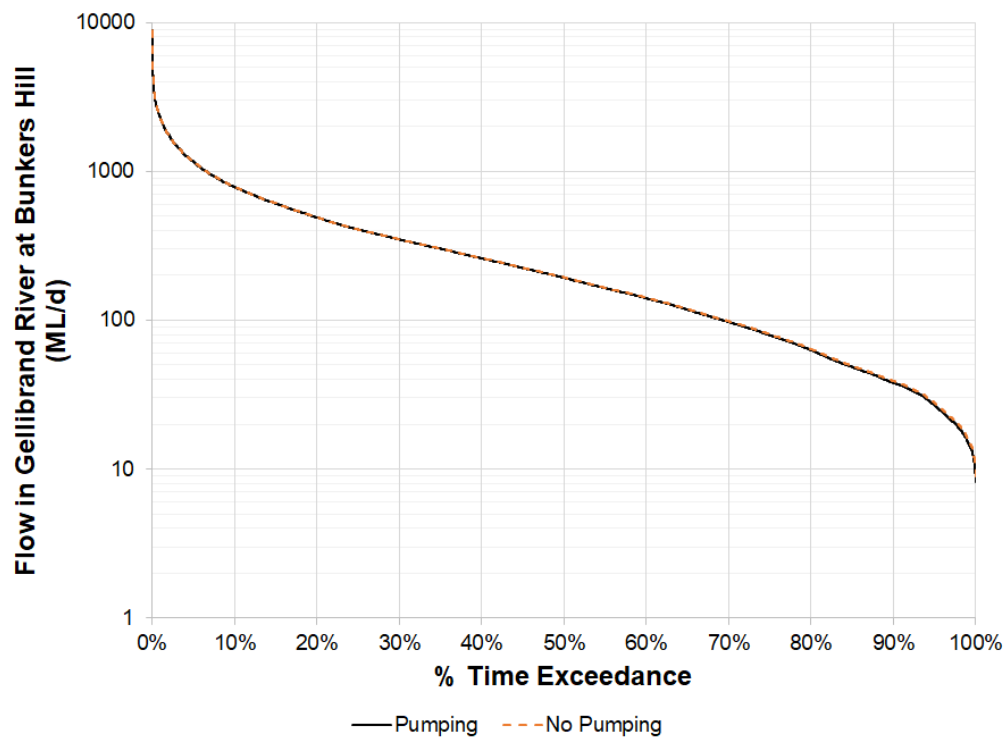


Figure 3-26 Flow duration curve comparison calculated for cool seasons (April to October) over full climate sequence for current groundwater pumping impacts in Gellibrand River at Bunkers Hill

3.4 Impact of full uptake of rural demands on system resilience under future climate

This section compares system performance under current level of development demand to the case where demands increase to full uptake. Both cases are run with 2040 and 2065 medium climate change projections and assume that successful remediation has been achieved – i.e. groundwater discharge from the LTA is nearing pre-pumping levels. To represent full uptake, take and use demands are increased such that the current licenced volume is fully utilised. There is no change to the farm dam growth assumptions outlined in Section 2.2.3 and adopted across all future scenarios.

The purpose of this section is to identify any vulnerability in the system due to take and use licence holders fully utilising their entitlement.

This section explores the question:

What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?

3.4.1 Water balance of system

The water balance of the Gellibrand system shows the impact of full uptake demands under the future climate change projections (Table 3-9 and Table 3-10). The key difference is the 110%



increase in rural demands in both 2040 and 2065 under a full uptake scenario. Despite the significant increase, this analysis indicates that there are negligible impacts on Gellibrand River outflows under a full uptake scenario for both the 2040 and 2065 medium climate change projections. This is because rural demands are still small compared to the total annual flow within the Gellibrand system. This analysis indicates that a full uptake scenario would not impact on the resilience of the system.

Table 3-9 Water balance for Gellibrand system down to Bunkers Hill comparing full uptake scenario to the 2040 level of demands for 2040 medium climate change scenario

Average annual water availability calculated 1900- 2021 (ML/yr)			
	Current demands	Full uptake scenario	% diff to BC
Inflows	88,636	88,636	0.0%
Catchment Inflows	88,425	88,425	0.0%
Farm Dam inflows	211	211	0.0%
Demands	5,260	5,457	+3.7%
BW extractions to Colac	4,386	4,379	-0.2%
Rural Demands	186	391	+110%
Farm Dam impacts	669	669	0.0%
Urban demands	19	19	0.0%
Losses	1,225	1,225	0.0%
Groundwater Impacts	40	40	0.0%
River losses	1,291	1,291	0.0%
Net Evaporation	-106	-106	0.0%
Outflow	82,169	81,982	-0.2%
Gellibrand River at Bunkers Hill	82,166	81,980	-0.2%
Change in storage	2	2	
Balance error (%)	0%	0%	

Table 3-10 Water balance for Gellibrand system down to Bunkers Hill comparing full uptake scenario to the 2065 level of demands for 2065 medium climate change scenario

Average annual water availability calculated 1900- 2021 (ML/yr)			
	Current demands	Full uptake scenario	% diff to BC
Inflows	80,451	80,451	0.0%
Catchment Inflows	80,230	80,230	0.0%
Farm Dam inflows	221	221	0.0%
Demands	5,186	5,390	+3.9%
BW extractions to Colac	4,192	4,191	0.0%
Rural Demands	185	390	+111%
Farm Dam impacts	789	789	0.0%
Urban demands	20	20	0.0%
Losses	1,245	1,244	-0.1%
Groundwater Impacts	40	40	0.0%
River losses	1,295	1,294	-0.1%
Net Evaporation	-90	-90	0.0%
Outflow	74,035	73,849	-0.3%
Gellibrand River at Bunkers Hill	74,033	73,847	
Change in storage	2	2	
Balance error (%)	0%	0%	

3.4.2 Impact on flow at key locations

The flow at key locations has been analysed over the full climate sequence. As shown in Table 3-11, there are negligible impacts on the flow in the Gellibrand River catchment if all demands are accessed under a remediated state.

Table 3-11 Average annual flow calculated over the full climate sequence at key flow locations under a remediated state

Average annual flow compared to current demands calculated over the full climate sequence				
	235227 Gellibrand River at Bunkers Hill	235231 Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kwarren
2040 climate change projections				
Full uptake of rural demands	0.2% reduction in flow (average of 187 ML/yr)	No change in flow	0.1% reduction in flow (average of 8 ML/yr)	No change in flow
2065 climate change projections				
Full uptake of rural demands	0.3% reduction in flow (average of 187 ML/yr)	No change in flow	0.1% reduction in flow (average of 8 ML/yr)	No change in flow



4. Boundary Creek system modelling results

This section outlines the scenario modelling results for the Boundary Creek system. For the purposes of this project, the Boundary Creek system includes Boundary Creek and the Barwon River down to Ricketts Marsh.

Each analysis has been undertaken to illustrate the differences in surface water availability due to different assumptions for groundwater pumping or climate change. The following has been investigated:

- **What is the predicted response of each catchment to future medium climate change projections?**

The purpose of this section is to compare system behaviour under current climate and groundwater pumping conditions to system behaviour under future climate conditions, with and without further groundwater recovery. The medium climate change projection is used for each time slice (2020, 2040 and 2065).

- **What is the uncertainty in water availability under climate change?**

The purpose of this analysis is to compare the impact on system behaviour of a more severe (RCP 8.5 High Climate Change) or less severe (RCP 8.5 Low Climate Change) climate change projection. The results will show the uncertainty in modelling water availability under 2040 and 2065 climate change, under the remediated state.

- **What is likely to have occurred if groundwater pumping never happened?**

The purpose of this analysis is to better understand the impact of groundwater pumping related reductions in groundwater discharge on the overall flow regime and how this affects the resilience of the system

- **What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?**

The purpose of this analysis is to identify any vulnerability in the system due to take and use licence holders fully utilising their entitlement. The analysis has been undertaken for future climate and assuming a remediated groundwater state for 2040 and 2065. Take and use demands are increased such that the current licenced volume is fully utilised.

The full suite of results for each scenario modelled in the Boundary Creek system is outlined in Appendix A.2.

4.1 Predicted response to future median climate change projections

This section analyses the performance of the Boundary Creek system under medium climate change with and without groundwater recovery by utilising outputs from Scenario 1 (no further recovery) and Scenario 2 (remediated state). Note that for the remediated state scenario there are no Boundary Creek supplementary flows, as discussed in 2.2.1.

The purpose of this section is to explore the question:



What is the predicted response of each catchment to future medium climate change projections?

4.1.1 Water balance of system

The water balance of the Boundary Creek system down to Barwon River at Ricketts Marsh shows the impact of future climate on demands and inflows assuming there is no further groundwater recovery (Table 4-1) and with groundwater recovery (Table 4-2).

In comparing the two scenarios there is approximately 1% difference between the outflow Barwon River at Ricketts Marsh in 2040 and 2065 between the no further recovery and remediated state scenario, indicating that the forecast reduction in streamflow in the future (between 2.8 and 23%) is driven almost exclusively by climate related factors.

Table 4-1 Water balance for Boundary Creek catchment under a no further groundwater recovery scenario

	Average annual water availability calculated for the full climate sequence (ML/yr)				
	Base Case (current pumping impacts)	No further recovery 2040 Med	% diff to BC	No further recovery 2065 Med	% diff to BC
Inflows	61,390	58,977	-3.9%	48,206	-21%
Boundary Creek Catchment Inflow	4,056	3,943	-2.8%	3,292	-19%
Barwon River Catchment Inflow	39,989	38,872	-2.8%	32,455	-19%
Boundary Creek Supplementary Flows	364	0	-100%	0	-100%
Geelong Colac system contributions to Barwon River	16,637	15,817	-4.9%	12,114	-27%
Farm dam inflows	342	345	+0.9%	344	+0.6%
Demands	3,305	3,279	-0.8%	3,230	-2.3%
Rural Demands	45	27	-40%	27	-40%
Farm dam impacts	3,260	3,252	-0.2%	3,203	-2%
Losses	1,429	1,192	-16.6%	1,074	-25%
Groundwater impacts	949	749	-21.1%	692	-27%
River losses	468	439	-6.2%	379	-19%
Net evaporation	12	3	-75%	4	-67%
Outflow	56,589	54,441	-3.8%	43,840	-23%
Barwon River at Rickett's Marsh	56,589	54,443	-3.8%	43,841	-23%
Change in storage	-0.06	-1.2		-1.2	
Balance error (%)	0%	0%		0%	

Table 4-2 Water balance for Boundary Creek catchment under the remediated state scenario

Average annual water availability calculated for the full climate sequence (ML/yr)					
	Base Case (current pumping impacts)	Remediated state 2040 Med	% diff to BC	Remediated state 2065 Med	% diff to BC
Inflows	61,390	58,977	-3.9%	48,206	-21%
Boundary Creek Catchment Inflow	4,056	3,943	-2.8%	3,292	-19%
Barwon River Catchment Inflow	39,989	38,872	-2.8%	32,455	-19%
Boundary Creek Supplementary Flows	364	0	-100%	0	-100%
Geelong Colac system contributions to Barwon River	16,637	15,817	-4.9%	12,114	-27%
Farm dam inflows	342	345	+0.9%	344	+0.6%
Demands	3,305	3,279	-0.8%	3,230	-2.3%
Rural Demands	45	27	-40%	27	-40%
Farm dam impacts	3,260	3,252	-0.2%	3,203	-2%
Losses	1,429	636	-56%	585	-59%
Groundwater impacts	949	85	-91%	84	-91%
River losses	468	547	+17%	497	+6%
Net evaporation	12	4	-67%	4	-67%
Outflow	56,589	54,990	-2.8%	44,323	-22%
Barwon River at Rickett's Marsh	56,589	54,991	-2.8%	44,325	-22%
Change in storage	-0.06	-1.2		-1.2	
Balance error (%)	0%	0.0%		0.0%	

4.1.2 Supply of rural demands

The supply of rural demands has been analysed as the proportion of the restricted demand over the model run period. For the current pumping scenario (base case), nearly 100% of the restricted demand in Boundary Creek and the private on-stream dam is able to be supplied (Table 4-3).

