NOVEMBER 2021

Analysis of the social and economic values dependent on a flowing Barwon River (through Geelong) and lower Moorabool River

Final Report

Corangamite CMA

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Executive Summary

This report examines the social and economic benefits that the Barwon and Moorabool Rivers provide to the community of Geelong, and the importance of river flows for supporting and protecting these values.

BACKGROUND

The Barwon River system in Victoria is one of Geelong's most significant natural assets. The lower Barwon and Moorabool Rivers and their surrounding parklands support a wide range of recreational activities which are valued by Geelong locals and visitors alike. This includes walking, cycling, fishing, rowing, paddle sports and game hunting, or simply taking the time to enjoy nature. Green open spaces are vital to the well-being of the community and with a rapid growing population in the greater Geelong region, the demand for access to public recreation areas is increasing. Recent stay-at-home restrictions have highlighted the value that the community places on such areas.

The river also hosts events each year including the Head of the School Girls Regatta, Junior Girls State Champions Regatta, Sacred Heart, Loreto and Firbank School regattas and River Run – Geelong. In addition to recreational activities, the lower Barwon and Moorabool Rivers also provides:

- Special significance for the region's Traditional Owners, the Wadawurrung people of the Kulin Nation
- Increased liveability for local residents though open space, diverse native vegetation and stunning vistas, represented through higher property prices for housing near the river
- Environmental benefits, as the rivers and their flows also support a wide range of native plants and animals, including platypus, swamp wallabies, native fish, snakes and turtles and a rich bird life. All are supported through the management of 'water for the environment', or water that is managed to maintain the health of rivers and wetlands.

CURRENT ISSUES FACING THE BARWON RIVER

A growing population in Geelong and increased water use for agriculture and urban water supply, combined with the effects of climate change, has led to declining flows of water in the Barwon River and the lower Moorabool River.

This is leading to reduced water quality in the lower Barwon through Geelong, particularly in summer and autumn when the river is most widely used and valued by the local community.

It has also led to the increased frequency and severity of blue-green algal outbreaks, which impact the surrounding environment and can threaten safe boating and recreational watersports over the long-term.

Some river-based events, such as rowing, also need minimum water depths to ensure participants' safety. Waterway conditions can also impact land-based activities through increased odour, or a lack of amenity and capacity to support the surrounding environment, such as bird life.

PURPOSE

Until recently, the full impacts of reduced water flows in the Barwon River – particularly in terms of the social and economic impacts for Geelong were not fully understood.

As the manager for the Barwon River through Geelong, the Corangamite Catchment Management Authority (CMA) commissioned an independent study by consulting firm RMCG in partnership with HARC, focused on the lower Barwon and Moorabool Rivers near the Geelong Ring Road to the lower barrages at Reedy Lake.

The aim of the study was to:

1. Model a range of climate and water recovery scenarios on river flows in the lower Barwon and Moorabool Rivers
2. Examine the social and economic benefits from a flowing Barwon River through Geelong and lower Moorabool River.

The results from this study are intended to support more informed decision making around water resource management through the current Central and Gippsland Sustainable Water Strategy process, with the aim of understanding the social and economic benefits that would arise through an increased allocation of water for the lower Barwon and Moorabool Rivers through Geelong.

APPROACH

The study was undertaken in three parts, a hydrology and water quality analysis, a socio-economic assessment of the value of the waterways, and an economic analysis.

Several water modelling scenarios were considered as part of the hydrology and water quality analysis where different volumes of recovered water would be delivered along the Leigh/ Yarrowee, Barwon and Moorabool Rivers. These scenarios measured the impact of additional water on river flows, depth and water quality in the lower Moorabool and Barwon Rivers, including the expected likelihood of algal blooms.

A quantitative economic analysis was undertaken to estimate the use and value of the river, and its impact and benefits under each water recovery scenario. The analysis considered climate change, population growth and community behaviour assumptions.

KEY STUDY FINDINGS

EFFECT OF CLIMATE AND WATER RECOVERY SCENARIOS

Flow and algal bloom modelling showed that under current climate and levels of development algal blooms occur in Geelong for an average of 27 days per year (mainly in the summer), and critical rowing depths for regattas are expected to be met in around one third of years. Algal blooms and lower river flows impact the river's overall amenity and its capacity to support river events. Likewise, improved river flows can help protect water quality, maintain water levels and reduce the risk of algal blooms in the lower Barwon River through Geelong.

To examine the benefit of improved environmental flows at Geelong, a series of nine water recovery scenarios (through a combination of increased environmental entitlements in the Barwon and Moorabool Rivers and adjusted releases from the Ballarat South Wastewater Treatment Plant) were modelled.

Of these, three options (Scenario 3a, 3c and 4) were adopted for the economic benefits analysis:

- **Scenario 3a –** releasing water to the reaches immediately downstream of each storage (Lal Lal and West Barwon Reservoirs). This scenario, which slightly reduces the number of weeks of low river flows at Geelong, can provide a more significant reduction in the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing. This scenario is approximately equivalent to the 3,380 ML/year water recovery target from Lal Lal Reservoir cited in the Moorabool FLOWS study[1].
- **Scenario 3c –** releasing higher volumes of water (increased environmental entitlements in Lal Lal and West Barwon Reservoirs) over summer and winter to improve more constant flow through Geelong. This scenario significantly decreases the number of weeks of low flow at Geelong and the frequency of algal blooms. It also provides the best results in terms of the ability to maintain critical rowing depth. This scenario is approximately equivalent to the 5,140 ML/year water recovery target from Lal Lal Reservoir and the 3,773 ML/year water recover target from West Barwon Reservoir cited in the Moorabool and Upper Barwon FLOWS studies.[23])
- **Scenario 4 –** environmental water recovery with optimised wastewater treatment releases. This scenario, which combines the manipulation of Ballarat South Wastewater Treatment Plant discharge with an increased environmental entitlement, also successfully reduced the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing. The increased environmental entitlement in this scenario is approximately equivalent to the higher 6,150 ML/year water recovery target from Lal Lal Reservoir cited in the Moorabool FLOWS study.[4]

SOCIAL AND ECONOMIC IMPACT

An economic model was developed using an ecosystem services approach. The economic values of recreational use, major events and housing drawn from existing literature and consultation with river users were used to derive the annual direct and indirect benefits from use of the Barwon and Moorabool Rivers in Geelong and the surrounding area. On-river commercial activities such as commercial eel fishing and boating, however, were not included in the study and would require further analysis.

Once the annual value was established, the ability to access and participate in recreational and social events and an individual's willingness to pay for housing located within proximity to the river was linked to river depth, annual flow and blue-green algae events under a range of water recovery scenarios. Key findings include:

- The river currently provides an annual value of approximately $24.7 million to the Geelong community, assuming no impact from low water levels or algal blooms. The benefits are largely driven by land use surrounding the river, for example, recreation, aesthetic and social events as well as the willingness for housing in a more natural riverine environment.
- When considering the predicted frequency of low river levels and algal events, the average annual value of the river is reduced to $19.9 million per year (a $4.8 million per year reduction).
- When considering the optimal flow scenario 3c (which approximates to the 5,140 ML/year water recovery target at Lal Lal Reservoir and the 3,773 ML/year target at West Barwon Reservoir) the current average annual value of the river is estimated to be increased to $23.7 million per year (a $3.8 million per year increase). Over a 40-year period, this benefit is estimated to be a net present value of $95 million assuming the continuation of the current climate and consumptive demands.

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1 Jacobs, 2015
2 ibid
3 Alluvium, 2019
4 Jacobs, 2015

The economic benefits of additional flows through Geelong identified in this study (refer Figure E-1) underpin the importance of exploring these water recovery options further through the current Central and Gippsland Sustainable Water Strategy development process and subsequent studies into increased environmental water entitlements.

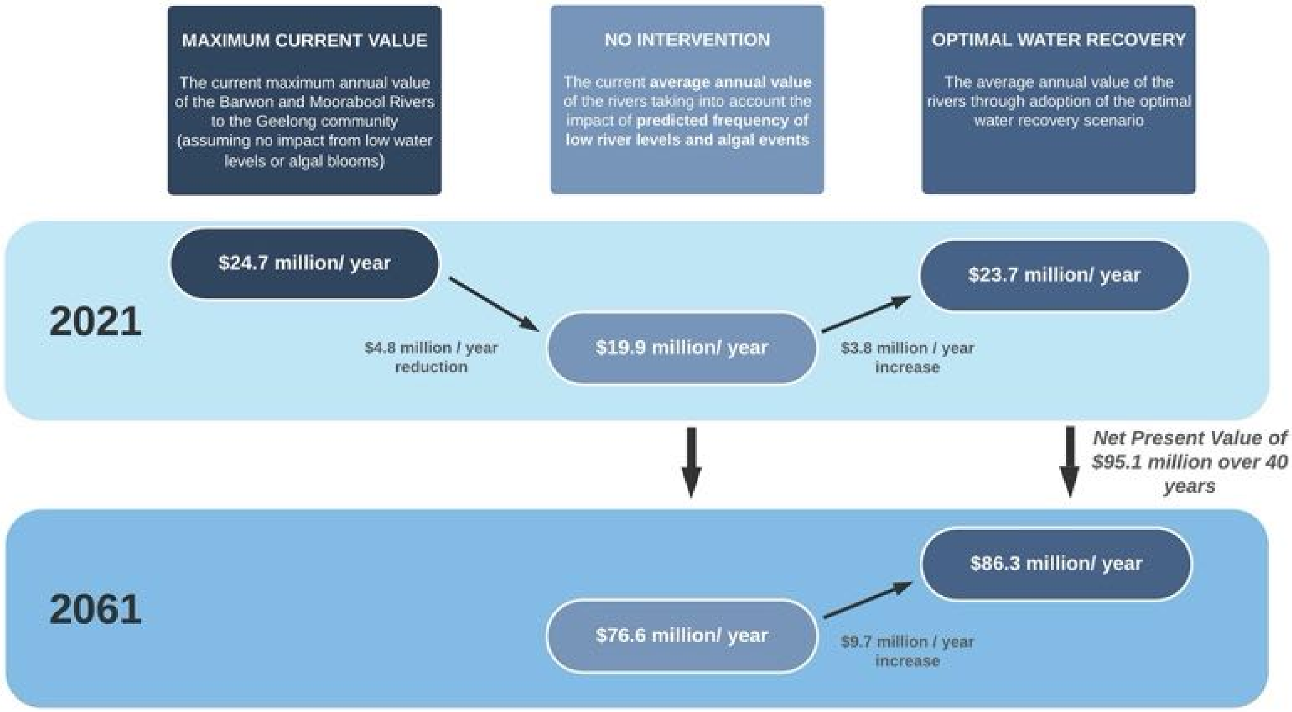

Figure E-1: Summary of the annual average value of the Barwon and Moorabool Rivers to the community in response to low flows and optimal water recovery

1 Introduction

1.1 STUDY OVERVIEW

This study, commissioned by the Corangamite Catchment Management Authority (CMA), seeks to understand the full suite of economic and social benefits derived from a flowing Barwon River (through Geelong) and lower Moorabool River, and the risks posed by climate change to river flows and the values identified.

The results of this study are intended to guide future water recovery decisions for the Barwon and Moorabool Rivers through the current Central and Gippsland Region Sustainable Water Strategy (SWS) development process and subsequent studies.

1.2 THIS REPORT

This report examines the social and economic benefits that the Barwon and Moorabool Rivers provide to the community of Geelong, and the importance of river flows for supporting and protecting these benefits.

It consists of three sections – the hydrology and water quality analysis, the socio-economic assessment of the value of the waterways, and the economic analysis.

In relation to the hydrology and water quality modelling, this report:

- Documents data collection and review
- Outlines findings of the literature review
- Documents water resource modelling scenarios, water quality and depth analysis, and algal bloom modelling and key findings.

A full copy of the water modelling report (HARC, 2021), which forms part of this study is provided as an attachment in Appendix 2 and should be read in conjunction with this report.

For the socio-economic assessment component of the study, this report:

- Provides a summary of current and future socio-economic uses and community values associated with the Barwon and Moorabool rivers
- Provides a review of key literature and data sources currently available
- Provides an assessment of the socio-economic values for the Lower Barwon and Moorabool River through Geelong over a forty-year time horizon based on predicted population growth.

Finally, the economic analysis estimates the marginal benefit for three water recovery scenarios, identifying the scenario that best delivers the target flows to maintain river water levels and prevent algal blooms.

1.3 ACKNOWLEDGEMENT OF COUNTRY

We acknowledge the Wadawurrung as the Traditional Owners of the Country on which this study was conducted. We recognise their continuing connection to land, waters and culture and pay our respects to their Elders past, present and emerging.

Moreover, we express gratitude for the knowledge and insight that Traditional Owner and other Aboriginal and Torres Strait Islander people contribute to our shared work.

2 Background

2.1 BARWON AND MOORABOOL FLOWS

As evident from the recent Long-Term Water Resource Assessment (LTWRA)[5] for Southern Victoria prepared by the Department of Environment, Land, Water and Planning (DELWP), the Barwon and Moorabool Rivers are experiencing declining flows attributable to climate change, with the greatest reductions borne by the environment relative to consumptive demands. In the 14-year period of the LTWRA, there was a corresponding 14% drop in the volume of water available to the environment from 212.6 gigalitres (GL)/year to 183.1 GL/year.

This decline in water availability is contributing to a decline in water quality in the Lower Barwon through Geelong, particularly in summer and autumn, when the river is most used and valued by the local community. Low flows, nutrient loads and a lack of periodic flushing events are expected to lead to an increased frequency and severity of Blue-green algal (BGA) outbreaks within the lower reaches of the river downstream of Buckley Falls. The low flows in this generally shallow reach of the river also pose a threat to safe boating and recreational watercraft use, as evident from the major silt dredging operation carried out in 2014-15 to facilitate ongoing use of the river for rowing events.

As the manager for the Barwon River through Geelong and lead agency for the Barwon River Parklands project, the Corangamite CMA is rightly concerned about the potential impact of a continual decline in flows on the social and economic values of the river in Geelong. The lower Moorabool River, which also contributes flow to the lower Barwon River at Geelong, has also been impacted by decreasing flows over recent years.

The full impact that this ongoing trajectory of decreasing flows will have on Geelong's community and the social and economic values associated with the Barwon River and lower Moorabool through Geelong has not been fully quantified. However, given the prominence the Barwon and Moorabool Rivers through Geelong, and the activities the rivers and their adjoining reserves support, there is good reason to suspect there will be a significant impact on a number of these values.

While there is some evidence to support this assumption (e.g. as set out in Table 2-1 on the following page), there has been a need to strengthen the basis and understanding of the extent of the problem before important social and economic, as well as environmental, values become compromised.

This includes the need to address identified key information gaps:

- Recent FLOWS Studies have been completed for the Moorabool, Barwon and Leigh Rivers, however these have focussed on the flow requirements for ecological values, rather than flows for social and economic values
- There has not been a recent extensive study examining the current social and economic values that the lower Barwon and Moorabool Rivers support, and those values dependent on river flows
- There is a need to understand the broader value the community places on the Barwon and Moorabool Rivers to inform not only discussions around declining flows and water quality, but also broader river planning and investment decisions undertaken by the CMA and its project partners.

The current study has provided an opportunity to test the assumptions set out in Table 2-1 and address the information gaps described above.

[5] DELWP (2020) Long-Term Water Resource Assessment for Southern Victoria.

2.2 SCOPE OF THE STUDY

The overall study area is the Barwon River through Geelong from the edge of the Western Geelong Growth Area downstream to Barwon Heads. The study area also includes the Moorabool River downstream of Batesford to the junction with the Barwon River. As there is no major impact between upstream flows and waterway conditions downstream of the lower barrages, water modelling of the estuarine reaches downstream of the lower barrages were not assessed as part of this study. Figure 2-1 shows the upstream and downstream extents of the study area.

Whilst important to the values underpinning social and economic use of the river, this study has not explicitly examined ecological flow requirements, which have been considered separately under the Upper Barwon Yarrowee and Leigh FLOWS Study Update[6] and Moorabool River FLOWS Study Update[7]. The study has also not examined Aboriginal water values and associated flow requirements, which are also critical considerations of any future management of flows within this stretch of the Barwon and Moorabool Rivers.

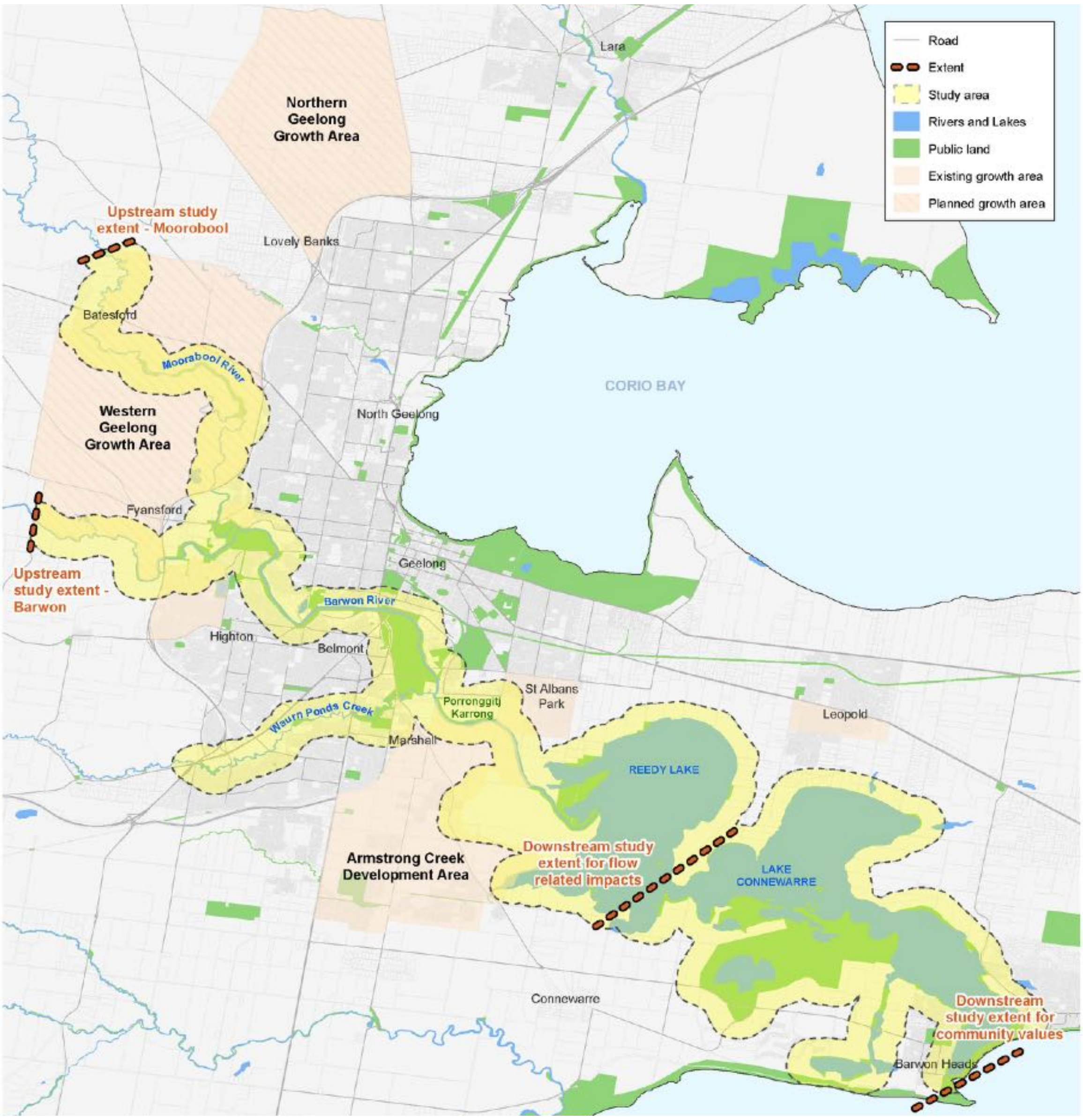

Figure 2-1: Map showing upstream and downstream extents of study area[8]