In 2040 and 2065, only 84-85% of rural demands and 55-56% of the private on-stream dams demands can be supplied irrespective of whether groundwater recovers or not. This is consistent with what is expected to occur if groundwater pumping never happened (Section 4.3), and is due to the absence of the Boundary Creek supplementary flows under a remediated state.

Table 4-3 Proportion of demand supplied (%) for future groundwater recovery scenarios

	Boundary Creek rural demands	Private on-stream dam demands
No further groundwater recovery		
Current pumping	99.8%	100%
2040 med	85.1%	56.3%
2065 med	84.3%	55.5%
Remediated state		
2040 med	85.1%	56.3%
2065 med	84.3%	55.5%

4.1.3 Impact of flow on at key locations

The flow at key locations has been analysed over the full model run period from 1900 to 2021 and for a low flow and typical wet period.

4.1.3.1 Full climate sequence

The average annual flow over the full climate sequence has been summarised for each gauge location and future climate case in Table 4-4, with flow duration curves provided for each scenario in Figure 4-1 to Figure 4-3.

The outputs from this analysis show that future climate will lead to a reduction in streamflow upstream of the private on-stream dam, with streamflow reductions of 16% and 32% projected in 2040 and 2065, respectively.

In the lower reaches of Boundary Creek downstream of the private on-stream dam, the recovery of groundwater discharge from the LTA leads to a 12-15% increase in flows in Boundary Creek in 2040. However, these improvements are short lived and a 7.4-12% reduction in streamflows in Boundary Creek is forecast to occur by 2065.

These localised increases are not reflected at Barwon River at Ricketts Marsh, where reductions are forecast to occur irrespective of groundwater recovery. Forecast reductions are similar under both scenarios, reporting a 2.8-3.8% reduction in 2040 and a 22-23% reduction in 2065.

If groundwater recovery cannot be achieved, streamflows in Boundary Creek downstream of the private on-stream dam are expected to decline by around 8% by 2040 and 30% by 2065.

The flow duration curve has also been plotted for Boundary Creek at Yeodene for each scenario annually, for the warm season (November to March) and for the cool season (April to October). Over the entire model run period, with no groundwater recovery the proportion of time in potential cease to flow conditions is around 30% higher in 2040 and 2065 when compared to the scenario where the groundwater recovery occurs (Figure 4-1). A potential cease to flow event has been defined as flow measured below 0.1 ML/d. This increase of time in potential cease to flow conditions is more prevalent in the warm season (Figure 4-2) with the impact of groundwater in the future than for the cool season (Figure 4-3). The improvement in flow in



Boundary Creek at Yeodone for both the warm and cool season is minimal for flows greater than 10 ML/d.



Table 4-4 Average annual flow calculated over the full climate sequence at key flow locations compared to the base case

	233231 Boundary Creek us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
2040 climate change projections				
No further recovery	16% reduction in flow (average of 449 ML/yr)	8.5% reduction in flow (average of 241 ML/yr)	8.4% reduction in flow (average of 221 ML/yr)	3.8% reduction in flow (average of 2,146 ML/yr)
Remediated state	16% reduction in flow (average of 449 ML/yr)	15% increase in flow (average of 422 ML/yr)	12% increase in flow (average of 327ML/yr)	2.8% reduction in flow (average of 1,598 ML/yr)
2065 climate change projections				
No further recovery	32% reduction in flow (average of 918 ML/yr)	29% reduction in flow (average of 819 ML/yr)	30% reduction in flow (average of 797 ML/yr)	23% reduction in flow (average of 12,748 ML/yr)
Remediated state	32% reduction in flow (average of 918 ML/yr)	7.4% reduction in flow (average of 211 ML/yr)	12% reduction in flow (average of 313 ML/yr)	22% reduction in flow (average of 12,264 ML/yr)

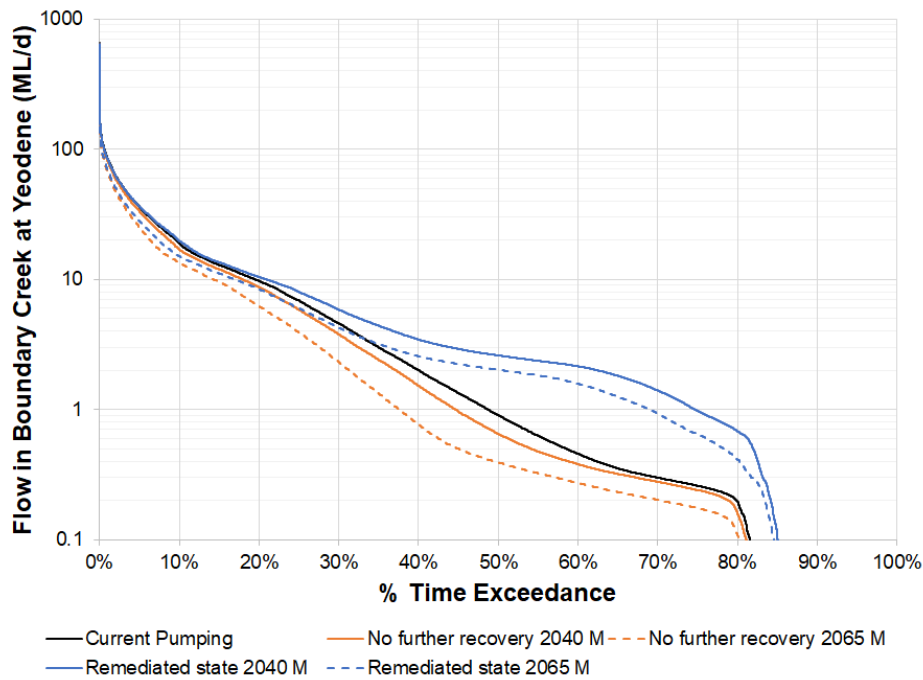


Figure 4-1 Flow duration curve comparison calculated across the full climate sequence for future performance scenarios in Boundary Creek at Yeodene

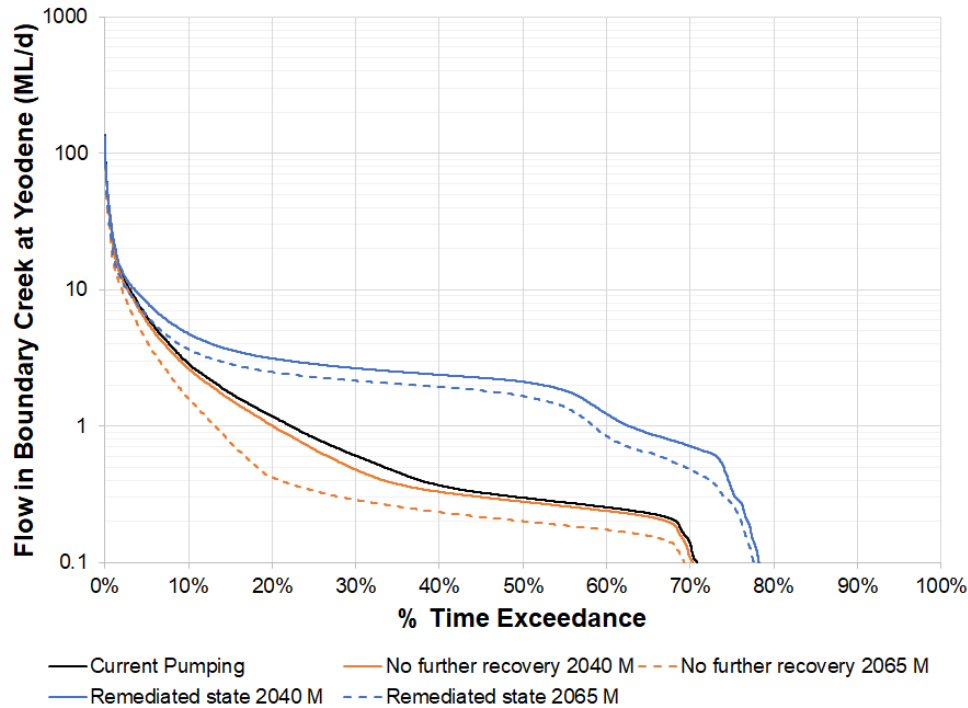


Figure 4-2 Flow duration curve comparison calculated for warm seasons (November to March) across the full climate sequence for future performance scenarios in Boundary Creek at Yeodene

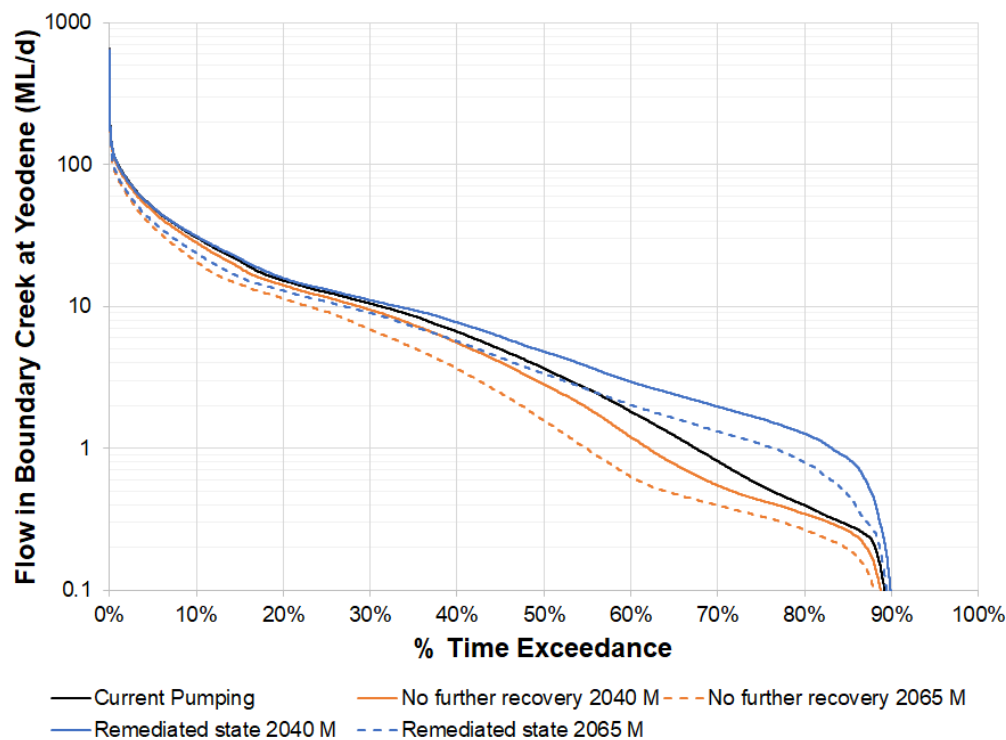


Figure 4-3 Flow duration curve comparison calculated for cool seasons (April to October) across the full climate sequence for future performance scenarios in Boundary Creek at Yeodene

4.1.3.2 Typical wet and dry periods

In addition to analysis of system performance over the predicted future climate sequence, the impacts of a future typical low flow and typical wet period have also been investigated to determine how the system may respond to the various scenarios.

Similar to the full climate sequence (refer section 4.1.3.1), the recovery of groundwater discharge from the LTA is not forecast to lead to noticeable improvement in typical low flow and wet period flows at Barwon River at Rickett's Marsh (Figure 4-8 and Figure 4-9).

For Boundary Creek upstream of the private on-stream dam, there is less water during future low flow periods under a remediated state, due to the absence of the Boundary Creek supplementary flows (Figure 4-4). The removal of the Boundary Creek supplementary flows is less evident during a typical winter period (Figure 4-5).