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[6] Alluvium, 2019

[7] Jacobs, 2015

[8] Source: RMCG, 2021

Table 2-1: Summary of the issues and current supporting evidence

COMPONENTS	ISSUES	CURRENT SUPPORTING EVIDENCE
Water availability and flow management issues	▪ During previous dry summer periods there has not been enough water to maintain a continuous flow along the river ▪ There has been a long term decline in water availability for the environment ▪ Climate change is expected to exacerbate water availability issues in the region ▪ Some current sources of flows may be uncertain. Such as: – Flows from the Batesford Quarry which is set to close in 2020/21 – Flows along the Leigh River which rely heavily on wastewater discharge from the South Ballarat Treatment Plant ▪ The Corangamite CMA has limited environmental entitlements to provide mitigating flows for low flow events.	▪ Cease to flow events in the Barwon and Moorabool Rivers: – Dec 2018 to March 2019 – Summer 2009 – Summer 2020 (Moorabool) ▪ Blue Green Algae (BGA) outbreaks at Geelong likely linked to low flows during: – Jan 2020 – Jan 2016 – Feb 2013 – Jan 2012 ▪ The recently completed Southern Victorian Long Term Water Resource Assessment (LTWRA) estimated a 14% decline in water available for the environment over the last 14 years ▪ Climate change projections (medium emissions scenario) for the Barwon Region is for a 10% reduction in rainfall in 10 years. This translates to significant estimated annual stream flow decline of 50% in the Moorabool by 2065.
Current and expected future social and economic uses of the rivers	▪ The Barwon River and its parklands through Geelong: – Provides extensive areas of natural open space for recreation – Are actively used by residents and visitors for paddle sports, water skiing, game hunting (Lower Barwon Wetlands), angling, cycling, walking – Hosts some of the state's most significant rowing events ▪ The estuary at Barwon Heads attracts large numbers of tourists especially during summer ▪ The new Geelong growth area centres around the lower Moorabool River, which will be an important feature in the future ▪ There is likely to be increasing demand for public open space in Geelong given its continued population growth.	▪ The annual Head of the School Girls and Barwon regattas attract more than 10,000 spectators, 1,200 athletes and generates an estimated $2 million per year to Geelong ▪ The Barwon Ministerial Advisory Committee (Barwon MAC) was established as a community led approach to future management and protection of the Barwon catchment in recognition of the increasing importance of the Barwon and Moorabool Rivers to Geelong ▪ 70,000 residents live within 2km of the parklands of the Barwon River ▪ Growth forecasts estimate Geelong will almost double to approximately 570,000 people by 2056 ▪ The importance of the Barwon River and its parklands is reflected in recent investment outcomes (2014–2017): – Barwon River Masterplan development business case (2019–20, $130,000) – Barwon River access upgrades (2018, $480,000) – Upgrade of rowing landing (2017, $850,000) – De-silting of rowing mile (2017, $550,000).
Impact of flows and BGA on social and economic uses	▪ The lower stretch of the river, which receives high recreational use, is very shallow and susceptible to sediment build up particularly in the absence of high flow events ▪ Outbreaks of BGA on the Barwon River are problematic for recreational uses due to the risk of health impacts on human or animal contact with BGA toxins ▪ Other low flow impacts on social and economic uses: – Bank instability – Increased spread of reeds, limiting recreational access and water use – Increased smell and odour – More frequent black water or fish death events – Impacts to riparian vegetation.	▪ The 'rowing mile' was de-silted (dredged) to a consistent depth of 1.9 m in 2017, costing approximately $550,000 to ensure Geelong could continue to host rowing events ▪ BGA outbreaks led to closures of the Barwon River to the public during: – Jan 2020 (central Geelong, for one week including cancellation of a major event) – Jan 2016 (Baum's Weir to Breakwater Rd) – Feb 2013 (above Baum's Weir) – Jan 2012 (Barwon Heads at Lake Connewarre and between Moorabool St Bridge to Baum's Weir, over the course of three months).

3 Hydrology and water quality analysis

Figure 3-1: The Barwon River through Geelong[9]

3.1 OVERVIEW

This section of the report provides an overview of the approach and findings of the water modelling results, that have been used to inform the economic analysis. A full copy of the water modelling report (HARC, 2021), which forms part of this study is provided as an attachment in Appendix 2, and should be read in conjunction with this report.

3.2 DATA COLLECTION AND REVIEW

A range of project reports, references and models were collected to assist with preparing the modelling report. These are summarised in Table 3-1 and Table 3-2.

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9 Source: RMCG 2021

Table 3-1: Reports/past projects

REFERENCE	DESCRIPTION / COMMENT
Water resources	
HARC (2019a): Update of the Barwon-Moorabool REALM Model Technical report – Model Inputs	Update of model inputs to support LTWRA modelling.
HARC (2019b): Update of Barwon-Moorabool REALM Model Technical report – REALM modelling	Model changes and modelling to support LTWRA modelling.
DELWP (2018): Central Region Sustainable Water Strategy Review	
WaterRes (2020): File note – Barwon-Moorabool REALM model development – Draft B	Model changes for SWS modelling.
Water quality	
Tom Snelder, Richard McDowell, Caroline Fraser (2014): Estimation of nutrient loads from monthly water quality monitoring data	Paper and PowerPoint presentation.
Different methods for calculating nutrient loads	
DELWP (2020): DELWP Sewerage Guidelines – Phase 1 – Scoping paper to develop Guidelines for Assessing the Impact of Climate Change on Sewerage Systems in Victoria	Summary of potential impacts under climate change. Discharge impacts relevant for this study.
SKM (2007): Modelling of sediment erosion and deposition in the Upper Barwon catchment	SedNet modelling of the Upper Barwon River. Shows sources of sediment due to bank erosion.
Environmental flows	
Alluvium (2019): Upper Barwon, Yarrowee and Leigh rivers FLOWS study update	
Jacobs (2015) Moorabool River FLOWS study update	
Corangamite CMA (2016): Moorabool River Environmental Water Management Plan	
Barwon River Ministerial Advisory Committee (2019) Our living rivers of the Barwon – A discussion paper for the future	
Lloyd et al (2020): Lower Moorabool River Groundwater and FLOWS Project	
Corangamite CMA (undated): Fact sheet Lower Moorabool Habitat Pools – Groundwater loss and environmental water requirements	Summary information on flows required to maintain health of pools.
Ballarat South Wastewater Treatment Plant (WWTP)	
CHW (2020): Ballarat South Treated Wastewater Discharge	Background and options.

Table 3-2: Models

MODEL	SOURCE	DESCRIPTION	COMMENT
Water resources			
Barwon-Moorabool REALM model.	DELWP via Corangamite CMA.	Weekly REALM model used for recent SWS runs.	Represents current conditions with allowance for delivery of environmental watering priorities.
Geelong-Colac Source model: Geelong Colac – Mar 2020.rsproj.	Barwon Water.	Most up-to-date daily Source model used by Barwon Water.	Use to apply daily pattern to weekly REALM model outputs.
Barwon hydraulic Model used for FLOWS study (HECRAS).	Corangamite CMA.		Updated for analysis of Moorabool pools.

3.3 WATER QUALITY ANALYSIS

Water quality in the lower Barwon River is influenced by the volumes and quality of water flowing into the reach from upstream sources.

In this report, several scenarios were considered that would modify the volumes of water that would come from various sources. Changes in the volume of water derived from different sources would also cause changes in the loads of total suspended solids (TSS) and nutrients that would be delivered into the Lower Barwon River. To test the impact of the changes in water management in the catchment, relationships were first developed for the sediment and nutrient concentrations that are associated with each of the major sources of water.

An algal growth model was established for the Lower Barwon River, as discussed in Section 3.6.

There are two significant point source inputs:

- Ballarat South Wastewater Treatment Plant
- Batesford Quarry.

In addition, there are four sub catchments providing diffuse inputs:

- Leigh River
- Upper Barwon River (to the confluence with the Leigh River)
- Moorabool River
- Barwon River, downstream of the confluence with the Leigh River.

An analysis was performed, using available water quality monitoring data, of the concentrations of the above constituents at monitoring sites throughout the catchment. The location of water quality monitoring sites is shown in Figure 3-2.

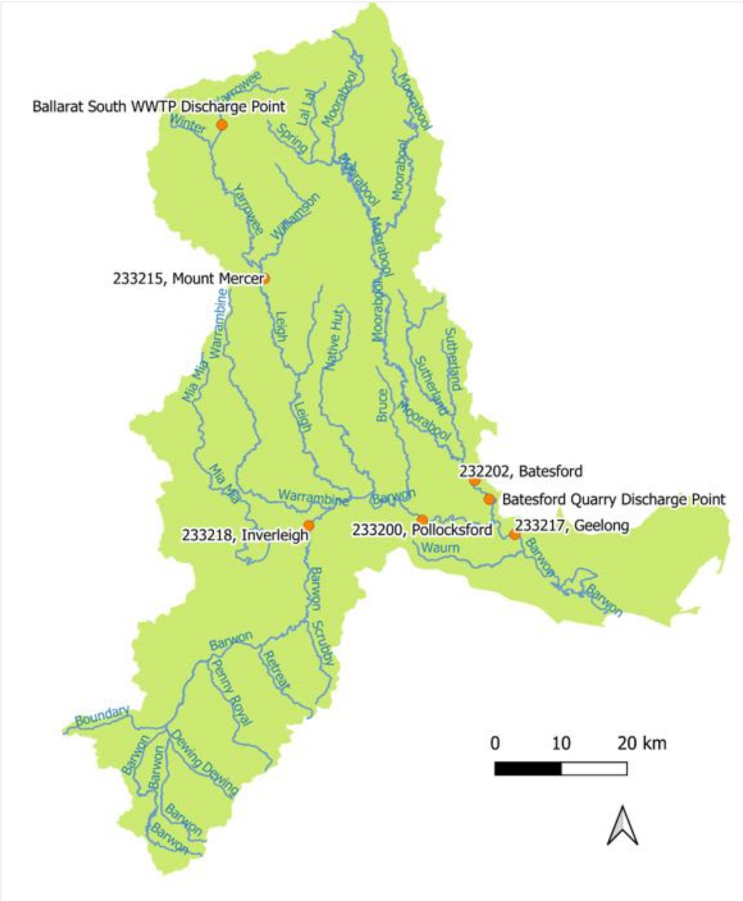

Figure 3-2: Location of water quality monitoring sites

3.4 WATER RESOURCES REVIEW AND MODELLING APPROACH

The weekly timestep Barwon-Moorabool REALM model has long been used for water resource planning in the region. It was created in 2006 and has been updated and refined many times over the years. In 2019 it was reviewed and updated with current rules to be suitable for use in DELWP's Long Term Water Resource Assessment. It was further modified in 2020 to support scenario modelling for the Central and Gippsland Region SWS. A schematic of the system is shown in Figure 3-4.

The REALM model was used to generate a time series of flows and depths at key locations, including at the upstream boundary of the algal bloom model. Some model changes are required to represent the base case for this study, as described in Section 3.6.

Inflows to the daily timestep Geelong Colac Source model and long term gauged flow data were used to apply an appropriate disaggregation pattern to weekly REALM outputs to create daily flows for input to the algal bloom model. Water quality relationships as a function of flow were used to generate corresponding water quality time series for input to the algal bloom model. Relationships were derived for oxidised nitrogen (NOx), ammonium (NH4+), total nitrogen (TN), total phosphorus (TP), TSS and electrical conductivity (EC).

The base case model was run under current and future climate cases. The model was then modified and run to determine the relative impact of discharge of treated wastewater from the Ballarat South WWTP and discharge of groundwater from Batesford Quarry on flow, water level and algal bloom behaviour. Then the model was run for a number of water recovery scenarios, where water was recovered or flow modified at Lal Lal Reservoir, West Barwon Dam, Ballarat South WWTP and Batesford Quarry. Scenarios determined the impact of achieving Barwon and Moorabool environmental water recovery targets, and water recovery and/or flow manipulation required to prevent or minimise blooms.

The model run process for the base case and for the scenarios is summarised in Figure 3-3.