For Boundary Creek at Yeodene, the recovery of groundwater discharge from the LTA is forecast to reduce the impacts of climate change on low flows (Figure 4-6), but has little impact on winter flows (Figure 4-7).

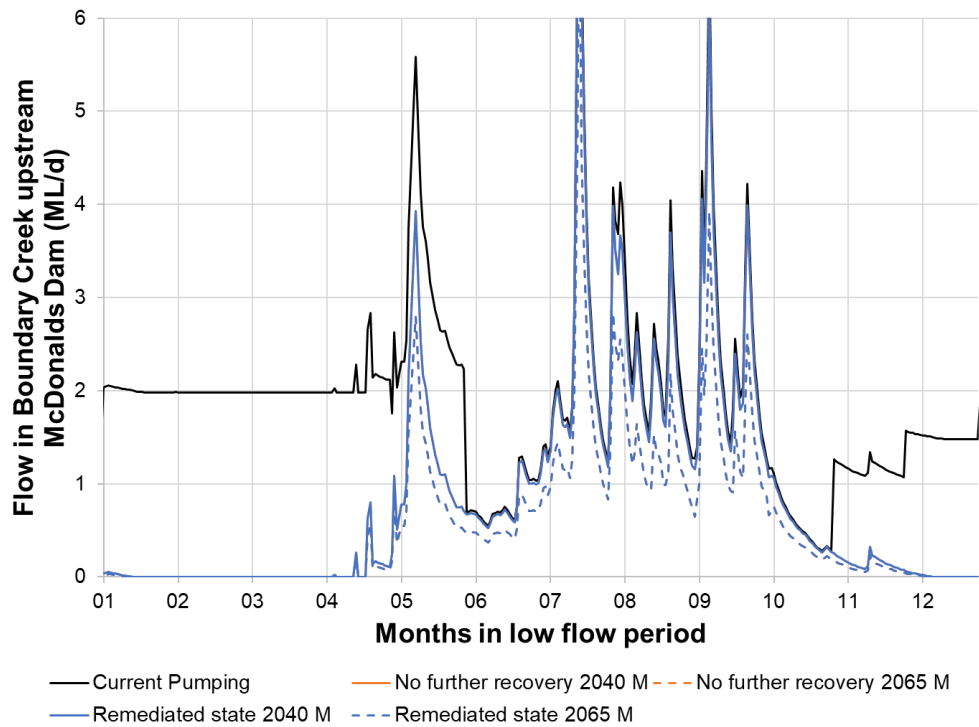


Figure 4-4 Comparison of flow during a low flow period for Boundary Creek upstream of the private on-stream dam

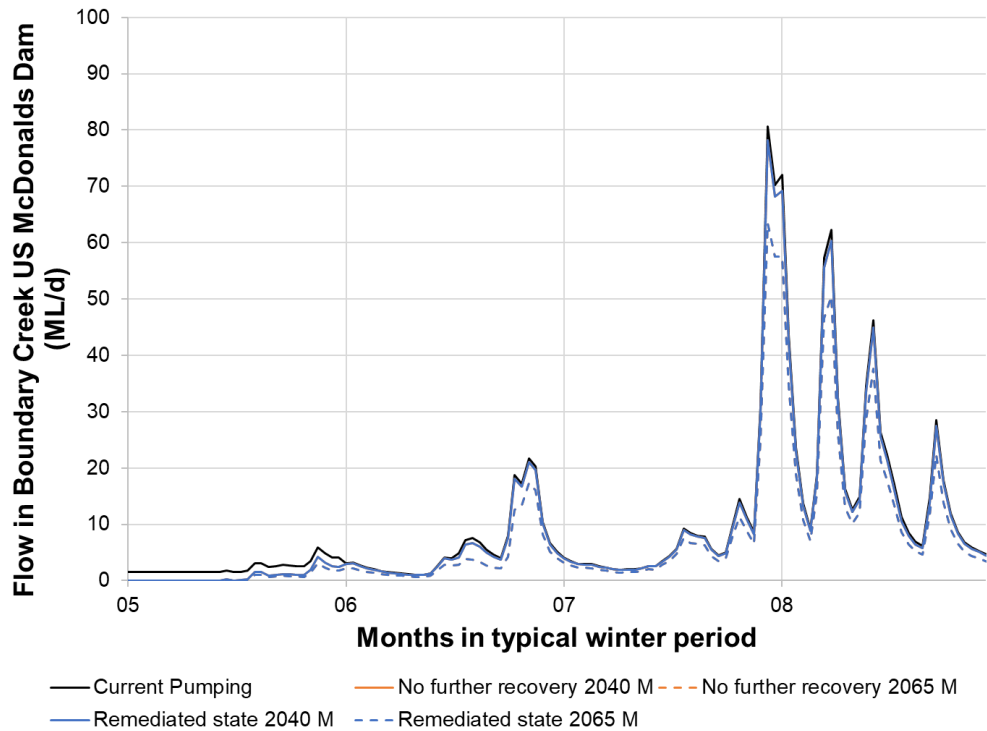


Figure 4-5 Comparison of flow during a typical winter period for Boundary Creek upstream of the private on-stream dam

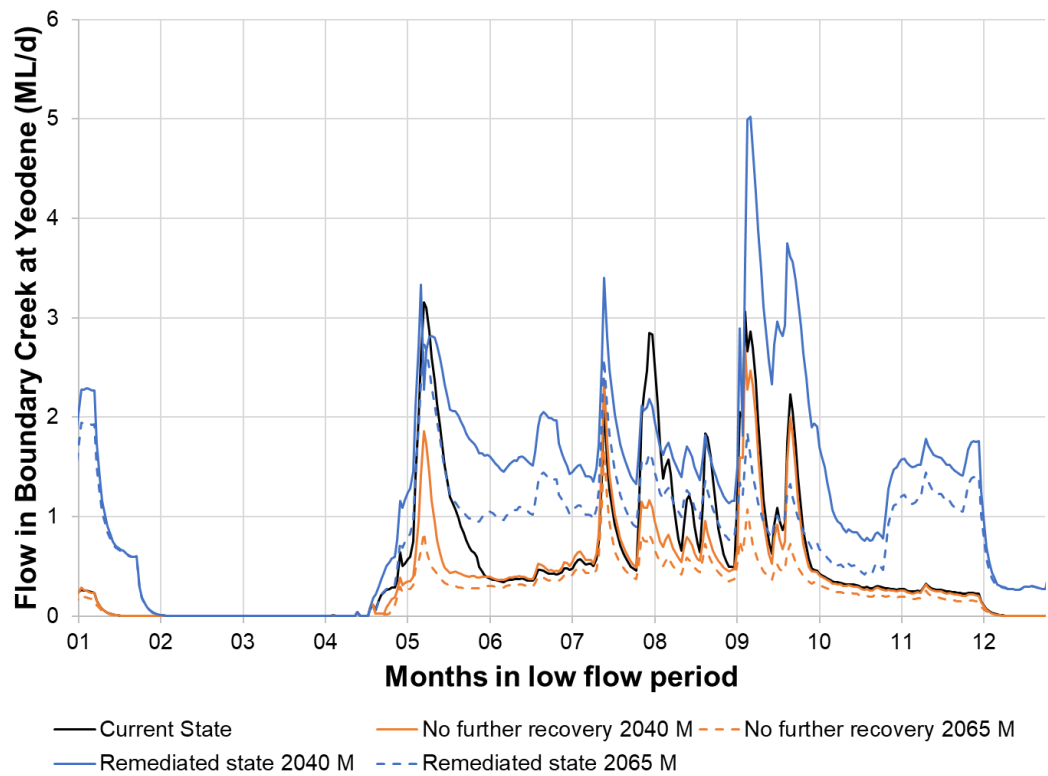


Figure 4-6 Comparison of flow during a low flow period for Boundary Creek at Yeodene

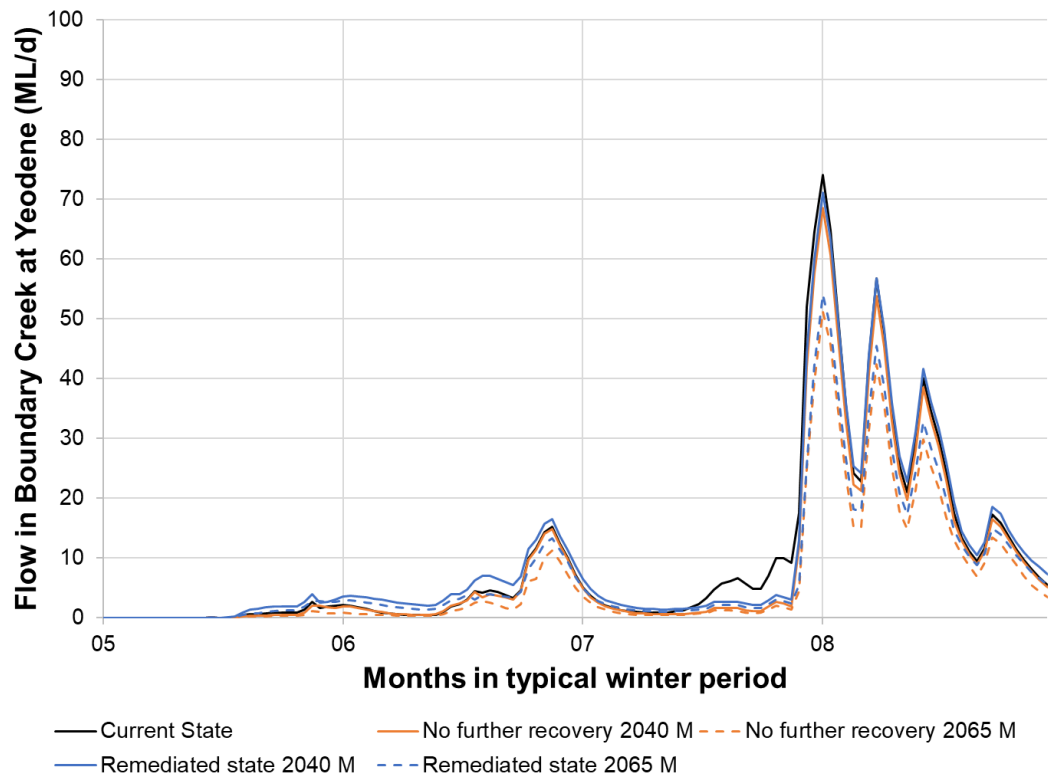


Figure 4-7 Comparison of flow during a typical winter period for Boundary Creek at Yeodene

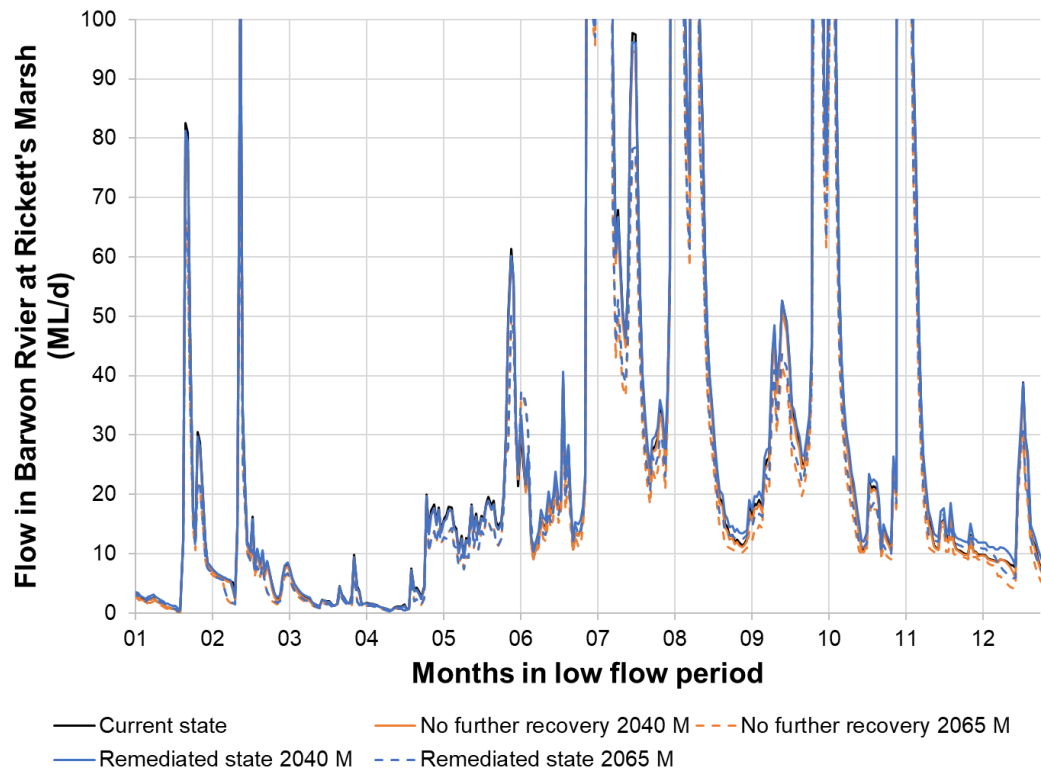


Figure 4-8 Comparison of flow during a low flow period for Barwon River at Rickett's Marsh