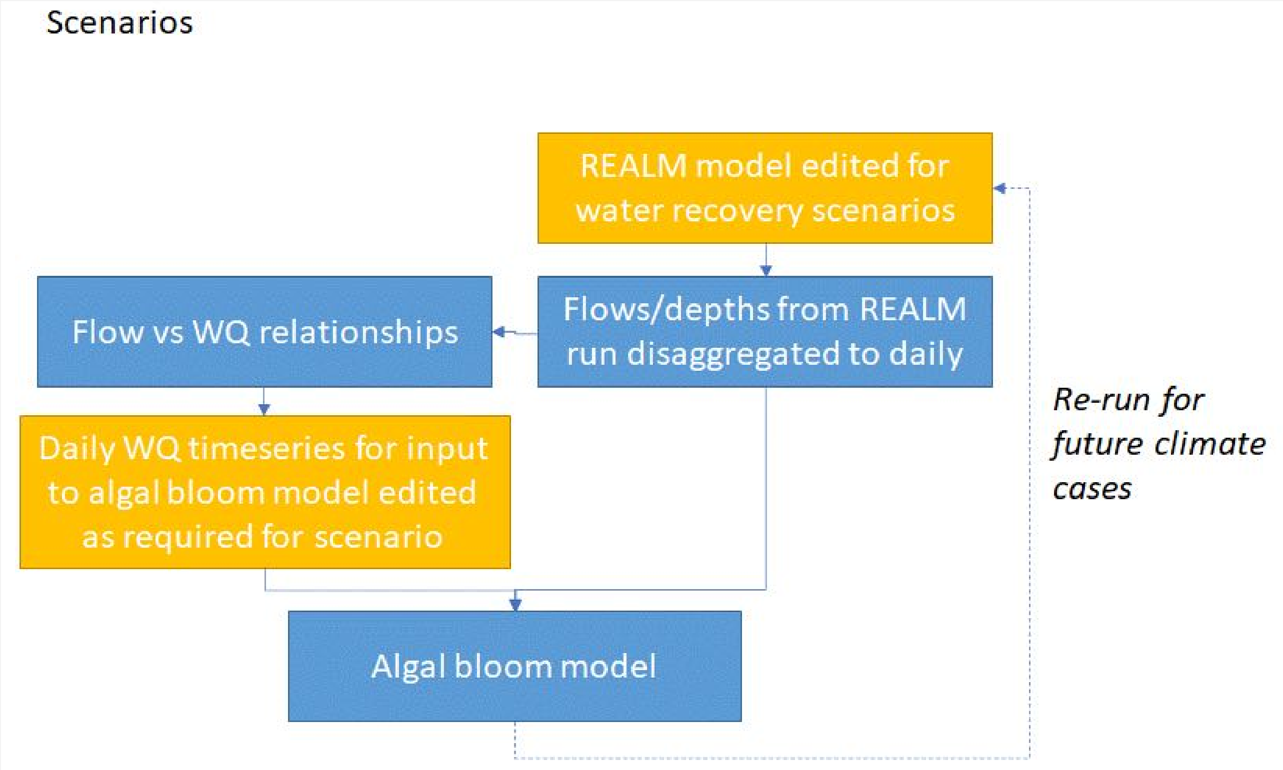

Figure 3-3: Model run process

Key model results reported were:

- Periods of flow below 140 megalitres (ML)/week (where there is a risk of algal blooms)
- River depth at Geelong at times of year of key rowing events
- Frequency and duration of algal blooms.

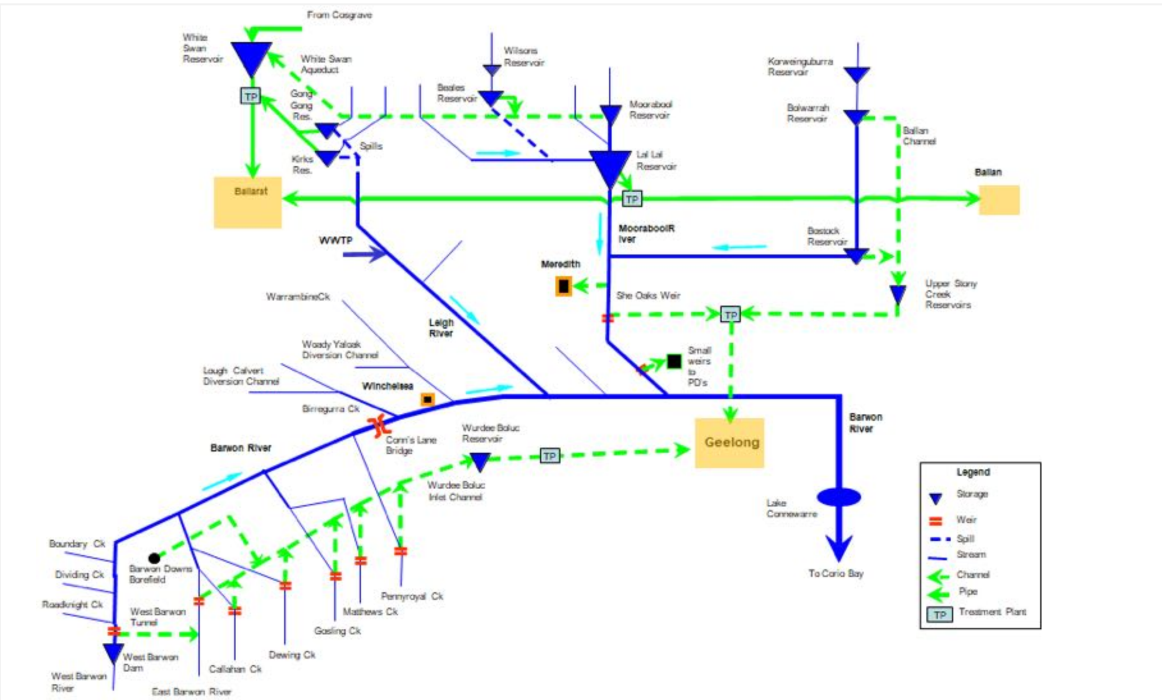

Figure 3-4: Barwon-Moorabool existing SWS model system schematic (DELWP)

3.4.1 CURRENT AND FUTURE CLIMATE CASES

Models are run over a long-term climate sequence to see how the system performs over a range of climate conditions and extended drought periods. Use of a long climate sequence also enables risk-based results to be reported, e.g. the probability of an algal bloom occurring in any given year.

Sometimes models are run under **historic** climate. That is, they show how the system would have behaved under current operating rules and demands if there was a repeat of the 1891–2019 climate sequence. As demands and operating rules are set to current, modelled behaviour in 1982/83 will be different to what actually happened in 1982/83.

In recent years, however, it has been recognised that the historic climate sequence has an embedded trend as climate change has increasingly impacted flows. This can impact upon the validity of the reporting of risked based results. The DELWP climate change guidelines (DELWP, 2016) provide advice on deriving a **baseline** climate sequence where historic inflows and climate inputs prior to 1975 are adjusted so they have the same statistical characteristics as inflows and climate conditions post 1975.

The baseline climate case has been used for all base case and scenario modelling for this study.

The performance of the base case has been sensitivity tested under other climate cases. The **step climate change** case is based on post 1997 climatic conditions, and the **high climate change projection for 2065** is taken from the DELWP climate change guidelines and was run with corresponding 2065 level of development demands.

The climate change assumptions made are consistent with those applied for the LTWRA and SWS modelling.

3.4.2 SOCIO-ECONOMIC METRICS

A range of other metrics are important for input to the socio-economic assessment such as period of low flow or cease to flow, river depth or times when depth or flow is outside the ranges required for recreational activity. Streamflow rating tables, for example in the Barwon R @ Geelong gauge (232202), have been used convert modelled flow at gauge locations to depths.

3.4.3 BASE CASE SCENARIOS

A series of **three** climate scenarios and **nine** water recovery scenarios (including the base case) were modelled to see which options produced the best outcomes.

Current climate

The base case model was run with post 1975 climate conditions, using adjusted climate data for the period from 1927 to 2017. Flows were extracted at key locations to enable the derivation of daily inputs to the algal bloom model. As noted in the project's Scoping Paper[10], investigations showed that flows in Geelong less than 20 ML/day are favourable for algal growth.

Analysis showed that flows are below 140 ML/week (i.e. 20 ML/day) on average 12 weeks per year, with the worst case being 28 weeks.

Climate change scenarios

The base case model was also run for two climate change scenarios: pre-1997 adjusted step climate change and 2065 High climate change scenario. The inflow and demand inputs for these climate change scenarios first developed for the LTWRA were adopted.

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[10] RMCG, 2020

3.4.4 WATER RECOVERY SCENARIOS

In line with the outcomes of the Scoping Report, the following water recovery (availability) scenarios were modelled:

Scenario 1: Changes to Ballarat South WWTP discharge

The Ballarat South WWTP currently discharges around 7.8 GL annually to the Upper Leigh River. **Scenario 1a** involves reducing that discharge to 2 GL/year to correspond with the recommendation in the existing Central Region SWS (DSE, 2005) which states that Corangamite CMA and CHW should work together to ensure 2 GL/year continues to be discharged from Ballarat South WWTP to address environmental water needs. **Scenario 1b** is run with WWTP discharges switched off to show the contribution they make to flows at Geelong. **Scenario 1c** involves storing some of the WWTP discharge so greater volumes can be discharged at times when Geelong flows are low. The pattern of releases made for Scenario 1c was manipulated to maintain flows of 140 ML/week at Geelong.

Scenario 2: Changes to Batesford Quarry discharge

Batesford Quarry currently discharges around 3.5 GL annually to the Moorabool River below Batesford. **Scenario 2a** involves reducing that by 50%, while **Scenario 2b** was run with quarry discharges switched off, to show the contribution they make to flows at Geelong. As stated in the Scoping Paper, the future of discharges from the quarry is uncertain with its closure planned in 2029.

Scenario 3: Meeting water recovery targets

Three scenarios were run increasing the environmental share of inflows and capacity in Lal Lal and West Barwon reservoirs in order to meet environmental flow targets. A minimum (**Scenario 3a**) and a higher (**Scenario 3b**) target were modelled for meeting flow recommendations immediately downstream of the storage. A third case (**Scenario 3c**) was run aiming to meet dry (Dec-May) and wet (Jun-Nov) season low flow recommendations in the Barwon River at Pollocksford and the Moorabool River at Batesford.

The scenario reach objectives and target reach locations are detailed further in Table 3-3.

Table 3-3: Scenario objectives and target reach locations

SCENARIO	WEST BARWON OBJECTIVE	LAL LAL OBJECTIVE
3a	Satisfy priority 1, 2 and 3 East and West Barwon River flow recommendations (Reaches 3 and 4)	Satisfy all prioritised Reach 3a flow recommendations
3b	Satisfy priority 1, 2 and 3 East and West Barwon River flow recommendations (Reaches 3 and 4) plus wet period fresh	Satisfy all Reach 3a flow recommendations
3c	Satisfy low flow recommendations (Reach 10)	Satisfy low flow recommendations (Reach 4)

Based on previous FLOWS studies, Jacobs (2015) and Alluvium (2019), the minimum water recovery target for Lal Lal Reservoir is 5,140 ML and for West Barwon Dam is 3,336 ML (both including the current environmental entitlements). These volumes correspond to the volume required to meet summer/autumn and winter/spring low flows and selected freshes required under “dry” conditions in Reach 3b and 4 in the Moorabool River and Reach 9 in the Barwon River. The higher water recovery target for Lal Lal Reservoir is 9,000 ML and for West Barwon Dam is 19,301 ML at these locations (with both including the current environmental entitlements). These volumes correspond to the volume required to meet summer/autumn and winter/spring low flows, as well as selected fresh requirements under “wet/average” conditions and include additional freshes.

Caps were placed on maximum annual releases at 19,301 ML/year from West Barwon Dam and 9,000 ML/year from Lal Lal Reservoir, corresponding with the higher water recovery targets. This was to ensure these targets were not exceeded.

Table 3-4 details the approximate alignment of each of the scenarios with the water recover targets detailed in these two FLOWS studies.