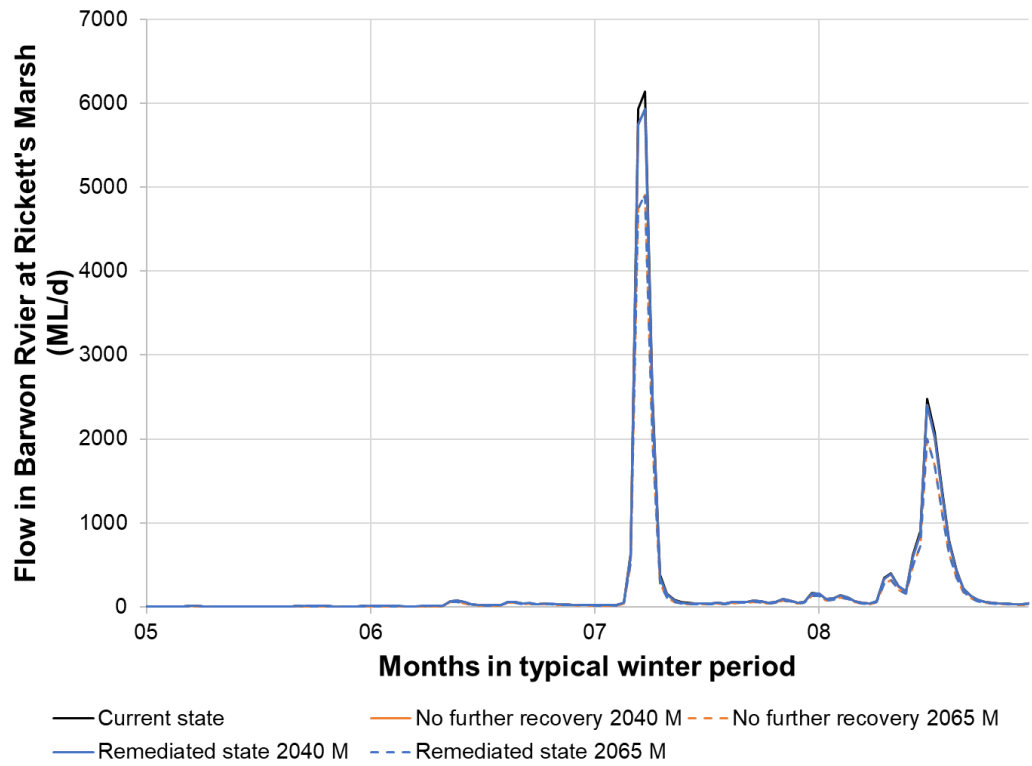


Figure 4-9 Comparison of flow during a typical winter period for Barwon River at Rickett's Marsh



4.2 Uncertainty in water availability under climate change

In the DELWP 2020 climate change guidelines (DELWP, 2020) low, medium and high values are published for 2020, 2040 and 2065 climate change. The low, medium and high values correspond to the 10th, 50th and 90th percentile results from the suite of 42 available GCMs used to make the climate change projection.

The purpose of this analysis is to compare the impact on system behaviour of a more severe (RCP 8.5 High Climate Change) or less severe (RCP 8.5 Low Climate Change) climate change projection is to occur. The results show the uncertainty in modelling water availability under 2040 and 2065 climate change projections under a remediated state.

This section explores the question:

What is the uncertainty in water availability under climate change?

4.2.1 Water balance of system

The water balance of the Boundary Creek system shows the impact on demands and inflows under 2040 climate change (Table 4-5) and 2065 climate change (Table 4-6). In 2040, the low climate change projection results in 30% higher inflows and outflows, whilst the 2040 high climate change projection results in approximately 30% lower inflows when compared to medium climate change. These differences are similar for 2065 climate change shown in Table 4-6.



Table 4-5 Water balance for Boundary Creek catchment extending down to Barwon River at Rickett's Marsh at for the different 2040 climate change projections under a remediated state

Average annual water availability calculated over the full climate sequence (ML/yr)					
	Medium climate change scenario	Low climate change scenario	% diff to Med	High climate change scenario	% diff to Med
Inflows	58,977	76,522	+30%	40,800	-31%
Boundary Creek catchment inflow	3,943	4,875	+24%	2,809	-29%
Barwon River catchment inflow (between West Barwon Dam and Ricketts Marsh)	38,872	48,062	+24%	27,695	-29%
Boundary Creek Supplementary Flows	0	0	0.0%	0	0.0%
Geelong Colac system contributions to Barwon River	15,817	23,240	+47%	9,951	-37%
Farm dam inflows	345	345	0.0%	345	0.0%
Demands	3,279	3,378	+3.0%	3,100	-5.5%
Rural demands	27	28	+3.7%	27	0.0%
Farm dam impacts	3,252	3,350	+3.0%	3,073	-5.5%
Losses	636	684	+7.5%	549	-14%
Groundwater impacts	85	87	+2.4%	83	-2.4%
River losses	547	593	+8.4%	461	-16%
Net evaporation	4	4	0.0%	4	0.0%
Outflow	54,990	72,384	+32%	37,088	-33%
Barwon River at Rickett's Marsh	54,991	72,385	+32%	37,089	-33%
Change in storage	-1.2	-1.2		-1.2	
Balance error (%)	0.0%	0.0%		0.0%	



Table 4-6 Water balance for Boundary Creek catchment extending down to Barwon River at Rickett's Marsh at for the different 2065 climate change projections under a remediated state

Average annual water availability calculated over the full climate sequence (ML/yr)					
	Medium climate change scenario	Low climate change scenario	% diff to Med	High climate change scenario	% diff to Med
Inflows	48,206	62,822	+30%	31,708	-34%
Boundary Creek catchment inflow	3,292	4,166	+27%	2,200	-33%
Barwon River catchment inflow (between West Barwon Dam and Ricketts Marsh)	32,455	41,066	+27%	21,692	-33%
Boundary Creek Supplementary Flows	0	0	0.0%	0	0.0%
Geelong Colac system contributions to Barwon River	12,114	17,246	+42%	7,471	-38%
Farm dam inflows	344	344	0.0%	344	0.0%
Demands	3,230	3,350	+3.7%	3,005	-7.0%
Rural demands	27	27	0.0%	26	-3.7%
Farm dam impacts	3,203	3,323	+3.7%	2,979	-7.0%
Losses	585	644	+10%	471	-20%
Groundwater impacts	84	86	+2.4%	79	-6.0%
River losses	497	554	+12%	388	-22%
Net evaporation	4	4	0.0%	4	0.0%
Outflow	44,323	58,756	+33%	28,173	-36%
Barwon River at Rickett's Marsh	44,325	58,757	+33%	28,174	-36%
Change in storage	-1.2	-1.2		-1.2	
Balance error (%)	0.0%	0.0%		0.0%	

4.2.2 Supply of rural demands

The supply of rural demands has been analysed as the proportion of the restricted demand able to be supplied over the model run period for each climate change scenario, as shown in Table 4-7. The low climate change scenario increases the proportion of demand able to be supplied by approximately 1% when compared to the medium climate change scenario. The high climate change scenario reduces the proportion of demand able to be supplied by 1-2% in 2040 and 2065 when compared to the medium climate change scenario.



Table 4-7 Proportion of demand supplied (%) for climate change scenarios under a remediated state

	Boundary Creek rural demands	Private on-stream dam demands
2040 Climate Change projection		
Medium Climate Change	85.1%	56.3%
Low Climate Change	85.8%	57.3%
% diff to Medium Climate Change	+0.7%	+1.0%
High Climate Change	83.7%	55.0%
% diff to Medium Climate Change	-1.4%	-1.3%
2065 Climate Change projection		
Medium Climate Change	84.3%	55.5%
Low Climate Change	85.3%	56.5%
% diff to Medium Climate Change	+1.0%	+1.0%
High Climate Change	82.2%	53.3%
% diff to Medium Climate Change	-2.1%	-2.2%

4.2.3 Impact on flow at key locations

The flow at key locations has been analysed over the full climate sequence and has been summarised for each gauge location and future climate projection in Table 4-8. Compared to medium climate change, low climate change produces flow at key gauge locations 25-35% higher in 2040 and 29-40% higher in 2065. By comparison, high climate change results in flow at key gauge locations by 31-35% lower in 2040 and 36-42% lower in 2065 when compared to the medium climate change projection.

Given that the climate change adjustments have been undertaken using an annual scaling factor, only the annual flow duration curve has been compared for 2040 and for 2065. As shown in Figure 4-10, the 2040 high climate change scenarios have more low flow events than the medium and low climate change scenarios. This is also observed for the 2065 climate change scenario in Figure 4-11.



Table 4-8 Average annual flow calculated over full climate sequence at key flow locations under a remediated state compared to the medium climate change scenario

Average annual flow compared to the medium climate change scenario calculated over the full climate sequence				
	233231 Boundary Creek us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
2040 climate change projections				
Low climate change	25% higher flow (average of 619 ML/yr)	26% higher flow (average of 849 ML/yr)	30% higher flow (average of 879 ML/yr)	32% higher flow (average of 17,394 ML/yr)
High climate change	31% lower flow (average of 753 ML/yr)	32% lower flow (average of 1,031 ML/yr)	35% lower flow (average of 1,039 ML/yr)	33% lower flow (average of 17,902 ML/yr)
2065 climate change projections				
Low climate change	29% higher flow (average of 581 ML/yr)	30% higher flow (average of 795 ML/yr)	35% higher flow (average of 809 ML/yr)	33% higher flow (average of 14,432 ML/yr)
High climate change	37% lower flow (average of 725 ML/yr)	38% lower flow (average of 990 ML/yr)	42% lower flow (average of 970 ML/yr)	36% lower flow (average of 16,151 ML/yr)

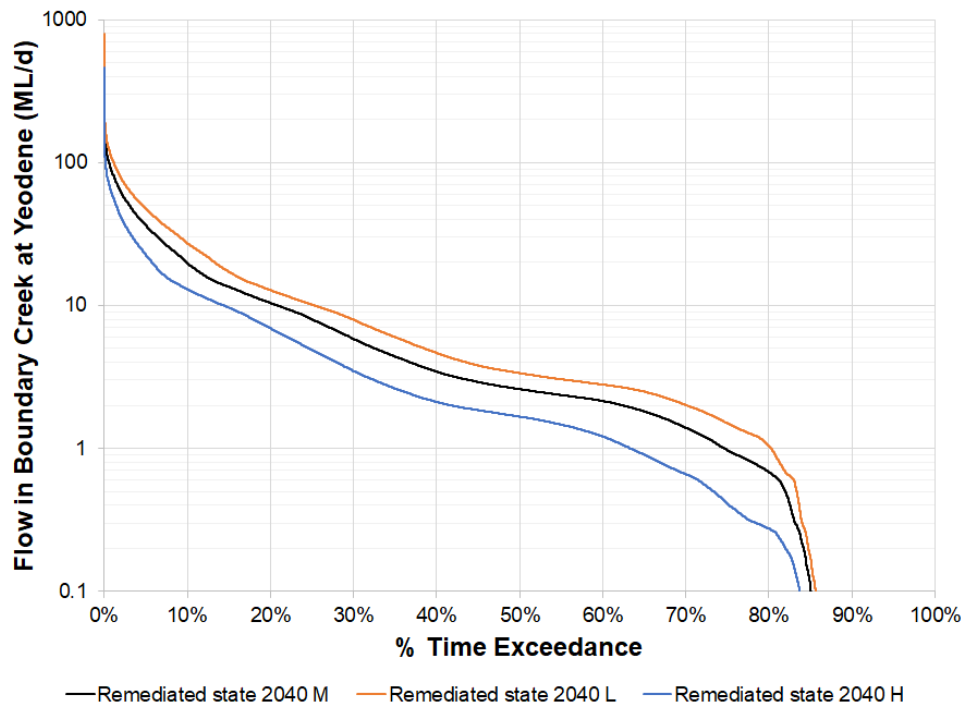


Figure 4-10 Flow duration curve comparison calculated across the full climate sequence for remediated state scenarios in Boundary Creek at Yeodene for 2040 climate change scenarios

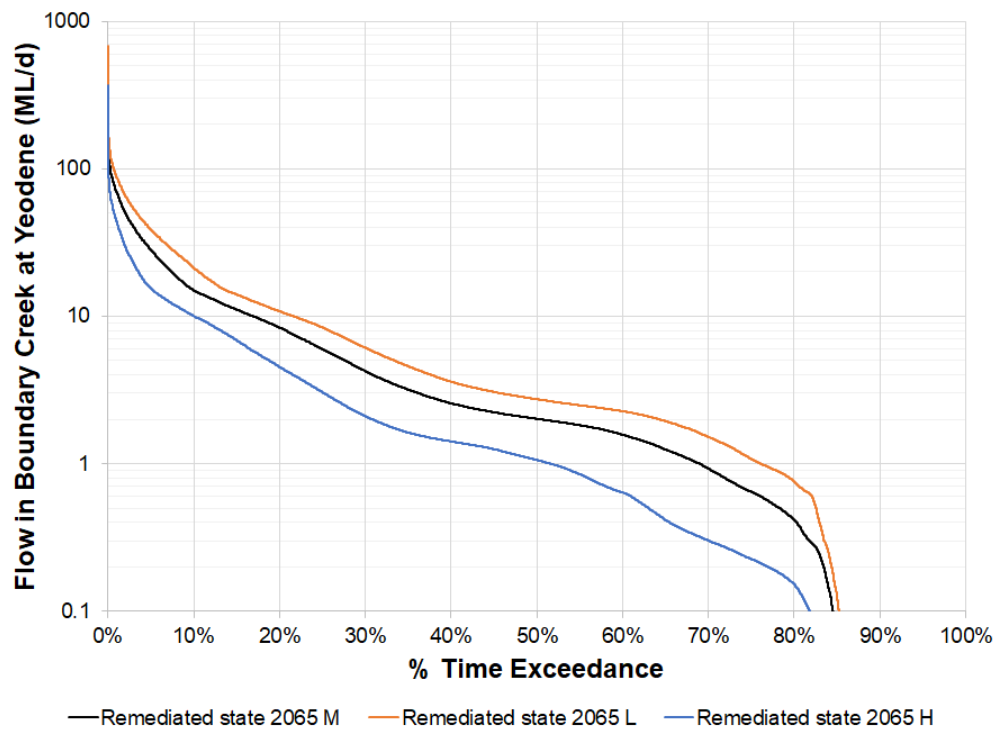


Figure 4-11 Flow duration curve comparison calculated across the full climate sequence for remediated state scenarios in Boundary Creek at Yeodene for 2065 climate change scenarios



4.3 Impact of groundwater pumping on current surface water flow regime

The purpose of this section is to show the difference in surface water availability with and without groundwater pumping, assuming current climate conditions and demand levels. This section does not consider any impacts of future climate and is intended to only look at changes in system behaviour driven by current groundwater pumping impacts. Note that when it is assumed that there are no pumping impacts, there is no Boundary Creek Supplementary Flows.

This section explores the question:

What is likely to have occurred if groundwater pumping never happened?

4.3.1 Water balance of system

The water balance of the Boundary Creek system shows the impact groundwater pumping has had on the average annual water availability down to Boundary Creek at Yeodene. As can be seen in Table 4-9, flows at Yeodene are expected to have been 19% higher if groundwater pumping never occurred. Noting that the difference is less than may be expected due to the addition of supplementary flows into the headwaters of Boundary Creek. As per the intent of their inclusion in the licence, these supplementary flows increase the inflows, and buffer against the groundwater pumping derived losses. Further analysis on the current impact of groundwater on key flow locations in Boundary Creek is included in Section 4.3.3.

Table 4-9 Water balance for Boundary Creek system (current climate)

	Average annual water availability calculated over the full climate sequence (ML/yr)		% diff between no pumping and no further recovery scenarios
	Pumping	No Pumping	
Inflows	4,464	4,100	-8.2%
Boundary Creek catchment inflow	4,056	4,056	0.0%
Boundary Creek Supplementary Flows	364	0	-100%
Farm dam inflows	44	44	0.0%
Demands	334	317	-5.1%
Rural demands	45	27	-40%
Farm dam impacts	289	289	0.0%
Losses	1,518	570	-62.5%
Groundwater impacts	1,038	0	-100%
River losses	468	566	+21%
Net evaporation	12	4	-67%
Outflow	2,634	3,140	+19.2%
Boundary Creek at Yeodene	2,634	3,141	+19.2%
Change in storage	-0.06	-1.2	
Balance error (%)	0%	0%	

4.3.2 Supply of rural demands

The supply of rural demands has been analysed as the proportion of restricted demand able to be supplied over the model run period.

As can be seen from Table 4-10, if groundwater pumping never occurred, there would not be sufficient flows in the upstream reaches of Boundary Creek to supply 100% of the rural demands along Boundary Creek. The addition of supplementary flows increases the proportion of rural demands that can be met, meaning nearly 100% of the restricted demands from Boundary Creek and the private on-stream dam can be supplied under the pumping scenario.

Table 4-10 Proportion of demand supplied (%) for current groundwater pumping impact

	Boundary Creek rural demands	Private on-stream dam demands
Pumping (with supplementary flows)	99.8%	100%
No pumping (no supplementary flows)	85.2%	56.4%

4.3.3 Impact on flow at key locations

The flow at key locations under a pumping and no pumping scenario has been analysed over the full climate sequence and has been summarised for each gauge location in Table 4-11. This analysis indicates that groundwater pumping (and the provision of supplementary flows) has increased the average annual flow in Boundary Creek upstream of the private on-stream dam by 13%, despite groundwater pumping leading to a decrease in Boundary Creek flows of 22% upstream of Big Swamp and 19% at Yeodene. As has been reported in section 4.3.1, the reported reductions in flow along Boundary Creek are of minimal downstream impact in the Barwon River at Ricketts Marsh.

Table 4-11 Average annual flow calculated across the full climate sequence at key flow locations with and without groundwater pumping impacts in Boundary Creek

	Average annual flow at key gauge locations calculated from 1900 to 2021 (ML/yr)			
	233231 Boundary Creek us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
No Pumping	2,524	3,453	3,141	57,096
Pumping	2,888	2,841	2,634	56,589
% difference comparing the pumping scenario to the no pumping scenario	+13%	-22%	-19%	-0.9%

Flow duration curves have been investigated for Boundary Creek at Yeodene for each scenario annually, for the warm season (November to March) and for the cool season (April to October). Over the entire model run period, there are 30% less potential cease to flow events in the no pumping scenario when compared to the pumping scenario (Figure 4-12). A potential cease to flow event has been defined as flow measured below 0.1 ML/d. This reduction in potential



cease to flow events is more prevalent in the warm season (Figure 4-13) than for the cool season (Figure 4-14). Irrespective of season, improvements are expected to be minimal when flows are greater than 11 ML/day.

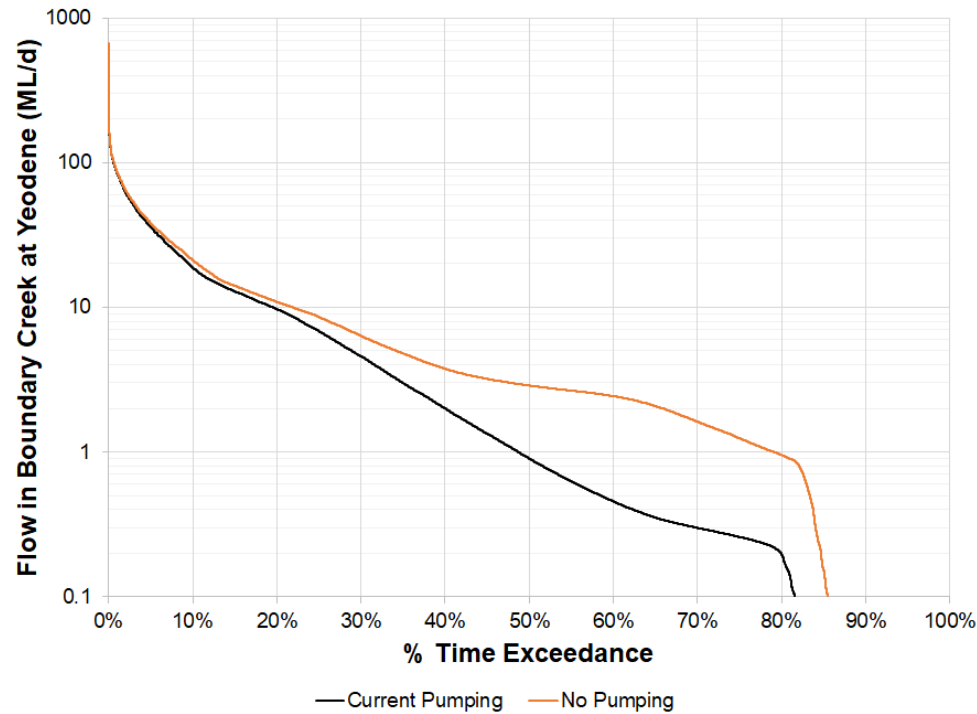


Figure 4-12 Flow duration curve comparison calculated for full climate sequence with and without groundwater pumping in Boundary Creek at Yeodene