Table 3-4: Water recovery targets identified in previous FLOWS studies

	WEST BARWON MINIMUM WATER RECOVERY TARGETS (ALLUVIUM, 2019)	LAL LAL MINIMUM WATER RECOVERY TARGETS (JACOBS, 2015)
Dry year (conditions)	3,336 ML/year (Reach 9) 3,773 ML/year (Reach 10): **approximates to Scenario 3c**	3,380 ML/year (Reach 3a): **approximates to Scenario 3a** 5,140 ML/year (Reach 3b & 4): **approximates to Scenario 3c**
Wet/ average year (conditions)	19,301 ML/year (Reach 9) 30,468 ML/year (Reach 10)	6,150 ML/year (Reach 3a): **approximates Scenario 3b** 9,000 ML/year (Reach 3b & 4)

To assist with comparing the scale of each water recovery option, Table 3-5 details environmental shares at storages for the base case and each of the scenarios, and the corresponding FLOWS study water recovery target.

It is important to note that all Scenario 3 runs depend on recovering additional water stored for the environment in West Barwon Reservoir and Lal Lal Reservoir. Also, more aspirational water recovery targets exist for both the Barwon and Moorabool basins than the scenarios modelled.

Table 3-5: Scenarios, corresponding approximate flow recommendations and shares at storages

Scenario	West Barwon Minimum Water Recovery Target (Alluvium, 2019)	West Barwon Dam Environ. Share of Storage (Capc = 22,064 ML)	West Barwon Environ. Share of Inflow	Lal Lal Minimum Water Recovery Target (Jacobs, 2015)	Lal Lal Reservoir Environ. Share of Storage (Capc = 59,549 ML)	Lal Lal Environ. Share of Inflow
Base case		2,000 ML	3.80%		7,086 ML	11.90%
3a	No water recovery target identified for this reach	9,000 ML	17.10%	3,380 ML/year*	11,910 ML	20%
3b	No water recovery target identified for this reach	12,000 ML	22.80%	6,150 ML/year~	14,887 ML	25%
3c	3,773 ML/year#	18,000 ML	34.20%	5,140 ML/year^	23,820 ML	40%

Reach 10 water recovery target, low flow and dry period freshes
* *Reach 3a water recovery target, minimum under dry conditions*
~ *Reach 3a water recovery target, minimum under wet/avg conditions*
^ *Reach 4 water recovery target, minimum under dry conditions.*

Scenario 4 (combined scenario): Ballarat WWTP discharge pattern manipulated and higher water recovery target

This scenario combined Scenario 1c (Ballarat WWTP discharge pattern manipulated) and Scenario 3b (Higher water recovery target for the environment).

3.5 WATER LEVELS AT GEELONG

A time series of water levels at Geelong were inferred from the modelled flows at Geelong. These modelled water levels were then analysed to check the depth in this reach of the Barwon River, particularly during periods of each year when it is used for rowing and other on river events and recreational use. The key events considered were:

- Barwon Regatta (Australia day weekend in January)
- Head of the School Girls Regatta (second weekend of March).

As outlined in GHD (2013), the entire extent of the rowing lanes require a minimum water depth of 1.9 metres for events to be held. As outlined in GHD (2013) this translates to a water level of 0.85 m AHD.

Levels at the 232217 gauge (Barwon River at Geelong) where converted to AHD using survey data taken in 2015. This showed that a survey height at the gauge of 0.926 m AHD corresponded to a gauge height of 0.935m.

The modelled flows at Geelong for each scenario were converted to water levels using the rating table (extracted from the Water Measurement Information System (WMIS)) for the gauge in the Barwon River at Geelong (232317), and converted to AHD using the adjustment described above.

The analysis for the minimum river level for rowing targeted the key rowing dates outlined above. To give a reasonable indication of water level over a run period of 1927 to 2017, these were assumed to be approximately over the fixed dates of 25-27 January and 18-20 March each year respectively.[11] The results are summarised in Table 3-4 and plotted in Figures 3-5 and 3-6.

The scenario results presented in Table 3-6 were all run with post 75 climate, which represents current climate conditions, and are directly comparable to results for the “Base case post 75 climate”. The run “Post-97 step change climate case” represents an alternate, more pessimistic representation of current climate where it is assumed that climate conditions that have occurred since 1997 will continue. The run “2065 high climate change case” shows results under a future (2065) climate assuming a high emissions scenario. Corresponding 2065 levels of development demands are used for this run.

It is evident that the WWTP discharges are important for maintaining river levels, and manipulating the pattern of discharge gives a significant improvement in results over the base case. Provision of environmental water for the lower reaches results in the greatest improvement in maintaining river levels.

The impact of climate change is evident on key rowing depths with a reduction of the percentage of years above critical depth of up to 21% for the Barwon Regatta and 20% for the Head of School Girls Regatta.

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[11] Assuming that results over these fixed three-day periods would be relatively representative of the nominated weekends for the events, which can move by a few days in each year

Table 3-6: Number of years critical rowing depth is reached for each scenario

SCENARIO*	BARWON REGATTA (AUSTRALIA DAY)		HEAD OF SCHOOL GIRLS REGATTA (MARCH)	
	NUMBER OF YEARS ABOVE CRITICAL DEPTH	% OF YEARS FROM 1927 TO 2017	NUMBER OF YEARS ABOVE CRITICAL DEPTH	% OF YEARS FROM 1927 TO 2017
Base case post 75 climate	34	37%	26	29%
Post 1997 climate case	27	30%	19	21%
Future 2065 high climate change case	15	16%	8	9%
Scenario 1a: Ballarat South WWTP discharge reduced to 2 GL	18	20%	14	15%
Scenario 1b: Ballarat South WWTP discharge turned off (Scenario 1 worst case)	15	16%	10	11%
Scenario 1c: Ballarat South WWTP discharge pattern manipulated (Scenario 1 best case)	74	81%	61	67%
Scenario 2a: Batesford quarry discharge reduced by 50% (Test impact of no winter discharge)	31	34%	25	27%
Scenario 2b: Batesford quarry discharge turned off (Scenario 2 worst case)	25	27%	24	26%
Scenario 3a: Minimum environmental water recovery target	41	45%	31	34%
Scenario 3b: Higher environmental water recovery target	41	45%	32	35%
Scenario 3c: Environmental water recovery for lower reaches	82	90%	80	88%
Scenario 4: Ballarat South WWTP discharge pattern manipulated and Higher water recovery target	72	79%	58	64%

*Note these results assume no dredging or other intervention works are undertaken to improve river depths.