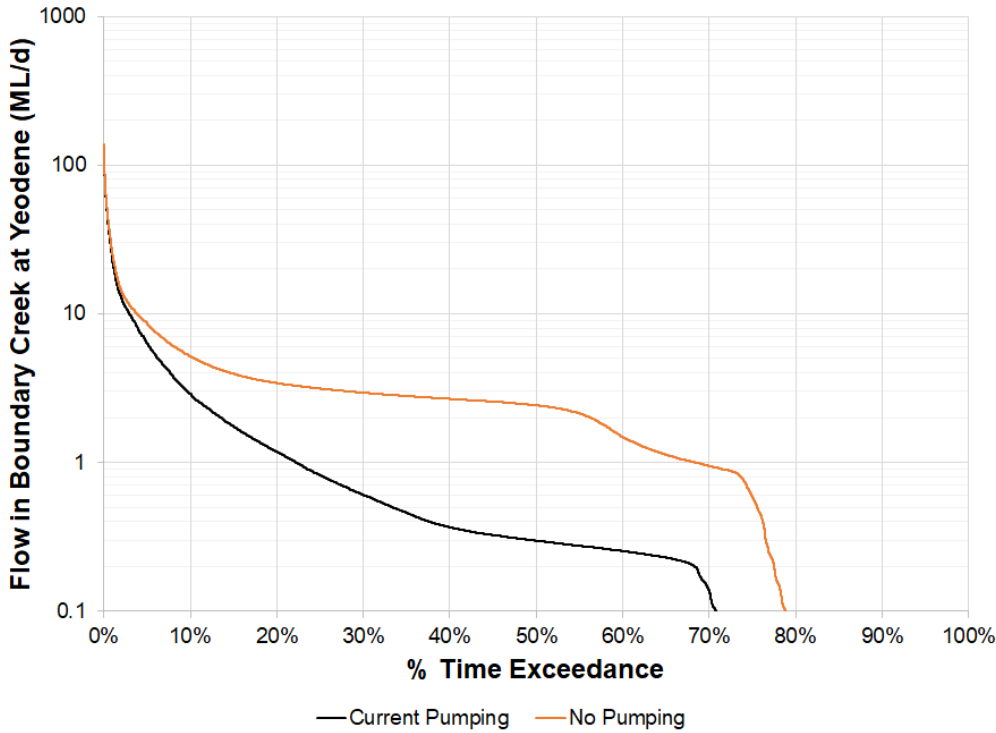


Figure 4-13 Flow duration curve comparison calculated for warm seasons (November to March) for full climate sequence with and without groundwater pumping in Boundary Creek at Yeodene

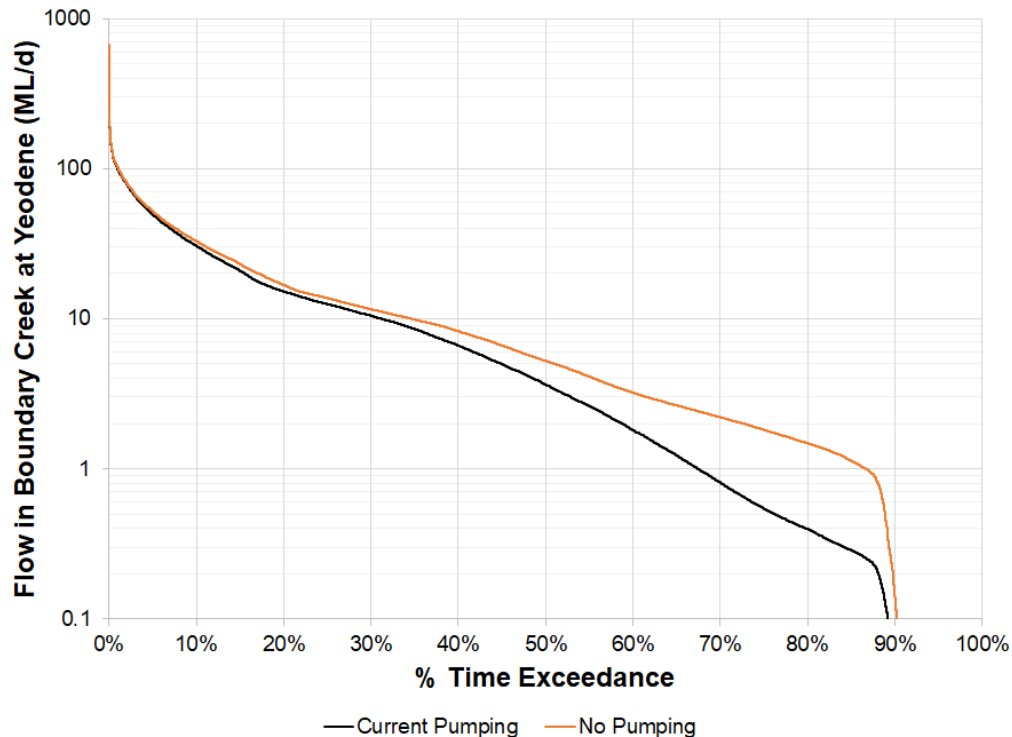


Figure 4-14 Flow duration curve comparison calculated for cool seasons (April to October) for full climate sequence with and without groundwater pumping in Boundary Creek at Yeodene

4.4 Impact of full uptake of rural demands on system resilience under future climate

This section compares system performance under current level of development demand to the case where demands increase to full uptake. Both cases are run with 2040 and 2065 medium climate change projections and assume that successful remediation has been achieved – i.e. groundwater discharge from the LTA is nearing pre-pumping levels.

The purpose of this section is to identify any vulnerability in the system due to take and use licence holders fully utilising their entitlement.

This section explores the question:

What impact does the full uptake of rural demands have on the resilience of each catchment under future climate?

4.4.1 Water balance of system

The water balance of the Boundary Creek system shows the impact of full uptake demands under the future climate change projections (Table 4-12 and Table 4-13). The key difference is



the 41% increase in rural demands under 2040 medium climate change and 37% under 2065 medium climate change due to the full uptake assumed. This analysis indicates that there are negligible impacts to the outflows of the Boundary Creek system under a full uptake scenario as demands are small compared to the total annual flow of the system.

Table 4-12 Water balance for Boundary Creek system comparing full uptake scenario to the 2040 level of demands for 2040 medium climate change scenario

Average annual water availability calculated over the full climate sequence (ML/yr)			
	Current demands	Full uptake scenario	% diff to BC
Inflows	3989	3989	0.0%
Boundary Creek Catchment Inflow	3943	3943	0.0%
Boundary Creek Supplementary Flows	0	0	0.0%
Farm dam inflows	46	46	0.0%
Demands	322	333	+3.4%
Rural Demands	27	38	+41%
Farm dam impacts	295	295	0.0%
Losses	645	641	-0.6%
Groundwater impacts	94	93	-1.1%
River losses	547	544	-0.5%
Net evaporation	4	3	-25%
Outflow	2960	2954	-0.2%
Boundary Creek at Yeodene	2961	2955	-0.2%
Change in storage	-0.2	-0.2	
Balance error (%)	0.0%	0.0%	

Table 4-13 Water balance for Boundary Creek system comparing full uptake scenario to the 2065 level of demands for 2065 medium climate change scenario

Average annual water availability calculated over the full climate sequence (ML/yr)			
	Current demands	Full uptake scenario	% diff to BC
Inflows	3337	3337	0.0%
Boundary Creek Catchment Inflow	3292	3292	0.0%
Boundary Creek Supplementary Flows	0	0	0.0%
Farm dam inflows	45	45	0.0%
Demands	366	376	+2.7%
Rural Demands	27	37	+37%
Farm dam impacts	339	339	0.0%
Losses	593	589	-0.7%
Groundwater impacts	92	92	0.0%
River losses	497	494	-0.6%
Net evaporation	4	3	-25%
Outflow	2319	2314	-0.2%
Boundary Creek at Yeodene	2321	2315	-0.3%
Change in storage	-0.2	-0.2	
Balance error (%)	0.0%	0.0%	

4.4.2 Supply of rural demands

Supply of rural demands has been analysed over the full climate sequence from 1900 to 2021. As shown in Table 4-14, under 2040 and 2065 climate, 5.2% less demand can be supplied on average under the full uptake case suggesting supply is constrained by reduced water availability under future climate.

Table 4-14 Proportion of demand supplied (%) for medium climate change scenarios under a remediated state

	Boundary Creek rural demands	Private on-stream dam demands
2040 with current demands	85.1%	56.3%
2040 Full uptake scenario	85.1%	51.1%
% diff to current	0%	-5.2%
2065 with current demands	84.3%	55.5%
2065 Full uptake scenario	84.3%	50.3%
% diff to current	0%	-5.2%

4.4.3 Impact on flow at key locations

The flow at key locations has been analysed over the full climate sequence. As shown in Table 4-15, there are negligible impacts on flows in the Boundary Creek catchment if full demands are



accessed under a remediated state. However, it is important to note that when supplementary flows are ceased, licence holders are unlikely to be able to access their full entitlement.

Table 4-15 Average annual flow calculated over the full climate sequence at key flow locations under a remediated state

Average annual flow compared to current demands calculated over the full climate sequence				
	233231 us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
2040 climate change projections				
Full uptake of rural demands	No change in flow	0.3% reduction in flow (average of 9 ML/yr)	0.2% reduction in flow (average of 6 ML/yr)	<0.1% reduction in flow (average of 6 ML/yr)
2065 climate change projections				
Full uptake of rural demands	No change in flow	0.3% reduction in flow (average of 9 ML/yr)	0.3% reduction in flow (average of 6 ML/yr)	<0.1% reduction in flow (average of 6 ML/yr)



5. Conclusions

A summary of the outcomes of the above analysis is provided in Table 5-1. Based on these findings the following conclusions can be made regarding the future climate resilience of these systems:

- All catchments are susceptible to future climate related impacts. With the highest percentage reduction in flows expected to occur within the Barwon River, irrespective of groundwater remediation.
- Under a medium climate change scenario:
 - Remediation actions are expected to reduce the impacts of climate change on Boundary Creek, at least for a short period of time, but in the longer-term term (beyond 2040) are unlikely to lead to any net improvement. This indicates that in the future, climate related factors alone may result in conditions returning to what we see today.
 - The increase in flows anticipated in Yahoo Creek due to recovery of groundwater discharge from the LTA is greater than the predicted climate related impacts, leading to a net increase in flows in 2040 and 2065 compared to the current state.
- Full uptake of rural demands has a negligible impact on the resilience of each catchment. However, under a remediated state, take and use licence holders along Boundary Creek are unlikely to be able to access their full entitlements in the absence of supplementary flows.
- Forecast climate related impacts could be 20-40% higher or 14-35% lower depending on the severity of climate change. The uncertainty in the impact of climate change on water availability was found to be similar, regardless of the subcatchment.



Table 5-1 Summary of scenario modelling outcomes in Gellibrand River catchment and Boundary Creek catchment

	Gellibrand System	Boundary Creek System
What is the predicted response of each catchment to future climate change?	<ul style="list-style-type: none"> Average annual flows at Gellibrand River at Bunkers Hill are predicted to decline by 3.2% by 2040 and 12.8% by 2065. If no further recovery of groundwater discharge occurs, flows are expected to decline by a further 0.4%. Slightly lower declines of 1.3% by 2040 and 11.9% by 2065 are predicted to occur in Love Creek under a remediated state. However, further declines of 2.6% are predicted to occur if there is no further recovery of groundwater discharge. Given Yahoo Creek receives direct groundwater discharge from the LTA, flows in Yahoo Creek are predicted to increase by 13% by 2040 and 1.8% by 2065 under a remediated state. These improvements primarily relate to flows <2 ML/day. On the other hand, declines of 4% by 2040 and 14.8% by 2065 are predicted to occur if there is no further recovery of groundwater discharge. 	<ul style="list-style-type: none"> Average annual flows at Boundary Creek upstream of the private on-stream dam are predicted to decline by 16% by 2040 and 32% by 2065. Average annual flows at Boundary Creek at Yeodene are predicted to increase by 12% by 2040 but decline by 12% by 2065 leading to no net change in flows over the long-term. Predicted improvements are mostly isolated to low flows. If no further recovery of groundwater discharge occurs, flows are expected to decline by a further 3.6% by 2040 and 18% by 2065. Barwon River at Ricketts Marsh, flows are predicted to decline by 2.8% by 2040 and 21.7% by 2065. If no further recovery of groundwater discharge occurs, flows are expected to decline by a further 1.0%.
What is the uncertainty in water availability under climate change?	In the Gellibrand system, a high climate change scenario is predicted to result in a 20% reduction in flows by 2040 and a 30-35% reduction in flows by 2065 compared to the medium climate change scenario. On the other hand, a low climate change scenario is predicted to result in a 14-16% increase in flow compared to the medium climate change scenario	In the Boundary Creek system, a high climate change scenario is predicted to result in a 31-42% reduction in flows compared to the medium climate change scenario. On the other hand, a low climate change scenario is predicted to result in a 25-35% increase in flow compared to the medium climate change scenario.
What impact does the full uptake of rural demands have on the resilience of each catchment?	In the Gellibrand system, the full uptake of rural demands has a negligible impact (0.2%) on the overall flows in the Gellibrand system.	In the Boundary Creek system, the full uptake of rural demands has a negligible impact (0.6%) on the overall flows in the Boundary Creek system. However, the modelling work indicates that licence holders are unlikely to be able to access their full entitlement when supplementary flows are ceased.
What is likely to have occurred if groundwater pumping never happened?	If groundwater pumping never occurred, average annual flows are expected to be 19% higher in Yahoo Creek and 3% higher in Love Creek. Despite this, if groundwater pumping never occurred, flows at Gellibrand River at Bunkers Hill are expected to be only 0.5% higher than current. This shows that the localised groundwater pumping impacts in Yahoo Creek and to a lesser extent, Love Creek have little effect on the Gellibrand catchment overall.	<ul style="list-style-type: none"> If groundwater pumping never occurred, the flows in Boundary Creek upstream of the private on-stream dam are expected to be 13% lower (as supplementary flows would not be artificially inflating the inflows). Further downstream, within and downstream of the discharge zone average annual flows are expected to be 19-22% higher under a no pumping scenario.



--	--	--



6. References

- Barwon Water (2024), Boundary Creek, Big Swamp and Surrounding Environment – Remediation and Environmental Protection Plan (REPP), Submitted 28 August 2024, Accepted 8 October 2024
- BW and HARC (2024), *Climate resilience modelling of waterways influenced by Barwon Downs borefield*, Model Development Report, Final, December 2024
- DELWP (2020), Guidelines for Assessing the Impact of Climate Change in Water Availability in Victoria, November 2020
- Fowler, K.R, Donohue, R, Morden, R., Durrant J, Hall, J (2012), *Decision support and uncertainty in self-supply irrigation areas*, Hydrologic and Water Resources Symposium
- GHD and DEECA (2022), Development of the Barwon Moorabool Source Model, December 2022
- HARC (2020), Investigation of trends in farm dam development over time, Version 3, prepared for Department of Environmental, Land, Water and Planning, February 2020
- HARC (2024), Climate resilience modelling of waterways influenced by Barwon Downs borefield, Review Report, Final, 22 February 2024

Appendix A Scenario modelling results

A.1 Gellibrand River catchment

A.1.1 Water Balances

Table 6-1 Water balance for current demands and current groundwater pumping for Gellibrand catchment (Scenario 1)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	98,931	91,690	82,066	101,785	88,636	71,389	91,028	80,451	55,582
Catchment Inflows	98,715	91,474	81,850	101,574	88,425	71,178	90,807	80,230	55,361
Farm Dam inflows	216	216	216	211	211	211	221	221	221
Demands	5,361	5,248	5,248	5,449	5,260	4,894	5,435	5,185	4,678
BW extractions to Colac	4,512	4,400	4,224	4,574	4,386	4,023	4,440	4,192	3,692
Rural Demands	187	186	185	187	186	183	186	185	178
Farm Dam impacts	644	644	643	669	669	669	789	789	788
Urban demands	18	18	18	19	19	19	20	20	20
Losses	1,530	1,557	1,586	1,525	1,574	1,574	1,550	1,590	1,633
Groundwater Impacts	399	397	395	399	397	392	397	395	382
River losses	1,269	1,279	1,288	1,265	1,283	1,291	1,277	1,285	1,269
Net Evaporation	-138	-120	-97	-139	-106	-66	-125	-90	-18
Outflow	92,065	84,901	75,421	94,840	81,821	64,890	84,070	73,690	49,287
Gellibrand River at Bunkers Hill	92,062	84,899	75,418	94,838	81,819	64,888	84,067	73,688	49,284
Change in storage	2.2	2	2	2	2	2	2	2	2
Balance error (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 6-2 Water balance for current demands and future groundwater recovery for Gellibrand catchment (Scenario 2)

	RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High
Inflows	101,785	88,636	71,389	91,028	80,451	55,582
Catchment Inflows	101,574	88,425	71,178	90,807	80,230	55,361
Farm Dam inflows	211	211	211	221	221	221
Demands	5,449	5,260	4,894	5,435	5,186	4,680
BW extractions to Colac	4,574	4,386	4,023	4,440	4,192	3,692
Rural Demands	187	186	184	186	185	179
Farm Dam impacts	669	669	669	789	789	789
Urban demands	19	19	19	20	20	20
Losses	1,172	1,225	1,276	1,200	1,245	1,304
Groundwater Impacts	40	40	40	40	40	40
River losses	1,271	1,291	1,302	1,285	1,295	1,282
Net Evaporation	-139	-106	-66	-125	-90	-18
Outflow	95,192	82,169	65,231	84,419	74,035	49,614
Gellibrand River at Bunkers Hill	95,190	82,166	65,228	84,417	74,033	49,611
Change in storage	2	2	2	2	2	2
Balance error (%)	0%	0%	0%	0%	0%	0%

Table 6-3 Water balance for current demands and no groundwater pumping for Gellibrand catchment (Scenario 3)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	98,931	91,690	82,066	101,785	88,636	71,389	91,028	80,451	55,582
Catchment Inflows	98,715	91,474	81,850	101,574	88,425	71,178	90,807	80,230	55,361
Farm Dam inflows	216	216	216	211	211	211	221	221	221
Demands	5,361	5,248	5,071	5,450	5,260	4,894	5,436	5,186	4,680
BW extractions to Colac	4,512	4,400	4,224	4,574	4,386	4,023	4,440	4,192	3,692
Rural Demands	187	187	186	187	186	184	186	185	179
Farm Dam impacts	644	644	644	669	669	669	789	789	789
Urban demands	18	18	18	19	19	19	20	20	20
Losses	1,139	1,168	1,201	1,133	1,186	1,237	1,161	1,206	1,265
Groundwater Impacts	0	0	0	0	0	0	0	0	0
River losses	1,277	1,288	1,298	1,272	1,292	1,303	1,286	1,296	1,284
Net Evaporation	-138	-120	-97	-139	-106	-66	-125	-90	-18
Outflow	92,455	85,290	75,805	95,232	82,208	65,269	84,458	74,074	49,652
Gellibrand River at Bunkers Hill	92,453	85,288	75,803	95,230	82,206	65,267	84,456	74,072	49,650
Change in storage	2	2	2	2	2	2	2	2	2
Balance error (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 6-4 Water balance for full demands and current groundwater pumping for Gellibrand catchment (Scenario 4)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	98,931	91,690	82,066	101,785	88,636	71,389	91,028	80,451	55,582
Catchment Inflows	98,715	91,474	81,850	101,574	88,425	71,178	90,807	80,230	55,361
Farm Dam inflows	216	216	216	211	211	211	221	221	221
Demands	5,535	5,430	5,258	5,636	5,457	5,098	5,627	5,186	4,883
BW extractions to Colac	4,499	4,394	4,223	4,556	4,379	4,022	4,427	4,192	3,691
Rural Demands	374	374	374	392	391	388	391	185	383
Farm Dam impacts	644	644	643	669	669	669	789	789	789
Urban demands	18	18	18	19	19	19	20	20	20
Losses	1,530	1,556	1,586	1,172	1,225	1,275	1,200	1,245	1,303
Groundwater Impacts	399	397	395	40	40	40	40	40	40
River losses	1,269	1,279	1,288	1,271	1,291	1,301	1,284	1,295	1,281
Net Evaporation	-138	-120	-97	-139	-106	-66	-125	-90	-18
Outflow	91,878	84,714	75,234	95,006	81,982	65,044	84,232	74,035	49,427
Gellibrand River at Bunkers Hill	91,876	84,712	75,232	95,003	81,980	65,042	84,230	74,033	49,425
Change in storage	2	2	2	2	2	2	2	2	2
Balance error (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%



A.1.2 Average annual flows

Table 6-5 Average annual flow calculated from 1900 to 2021

	235227 Gellibrand River at Bunkers Hill	235231 Gellibrand River at Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kawarren
Base Case	105,729	44,112	9,625	1,535
Scenario 1: No further recovery				
2020 Low	92,065	38,350	8,500	1,314
2020 Med	84,899	35,287	7,806	1,201
2020 High	75,418	31,251	6,886	1,052
2040 Low	94,838	39,533	8,762	1,357
2040 Med	81,819	33,960	7,502	1,153
2040 High	64,888	26,776	5,857	886
2065 Low	84,068	34,951	7,688	1,187
2065 Med	73,688	30,553	6,677	1,023
2065 High	49,284	20,167	4,327	645
Scenario 2: Remediated state				
2040 Low	95,190	39,687	8,966	1,562
2040 Med	82,167	34,114	7,704	1,355
2040 High	65,228	26,930	6,054	1,083
2065 Low	84,417	35,106	7,890	1,389
2065 Med	74,033	30,708	6,877	1,223
2065 High	49,611	20,322	4,513	831
Scenario 3: No pumping				
2020 Low	92,453	38,521	8,727	1,541
2020 Med	85,288	35,459	8,032	1,427
2020 High	75,803	31,423	7,109	1,275
2040 Low	95,230	39,705	8,989	1,585
2040 Med	82,206	34,131	7,727	1,378
2040 High	65,267	26,948	6,077	1,106
2065 Low	84,456	35,123	7,913	1,412
2065 Med	74,072	30,725	6,900	1,246
2065 High	49,650	20,339	4,536	854
Scenario 4: Full uptake				
2020 Low	91,876	38,350	8,492	1,314
2020 Med	84,712	35,287	7,798	1,201
2020 High	75,232	31,251	6,878	1,052
2040 Low	95,003	39,687	8,958	1,562
2040 Med	81,980	34,114	7,696	1,355
2040 High	65,042	26,930	6,046	1,083
2065 Low	84,230	35,106	7,882	1,389
2065 Med	73,846	30,708	6,869	1,223
2065 High	49,425	20,322	4,506	831



Table 6-6 Average annual flow calculated from 2004 to 2009 (Millennium Drought)

	235227 Gellibrand River at Bunkers Hill	235231 Gellibrand River at Rafferty Lane	235234 Love Creek at Gellibrand	235240 Yahoo Creek at Kawarren
Base Case	57,933	24,600	4,037	423
Scenario 1: No further recovery				
2020 Low	60,180	25,585	4,208	445
2020 Med	55,449	23,547	3,834	397
2020 High	49,173	20,841	3,342	335
2040 Low	62,085	26,452	4,343	463
2040 Med	53,431	22,689	3,665	377
2040 High	42,330	17,973	2,790	267
2065 Low	54,946	23,422	3,740	391
2065 Med	48,085	20,483	3,200	323
2065 High	32,124	13,687	1,960	172
Scenario 2: Remediated state				
2040 Low	62,431	26,607	4,545	665
2040 Med	53,769	22,844	3,862	574
2040 High	42,655	18,128	2,976	454
2065 Low	55,285	23,576	3,938	589
2065 Med	48,418	20,638	3,392	516
2065 High	32,431	13,841	2,130	343
Scenario 3: No pumping				
2020 Low	60,562	25,756	4,432	669
2020 Med	55,827	23,719	4,055	618
2020 High	49,544	21,012	3,558	551
2040 Low	62,470	26,624	4,568	688
2040 Med	53,807	22,861	3,885	597
2040 High	42,694	18,145	2,999	477
2065 Low	55,324	23,593	3,961	612
2065 Med	48,456	20,655	3,415	539
2065 High	32,468	13,858	2,153	366
Scenario 4: Full uptake				
2020 Low	60,001	38,350	4,197	445
2020 Med	55,271	23,547	3,823	397
2020 High	48,995	20,841	3,331	335
2040 Low	62,252	26,607	4,534	665
2040 Med	53,591	22,844	3,851	574
2040 High	42,478	18,128	2,965	454
2065 Low	55,107	23,576	3,927	589
2065 Med	48,240	20,638	3,381	516
2065 High	32,253	13,841	2,120	343