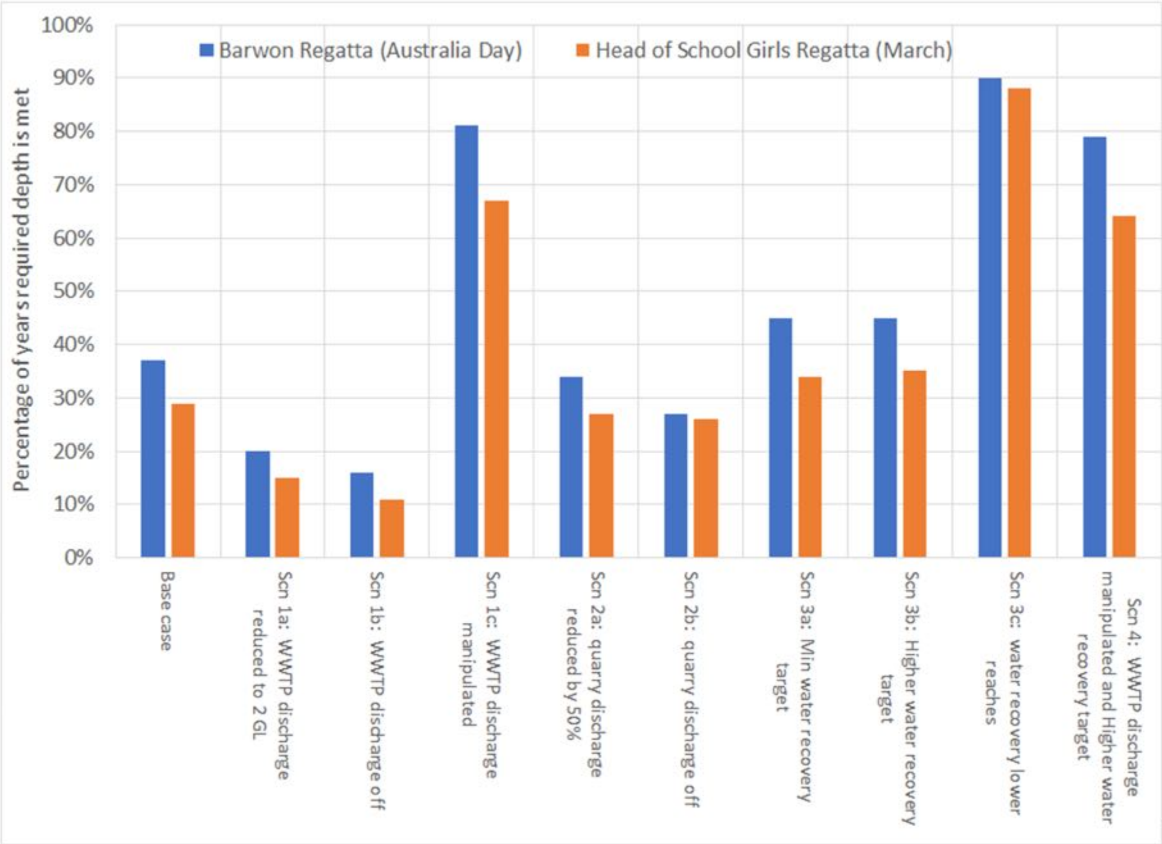

Figure 3-5: Percentage of years required rowing depth can be met for key events

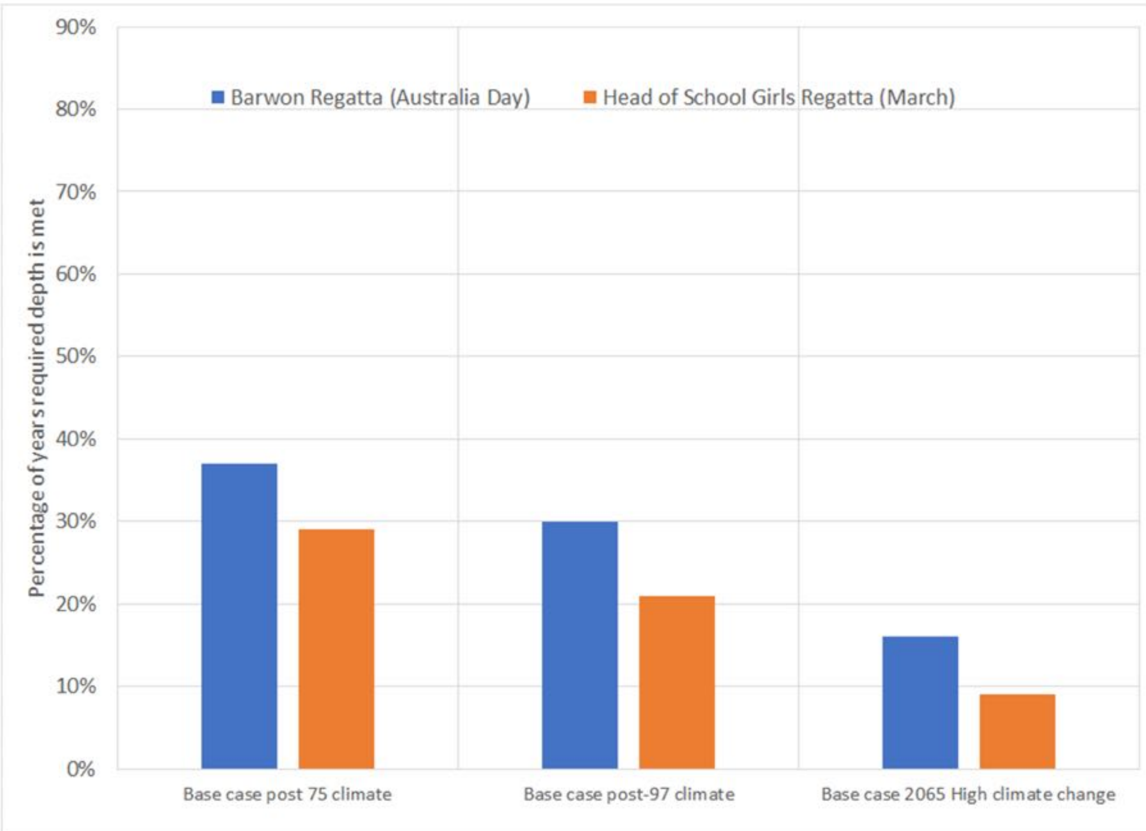

Figure 3-6: Impact of climate change on percentage of years required rowing depth can be met for key events

3.6 ALGAL BLOOM ANALYSIS AND MODELLING

3.6.1 OBJECTIVE

The objective of this component of the study was to develop a simple predictive algal bloom model to test the effects of future flow scenarios in the Barwon River. This involved identifying the causes and contributing factors of algal blooms in the Barwon River at Geelong and deriving flow-algal bloom relationships based on available historical monitoring data.

3.6.2 LITERATURE REVIEW

Algal blooms are a natural phenomenon in the Australian landscape. However, their magnitude, frequency and duration has increased over time due to anthropogenic impacts, such as flow regulation, diffuse and point source pollution and a changing climate.

Recent blue-green algal blooms in the Barwon River at Geelong have been identified as the cyanobacterial species *Microcystis* and *Dolichospermum* (the algae formerly known as *Anabaena*). These are commonly found in freshwater phytoplankton assemblages and can form dense blooms. Both species form in warm, calm weather with high nutrient concentrations or a low nitrogen to phosphorus ratio (N:P <16).

Microcystis does not fix nitrogen from the atmosphere but is very efficient in taking up inorganic forms of nitrogen (ammonium, nitrate, nitrate), and can out compete other species in nitrogen limiting conditions. *Dolichospermum* is capable of fixing nitrogen from the atmosphere and can dominate when inorganic nitrogen becomes limiting to all other species.[12] The proliferation of the bloom is only limited by the available phosphorus, which can be released from the sediment during low oxygen conditions in the bottom waters of stratified waterways. Both *Microcystis* and *Dolichospermum* can release cyanotoxins into the ambient environment. Toxin production is associated with higher water temperatures and light. Not all blooms result in the release of toxins. However, toxin production is noted to coincide with the production of taste and odour compounds (geosmin and 2-methylisoborneol (MIB)).[13]

Microcystis and *Dolichospermum* have gas vesicles that allow them to move up and down in the water column, which increases their access to nutrients and gives them resilience to minor changes in weather conditions. Small freshening flow increases may overturn any blooms, but due to the buoyancy of these cyanobacteria this type of flow is likely to only fuel the algal blooms through refreshing nutrients in the surface waters. Large increases in flow are needed to disperse the blooms and flush them from the waterway.

3.6.3 ANALYSIS OF HISTORICAL BLUE-GREEN ALGAL DATA

MONITORING SITES

Blue-green algae monitoring has been conducted intermittently since 1999 in the Barwon River at Geelong over the recreational period (September to April). Nine monitoring sites are located within the river stretch between Baums Weir (located upstream of the Moorabool River confluence) and the terminal of Wilsons Road at St Albans Park, with the majority centred around the rowing zone (Table 3-7).

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12 *Dolichospermum* in iNaturalist [accessed 9 December 2020] https://www.inaturalist.org/guide_taxa/707293.

13 Freeman, K.S. (2010) Harmful algal blooms: musty warnings of toxicity. *Environ Health Perspectives.* 118(11): A473.

Table 3-7: Blue green algae monitoring sites

SITE CODE	SITE NAME	DATES
B74	Baums Weir	1999–2005; 2008–2011; 2018–2020
B50	Queens Park	1999–2005; 2008–2011; 2018–2020
B67	Fyans Park	1999–2005; 2008–2011; 2018–2020
B70	Start of Rowing Mile	1999–2005; 2008–2011; 2018–2020
B63	MacIntyre Bridge	1999–2005; 2008–2011; 2018–2020
B66	Rowing Sheds	1999–2005; 2008–2011; 2018–2020
B00	Factories Road	2005–2011; Sept 2018–2020
B69	Breakwater Road	1999–2005; 2008–2011; 2018–2020
B68	Wilson Road	1999–2005; 2008–2011; 2018–2020

ANALYSIS OF DATA

The available data shows that algal blooms occur annually in varying intensities in the Barwon River at Geelong during low flow periods over the warmer months. However, there have been exceptional wet summer periods (2001, 2011) where algal blooms have not occurred.

3.6.4 CAUSES AND CONTRIBUTING FACTORS

Algal blooms develop when favourable conditions are present, such as warm, calm water, elevated nutrients, and good light availability. The most common time of year for algal blooms to develop in the Barwon River is from mid-summer to early autumn (January to March). This coincides with the lowest river flows, warmest water temperatures and good light availability.

FLOW THRESHOLDS

River flow is an important factor that determines whether conditions are favourable. The following flow-related thresholds have been identified by studying the blue green algal data relationship with flow over some algal bloom events in the Barwon River at Geelong (for example see Figure 3-7 where summer freshening flows reduce algal growth):

- Flows < 20 ML/day are favourable for algal growth
- 20–50 ML/day inhibits growth but does not disperse the bloom
- 50–100 ML/day reduces but does not eliminate small blooms
- 100–150 ML/day reduces but does not eliminate large blooms
- 150–400 ML/day eliminates small algal blooms from the river
- >400 ML/day eliminate large blooms from the river.

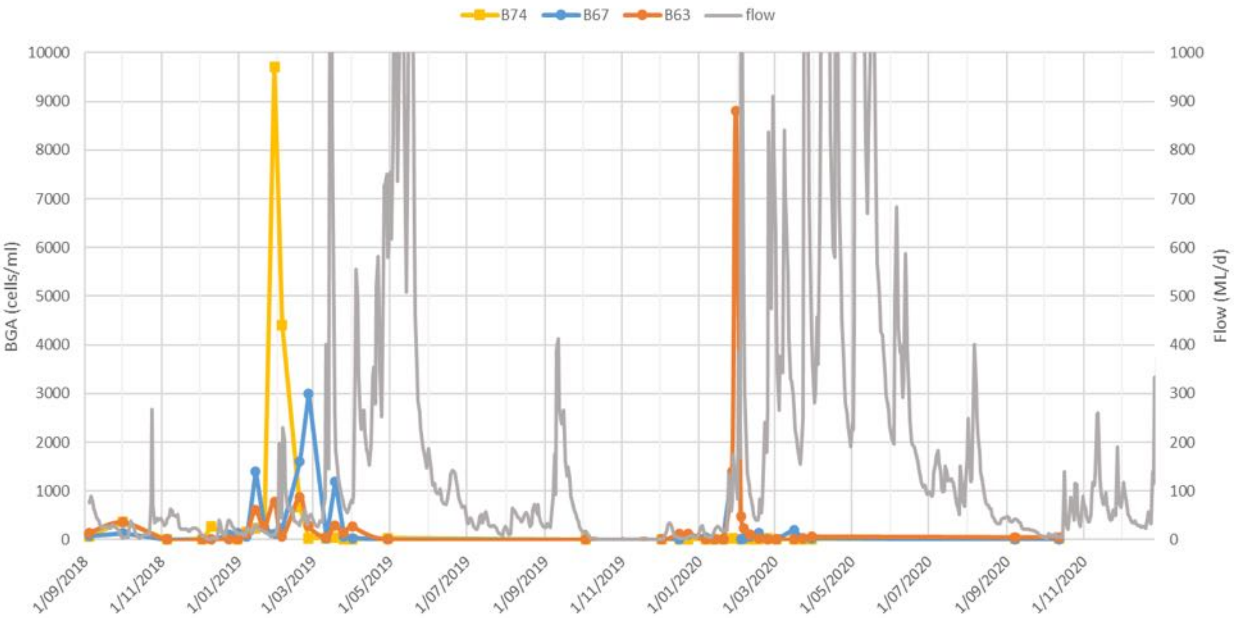

Figure 3-7: BGA data (cells/ml) at three sites (2018-2020) compared with flow in the Barwon River

NUTRIENT LIMITATION

Cyanobacteria have a competitive advantage over other algal types in nitrogen-limiting conditions. Available nutrient data (total nitrogen (TN), total phosphorus (TP), nitrate + nitrite (NOx) and filterable reactive phosphorus (PO4) data were analysed in the Barwon River at Geelong (monthly data at site 233217; 2005–2020). When the molar ratio of N:P, or the bioavailable fraction as NOx:PO4, is less than 16:1 (Redfield's ratio), this indicates that the ecosystem is nitrogen limiting. While the N:P ratio did not indicate nitrogen limiting conditions, the NOx:PO4 showed severe nitrogen limitation over the summer period. The severe depletion of bioavailable inorganic nitrogen over the summer period explains why cyanobacterial blooms of *Microcystis* and *Dolichospermum* have a competitive advantage in the Barwon River. The limiting factor for cyanobacterial algal blooms are phosphorus and light availability. Phosphorus can be released from sediment when the bottom waters become oxygen-depleted, which can happen if the waterway stratifies under warm, calm conditions.

DISSOLVED OXYGEN EFFECTS

Algal blooms cause high rates of primary productivity during daylight hours, and high rates of respiration during the night which causes large fluctuations in dissolved oxygen and pH in the water column. Continuous dissolved oxygen and pH monitoring data is available for the Barwon River at the MacIntyre Bridge monitoring site (B63) from July 2010 to present (of varying quality). The difference between the minimum and maximum diurnal dissolved oxygen levels (percent saturation) monitored on a continuous basis could be a good indicator of algal biomass in the Barwon River (which gives more data than sporadic grab algal sampling). Unfortunately, there is not enough overlapping data to derive a strong relationship between dissolved oxygen levels (max-min) and the blue-green algae sampling data.

3.6.5 APPROACH TO ALGAL BLOOM MODELLING

A simple Excel-based water quality model was used to quantitatively predict chlorophyll-a concentrations (as an indicator of algal bloom intensity) in the lower Barwon River around Geelong based on flow thresholds, bioavailable nitrogen and phosphorus concentrations and light availability. Inputs included daily time series of flow NOx, NH4+, TN, TP, TSS and EC.

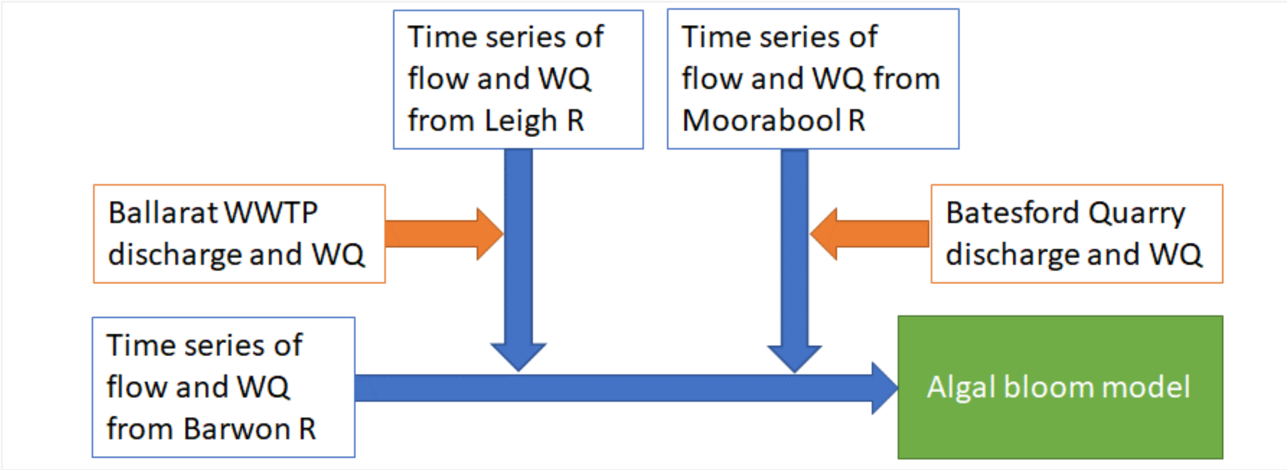

Figure 3-8: Daily inputs to the algal bloom model

The algal bloom model was also calibrated with historic data and used to predict future algal concentrations under a range of climate change and flow recovery scenarios.

3.6.6 SUMMARY OF ALGAL BLOOM MODELLING FINDINGS

According to the algal bloom model simulations, reducing the Ballarat South WWTP discharges reduces the algal bloom frequency/duration compared to the base case due to the reduction in nutrient loads (Scenario 1). *However, the decay/assimilation of the effluent-derived nutrients along the river prior to Geelong needs greater attention to verify this result.* Reducing or eliminating the discharges from Batesford Quarry causes algal bloom frequency/duration to increase (Scenario 2). Delivering low flow environmental flow recommendations to the lower reaches of the system significantly reduces the frequency/duration of algal blooms (Scenario 3c).

Table 3-8 Comparison of no. days per year with algal blooms in Barwon River at Geelong per Scenario. [green shading = better than base case; orange shading = worse than base case]

STATS	BASE CASE	POST 1997 CASE	2065 CASE	SC1A	SC1B	SC1C	SC2A	SC2B	SC3A	SC3B	SC3C	SC4
Median	25	17	18	6	2	1	30	35	13	11	0	3
Ave	27	18	18	6	3	7	33	38	12	12	1	6
Max	105	65	42	37	17	30	92	86	38	42	24	29

Modelled time series were then analysed to check the periods of each year when this reach of river is used for rowing and other on river events and recreational use. As above, the key events considered were:

- Barwon Regatta (Australia day weekend in January)
- Head of the School Girls Regatta (second weekend of March).

The impact of the climate change and water recovery scenarios is evident on these key rowing events as seen in Table 3-9 below.

Table 3-9 Number of years BGA cell counts exceed 50,000 cells per ml at the time of key rowing events.

SCENARIO*	BARWON REGATTA (AUSTRALIA DAY)		HEAD OF SCHOOL GIRLS REGATTA (MARCH)	
	NO OF YEARS ABOVE 50,000 CELLS PER ML***	% YEARS FROM 1927 TO 2017	NO OF YEARS ABOVE 50,000 CELLS PER ML***	% YEARS FROM 1927 TO 2017
Base case post 75 climate	28	30%	19	21%
Post 1997 climate case	13	14%	20	22%
Future 2065 high climate change case	11	12%	10	11%
Scenario 1a: Ballarat South WWTP discharge reduced to 2 GL	5	5%	11	12%
Scenario 1b: Ballarat South WWTP discharge turned off (Scenario 1 worst case)	0	0%	7	8%
Scenario 1c: Ballarat South WWTP discharge pattern manipulated (Scenario 1 best case)	7	8%	10	11%
Scenario 2a: Batesford quarry discharge reduced by 50% (Test impact of no winter discharge)	36	39%	23	26%
Scenario 2b: Batesford quarry discharge turned off (Scenario 2 worst case)	38	41%	28	31%
Scenario 3a: Minimum environmental water recovery target	12	13%	10	11%
Scenario 3b: Higher environmental water recovery target	12	13%	12	13%
Scenario 3c: Environmental water recovery for lower reaches	0	0%	3	3%
Scenario 4: Ballarat South WWTP discharge pattern manipulated and Higher water recovery target	8	9%	6	7%

Notes

* The event date used is 26/01 in any given year

** The event dates used are Friday to Sunday (inclusive) of the third weekend in March in any given year

*** A year is counted if BGA levels are higher than 50,000 cells per ml on any one of the days counted for the event dates.

3.6.7 ALGAL BLOOM MODELLING OF WATER RECOVERY SCENARIOS

The model was set up to compare future flow scenarios (with associated water quality). This will give an indication of which scenarios increase the risk of algal blooms in the Barwon River and which scenarios mitigate the risk compared to the base case, as well as the impact of climate change.

Scenario 1: Changes to Ballarat South WWTP discharges

Explored the contribution the Ballarat South WWTP makes to flows and nutrient loads, and the impact that changed discharges have on the results.

Reducing discharges to 2 GL, which is the volume to be maintained for environmental purposes as specified in the current Central Region SWS (Scenario 1a) increases the number of weeks of low flows per year, but decreases the average number of days of algal blooms per year due to a reduced nutrient load during summer.

Turning discharges off (Scenario 1b) results in a significantly reduced average number of days per year of algal blooms due to reduced nutrient loads.

Manipulating the pattern of discharge so that the incidence of low flow times are reduced (Scenario 1c) increased the variability, but also reduced the number of days per year of algal blooms compared to the base case. This suggests that the nutrient load impact can be offset by maintaining higher flows.

It is noted the decay/assimilation of the effluent-derived nutrients along the river prior to Geelong needs greater attention to verify this result.

In terms of the ability to maintain the critical river depths required for rowing, this reduces significantly compared to the base case if WWTP discharges are reduced (Scenarios 1a and 1b), but can be significantly improved by the manipulation of the WWTP discharge pattern (Scenario 1c).

Scenario 2: Changes to Batesford Quarry discharges

This scenario showed that while changing discharges from the quarry makes only a small difference to the number of weeks per year that Geelong flows are below 140 ML/week, these discharges have an important dilution effect in summer, as the average number of days of algal bloom increases substantially when they are decreased or turned off.

Decreasing or turning off this discharge also has a small impact on the ability to maintain the critical river depths required for rowing.

Scenario 3: Meeting environmental water recovery targets.

Scenarios 3a and 3b focussed on delivering environmental flows to the reaches immediately downstream of each storage. These scenarios slightly reduce the number of weeks of low flow at Geelong, provide a more significant reduction in the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing.

Scenario 3c focusses on delivering wet and dry season low flows to reaches immediately upstream of Geelong. This scenario significantly decreases the number of weeks of low flow at Geelong and hence the frequency of algal blooms. It provides the best results in terms of the ability to maintain critical rowing depth.

It is important to note that all Scenario 3 runs depend on recovering additional stored water for the environment. Refer to Section 3.4.4 above for further details on each of these scenarios and their approximate water recover targets.

Scenario 4: Environmental water recovery with optimised WWTP discharges

This scenario also successfully reduces the average number of days of algal blooms, and significantly improves the ability to maintain the critical river depth required for rowing.

Climate change modelling showed that the number of weeks with flow below 140 ML/week increases compared to the current (baseline) climate case, but that algal blooms actually decrease due to the overall drop in nutrient load from the whole catchment. In terms of river levels at Geelong for key events, climate change has a significant impact on how often required depths can be achieved for key events.

3.6.8 UNCERTAINTY AND LIMITATIONS OF ALGAL BLOOM MODELLING

The following aspects are limitations of the model:

- The model is developed and calibrated based on incomplete and sporadic monitoring data, which limits the accuracy of the outputs
- The model does not account for stratification patterns or wind-driven mixing that may limit the algal biomass growth
- The model outputs are based on a simple stoichiometric relationship coupled to a derived flow-algal bloom site-specific relationship. This does not attempt to capture all the complex biological processes the contribute to or are affected by algal blooms.
- The model does not differentiate between blue-green algae and other algal species
- Fluctuations of water quality are accounted for by developing factors for seasonal and flow-based qualities from monthly water quality monitoring data.

Examination of water quality data shows there is a risk of algal blooms when flows drop below 20 ML/day. **Base case** modelling over a long climatic sequence showed that flows drop below 140 ML/week for an average of 12 weeks per year. When run thorough the algal bloom model, this results in algal blooms for an average of 27 days per year.