A.1.3 Proportion of supplied demands

Table 6-7 Proportion of demand supplied (%)

	Gellibrand River Rural Demands	Love Creek Rural Demands	Gellibrand River Winterfill Demands	Gellibrand Urban Demand
Base Case	100%	100%	100%	100%
Scenario 1: No further recovery				
2020 Low	100%	100%	100%	100%
2020 Med	100%	100%	100%	100%
2020 High	100%	100%	100%	100%
2040 Low	100%	100%	100%	100%
2040 Med	100%	100%	100%	100%
2040 High	100%	100%	100%	100%
2065 Low	100%	100%	100%	100%
2065 Med	100%	100%	100%	100%
2065 High	100%	100%	100%	100%
Scenario 2: Remediated state				
2040 Low	100%	100%	100%	100%
2040 Med	100%	100%	100%	100%
2040 High	100%	100%	100%	100%
2065 Low	100%	100%	100%	100%
2065 Med	100%	100%	100%	100%
2065 High	100%	100%	100%	100%
Scenario 3: No pumping				
2020 Low	100%	100%	100%	100%
2020 Med	100%	100%	100%	100%
2020 High	100%	100%	100%	100%
2040 Low	100%	100%	100%	100%
2040 Med	100%	100%	100%	100%
2040 High	100%	100%	100%	100%
2065 Low	100%	100%	100%	100%
2065 Med	100%	100%	100%	100%
2065 High	100%	100%	100%	100%
Scenario 4: Full uptake				
2020 Low	100%	100%	100%	100%
2020 Med	100%	100%	100%	100%
2020 High	100%	100%	100%	100%
2040 Low	100%	100%	100%	100%
2040 Med	100%	100%	100%	100%
2040 High	100%	100%	100%	100%
2065 Low	100%	100%	100%	100%
2065 Med	100%	100%	100%	100%
2065 High	100%	100%	100%	100%

A.2 Boundary Creek catchment

A.2.1 Water Balances

Table 6-8 Water balance for current demands and current groundwater pumping for Boundary catchment (Scenario 1)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	4985	4464	3834	4922	3989	2856	4211	3337	2246
Boundary Creek Catchment Inflow	4577	4056	3427	4875	3943	2809	4166	3292	2200
Boundary Creek supplementary flows	364	364	364	0	0	0	0	0	0
Farm dam inflows	44	44	44	46	46	46	45	45	45
Demands	334	334	334	323	322	322	367	366	365
Rural Demands	45	45	45	28	27	27	27	27	26
Farm dam impacts	289	289	289	295	295	295	339	339	339
Losses	1554	1518	1459	1401	1329	1191	1341	1247	1077
Groundwater impacts	1041	1038	1030	904	886	850	889	864	810
River losses	501	468	417	494	439	337	449	379	263
Net evaporation	12	12	12	3	3	4	3	4	4
Outflow	3107	2634	2088	3239	2411	1486	2568	1836	1009
Boundary Creek at Yeodene	3107	2634	2088	3240	2413	1487	2570	1837	1010

Table 6-9 Water balance for current demands with future groundwater recovery for Boundary catchment (Scenario 2)

	RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High
Inflows	4922	3989	2856	4211	3337	2246
Boundary Creek Catchment Inflow	4875	3943	2809	4166	3292	2200
Boundary Creek supplementary flows	0	0	0	0	0	0
Farm dam inflows	46	46	46	45	45	45

Demands	323	322	322	367	366	365
Rural Demands	28	27	27	27	27	26
Farm dam impacts	295	295	295	339	339	339
Losses	692	645	557	652	593	480
Groundwater impacts	95	94	91	94	92	88
River losses	593	547	461	554	497	388
Net evaporation	4	4	4	4	4	4
Outflow	3839	2960	1921	3129	2319	1350
Boundary Creek at Yeodene	3840	2961	1922	3130	2321	1351

Table 6-10 Water balance for current demands and no groundwater pumping for Boundary catchment (Scenario 3)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	4621	4100	3470	4922	3989	2856	4211	3337	2246
Boundary Creek Catchment Inflow	4577	4056	3427	4875	3943	2809	4166	3292	2200
Boundary Creek supplementary flows	0	0	0	0	0	0	0	0	0
Farm dam inflows	44	44	44	46	46	46	45	45	45
Demands	317	317	317	323	322	322	367	366	365
Rural Demands	28	27	27	28	27	27	27	27	26
Farm dam impacts	289	289	289	295	295	295	339	339	339
Losses	596	570	531	609	563	480	570	514	410
Groundwater impacts	0	0	0	0	0	0	0	0	0
River losses	592	566	526	604	559	476	566	510	405
Net evaporation	4	4	4	5	4	4	4	4	4
Outflow	3631	3140	2554	3912	3032	1989	3201	2390	1411
Boundary Creek at Yeodene	3633	3141	2555	3913	3033	1990	3202	2391	1412

Table 6-11 Water balance for full demands and future groundwater recovery for Boundary catchment (Scenario 4)

	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
	Low	Med	High	Low	Med	High	Low	Med	High
Inflows	4985	4464	3834	4922	3989	2856	4211	3337	2246
Boundary Creek Catchment Inflow	4577	4056	3427	4875	3943	2809	4166	3292	2200
Boundary Creek supplementary flows	364	364	364	0	0	0	0	0	0
Farm dam inflows	44	44	44	46	46	46	45	45	45
Demands	359	359	359	333	333	332	377	376	375
Rural Demands	69	69	69	38	38	37	38	37	36
Farm dam impacts	289	289	289	295	295	295	339	339	339
Losses	1548	1511	1452	688	641	553	648	589	1069
Groundwater impacts	1038	1034	1026	94	93	91	93	92	803
River losses	498	466	414	590	544	459	552	494	263
Net evaporation	12	12	12	3	3	3	3	3	3
Outflow	3089	2617	2072	3833	2954	1915	3122	2314	1009
Boundary Creek at Yeodene	3089	2617	2072	3834	2955	1917	3124	2315	1010



A.2.2 Average annual flows

Table 6-12 Average annual flow calculated from 1900 to 2021

	233231 Boundary Creek us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
Base Case	3,305	3,342	3,172	69,707
Scenario 1: No further recovery				
2020 Low	3,234	3,303	3,107	66,176
2020 Med	2,888	2,841	2,634	56,589
2020 High	2,469	2,295	2,088	46,138
2040 Low	3,058	3,404	3,240	71,786
2040 Med	2,439	2,600	2,413	54,443
2040 High	1,686	1,666	1,487	36,654
2065 Low	2,551	2,752	2,570	58,196
2065 Med	1,970	2,022	1,837	43,841
2065 High	1,245	1,169	1,010	27,833
Scenario 2: Remediated state				
2040 Low	3,058	4,112	3,840	72,385
2040 Med	2,439	3,263	2,961	54,991
2040 High	1,686	2,232	1,922	37,089
2065 Low	2,551	3,425	3,130	58,757
2065 Med	1,970	2,630	2,321	44,325
2065 High	1,245	1,640	1,351	28,174
Scenario 3: No pumping				
2020 Low	2,870	3,928	3,633	66,701
2020 Med	2,524	3,453	3,141	57,096
2020 High	2,106	2,879	2,555	46,605
2040 Low	3,058	4,199	3,913	72,458
2040 Med	2,439	3,349	3,033	55,063
2040 High	1,686	2,315	1,990	37,157
2065 Low	2,551	3,511	3,202	58,829
2065 Med	1,970	2,714	2,391	44,395
2065 High	1,245	1,719	1,412	28,234
Scenario 4: Full uptake				
2020 Low	3,234	3,282	3,089	66,158
2020 Med	2,888	2,821	2,617	56,572
2020 High	2,469	2,277	2,072	46,122
2040 Low	3,058	4,103	3,834	72,379
2040 Med	2,439	3,254	2,955	54,985
2040 High	1,686	2,223	1,917	37,083
2065 Low	2,551	3,416	3,124	58,751
2065 Med	1,970	2,621	2,315	44,319
2065 High	1,245	1,169	1,010	27,833



Table 6-13 Average annual flow calculated from 2004 to 2009 (Millennium Drought)

	233231 Boundary Creek us of the private on-stream dam	233275 Boundary Creek us Big Swamp	233228 Boundary Creek at Yeodene	233224 Barwon River at Ricketts Marsh
Base Case	1,799	1,601	1,375	28,884
Scenario 1: No further recovery				
2020 Low	1,942	1,800	1,571	31,850
2020 Med	1,740	1,519	1,298	27,775
2020 High	1,495	1,192	992	23,017
2040 Low	1,689	1,849	1,639	34,115
2040 Med	1,327	1,366	1,168	26,859
2040 High	886	827	673	18,407
2065 Low	1,381	1,447	1,246	28,453
2065 Med	1,042	1,019	846	21,877
2065 High	618	548	429	14,066
Scenario 2: Remediated state				
2040 Low	1,689	2,465	2,150	34,627
2040 Med	1,327	1,921	1,612	27,303
2040 High	886	1,264	989	18,723
2065 Low	1,381	2,013	1,705	28,912
2065 Med	1,042	1,506	1,215	22,246
2065 High	618	882	651	14,288
Scenario 3: No pumping				
2020 Low	1,581	2,373	2,045	32,324
2020 Med	1,378	2,069	1,745	28,221
2020 High	1,133	1,700	1,387	23,412
2040 Low	1,689	2,543	2,215	34,692
2040 Med	1,327	1,997	1,675	27,367
2040 High	886	1,336	1,046	18,781
2065 Low	1,381	2,090	1,769	28,976
2065 Med	1,042	1,579	1,276	22,307
2065 High	618	948	699	14,336
Scenario 4: Full uptake				
2020 Low	1,942	1,776	1,548	31,827
2020 Med	1,740	1,494	1,276	27,753
2020 High	1,495	1,174	978	23,003
2040 Low	1,689	2,455	2,143	34,620
2040 Med	1,327	1,911	1,605	27,296
2040 High	886	1,255	983	18,717
2065 Low	1,381	2,004	1,698	28,905
2065 Med	1,042	1,496	1,209	22,240
2065 High	618	548	429	14,065



A.2.3 Proportion of supplied demands

Table 6-14 Proportion of demand supplied (%)

	Boundary Creek rural demands	Private on-stream dam demands
Base Case	99.9%	100%
Scenario 1: No further recovery		
2020 Low	99.8%	100%
2020 Med	99.8%	100%
2020 High	99.8%	100%
2040 Low	85.8%	57.3%
2040 Med	85.1%	56.3%
2040 High	83.7%	55.0%
2065 Low	85.3%	56.5%
2065 Med	84.3%	55.5%
2065 High	82.2%	53.3%
Scenario 2: Remediated state		
2040 Low	85.8%	57.3%
2040 Med	85.1%	56.3%
2040 High	83.7%	55.0%
2065 Low	85.3%	56.5%
2065 Med	84.3%	55.5%
2065 High	82.2%	53.3%
Scenario 3: No pumping		
2020 Low	85.6%	57.1%
2020 Med	85.2%	56.4%
2020 High	84.5%	55.8%
2040 Low	85.8%	57.3%
2040 Med	85.1%	56.3%
2040 High	83.7%	55.0%
2065 Low	85.3%	56.5%
2065 Med	84.3%	55.5%
2065 High	82.2%	53.3%
Scenario 4: Full uptake		
2020 Low	99.8%	100%
2020 Med	99.8%	100%
2020 High	99.8%	100%
2040 Low	85.8%	52.0%
2040 Med	85.1%	51.1%
2040 High	83.7%	49.9%
2065 Low	85.3%	51.2%
2065 Med	84.3%	50.3%
2065 High	82.2%	48.2%