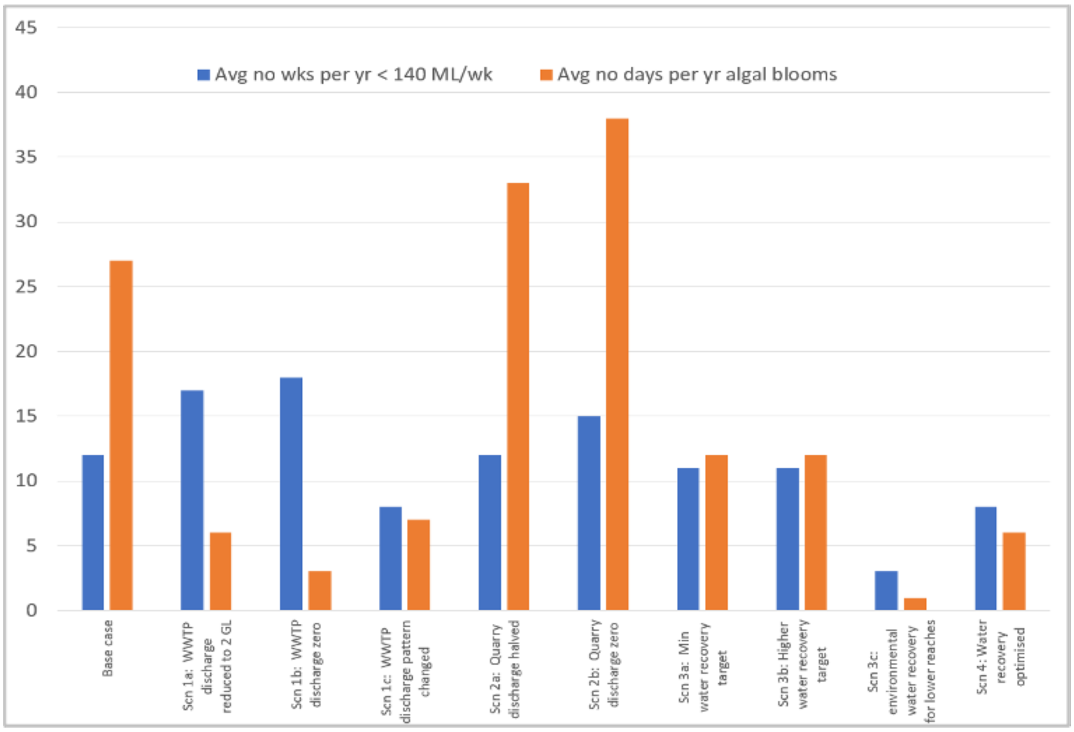

Figure 3-9: Summary of results – scenarios

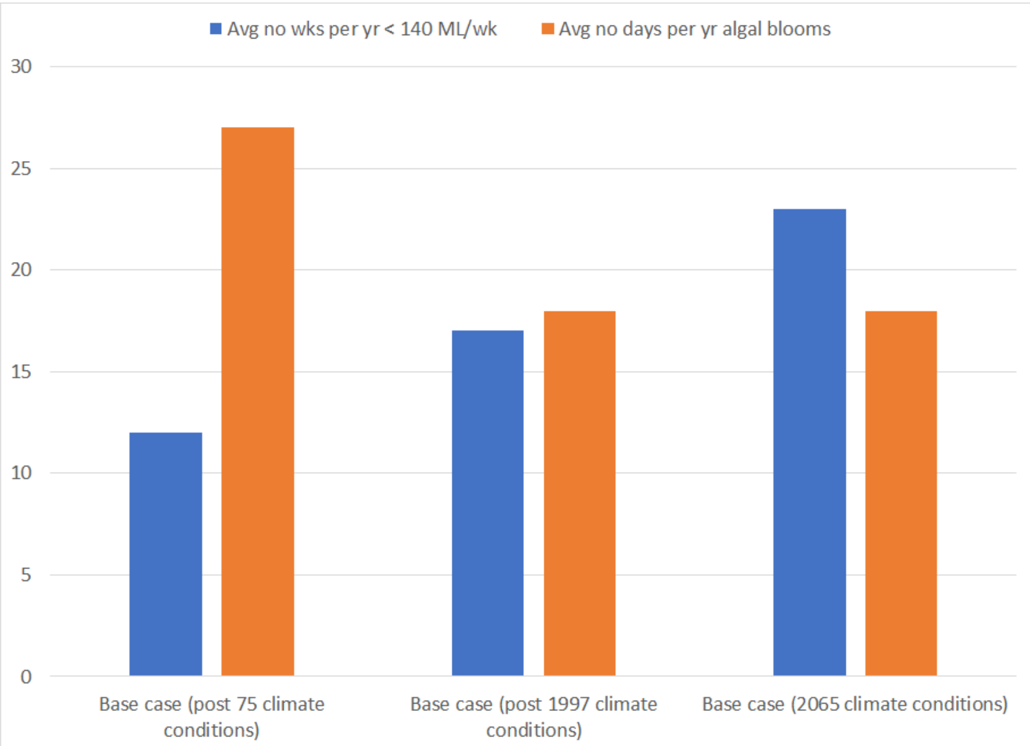

Figure 3-10: Summary of results – climate change

3.7 FLOW AND WATER QUALITY MODELLING DISCUSSION AND RECOMMENDATIONS

Flow and algal bloom modelling showed that under current climate and levels of development algal blooms occur in Geelong for an average of 27 days per year, and critical rowing depths for regattas are expected to be met in around one third of years.

The Ballarat South WWTP was shown to deliver a significant volume of water that helps maintain river depths in Geelong, but also a significant nutrient load that can drive algal blooms. The frequency with which this nutrient load creates algal blooms can largely be negated by manipulating the pattern of WWTP discharge to maintain flows above 20 ML/day in Geelong.

Batesford quarry discharge only contributes a small volume of flow to the river but was shown to have an important dilution effect, reducing nutrient load and hence algal blooms.

Scenario 3 runs depend on recovering additional stored water for the environment in both the West Barwon and Lal Lal Reservoirs. Providing most required environmental flow components for the reaches immediately downstream of West Barwon and Lal Lal Reservoirs provides good local environmental benefit but, due to losses along the river, has limited impact on reducing algal blooms or maintaining critical flow depth in Geelong. Targeting environmental flow provision to low flow requirements in the lower reaches of the Barwon and Moorabool rivers instead provided the largest reduction in the incidence of algal blooms and the best maintenance of critical river depth in Geelong compared to the base case. Modelling also showed combined environmental flow provision and manipulation of WWTP discharge is also successful. While not analysed for this study, it is noted that recovery of additional stored water for the environment provides a wide range of additional environmental benefits throughout both basins, in addition to mitigating algal blooms and maintaining depth at Geelong.

On the basis of these results, it is recommended that quarry discharges be maintained into the future, and that options to deliver low flows and manipulate WWTP discharge patterns be explored further. The manipulation of WWTP discharge patterns and the provision of low flow requirements both result in substantial reduction in algal blooms and times when critical rowing depths are not met. The manipulation of WWTP discharge patterns does not require extra water but does require development of additional storage, with the associated cost of construction and ongoing careful management to correctly time releases. The provision of low flow requirements requires extra water but provides a wide range of additional environmental and recreational benefits throughout the system. There would be benefit in exploring all these options further, including the combined manipulation of WWTP discharge patterns and the provision of low flow requirements via additional stored environmental entitlements to maximise benefits and minimise costs.

As noted throughout this report, the water quality modelling undertaken is simplified and does not represent the decay of WWTP nutrient loads as they pass downstream or any sediment fluxes. It is recommended that more detailed water modelling be undertaken to take into account these effects. It was also noted that there was no useful data on stormwater discharges from the Geelong urban area into the lower Barwon River or estuary. Gauging and monitoring of stormwater discharges would assist to quantify the stormwater contribution to flows and loads now and in future.

Water resource modelling was carried out on a weekly timestep and a daily pattern applied for the purposes of algal bloom modelling. DELWP is currently undertaking a project to create a daily timestep Source model of the Barwon-Moorabool system. Creation of this model will include a rederivation of reach inflows, lags and losses and the representation and prioritisation of environmental flow requirements by individual flow component. This will allow for the modelling of a more accurate daily time series at Geelong and hence more accurate algal bloom modelling. It will also allow for the targeting and reporting of the compliance of individual flow components in each reach. It is recommended that scenarios be re-run in the daily Source model once it is available to further explore the benefits of each of the water recovery scenarios.

4 Socio-economic assessment

Figure 4-1: Fishing platform, Barwon through Geelong[14]

For the residents of Geelong and the surrounding areas, the Barwon River is an iconic natural asset, providing a wide range of social and economic benefits. Quantifying those economic benefits and improving our understanding of how future river flows influence them will assist decision-makers in sustaining and enhancing the river's value to the community.

This section of the report summarises the findings of a detailed socio-economic analysis. The analysis included rigorous consultation and engagement with river users, modelling of future river flows under a range of climate scenarios, and a detailed desktop analysis to determine the current and likely future economic value of the lower Barwon and Moorabool rivers for range of possible water recovery scenarios. An ecosystem services framework was developed from existing literature that covered the direct and indirect benefits derived from the Barwon River's use in Geelong and the surrounding area.

Commercial activities that occur on the river, such as commercial eel fishing or any boat charters, have been excluded from the analysis. There was due to limited reliable data about the economic impact, and it was unclear as to what the specific impacts of changed river flow would have on business operations. To properly quantify the economic values and the expected impact from changed river flows would require further analysis, and although the values are likely significant, this investigation was outside the scope of this study.

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14 Source: Corangamite CMA.

Our approach involved establishing the current annual value that the river system provides to the community of Geelong. Once the annual value was established, two factors - the ability to access and participate in recreational and social events, and an individual's willingness to pay for housing located within proximity to the river - were linked to a set of variables relating to the rivers - depth, annual flow, and blue-green algae events under a range of water recovery scenarios. This involved the economic values being paired with climate modelling to determine the impact of river management strategies for increased flow on future blue-green algae events and low river levels, and how these strategies would influence the derived economic value over time.

4.1 CURRENT AND FUTURE USE OF THE WATERWAYS

BARWON RIVER THROUGH GEELONG

The Barwon River runs through the centre of Geelong and is a significant asset to the city. The river corridor provides open green space valued by residents and visitors alike. The river and its adjacent parklands are a focus for a wide range of recreational activities. The map in Figure 4-3 shows the designated waterway use rules for the Barwon River from the Geelong Ring Road to the lower barrages at Reedy Lake. Events, including sporting and recreational events and other social events, are also held along the Barwon River corridor. Figure 4-4 shows the event management zones for the Barwon through Geelong.

Current facilities and general recreational use

The Barwon River corridor through Geelong includes a series of riverside parklands and facilities, which attract a range of active and passive recreational uses. These are listed in Table 4-1 below.

Table 4-1: Summary of key Barwon River parklands and facilities for recreational and amenity use

LOCATION OR TYPE	USES
Geelong Ring Road to Queens Park Bridge	
Buckley Falls Lookout	▪ Environmental values ▪ Walking ▪ Fishing.
The Old Paper Mills at Fyansford	▪ Tourism ▪ Heritage Arts Precinct, winery and café.
Queens Park and Zilah Crawcour Park	▪ Adventure playground ▪ Picnic facilities ▪ Sporting facilities ▪ Walking and running ▪ Cycling.
Central Geelong (Queens Park Bridge to Breakwater Rd)	
Shared trails incl. Stan Lewis, Rotary and Wal Whiteside Walks	▪ Walking and running ▪ Cycling.
Canoe launches	▪ Paddlesport access ▪ Rowing access ▪ Paddlesports facilities (clubhouse - Geelong Canoe Club).
Boat ramps	▪ Waterskiing access.
Fyans Park	▪ Picnic facilities and boat ramp.

LOCATION OR TYPE	USES
King Lloyd and Yollinko Wetlands	▪ Picnic facilities ▪ Sporting facilities.
Balyang Sanctuary and Marnock Reserve	▪ Picnic facilities ▪ Bird watching ▪ Environmental values.
Bob Morell and Richardsons Reserves	▪ Picnic facilities.
North and South Bank Rowing Mile	▪ Rowing spectator vantage point ▪ Picnic facilities ▪ Boatsheds, rowing facilities (x five): – Geelong Grammar – Geelong College – Barwon Rowing Club – Corio Rowing Club – Geelong Rowing Association.
Barwon Edge Boathouse	▪ Direct river use/ visitation
Barwon Valley Park	▪ Adventure playground ▪ Picnic facilities ▪ Sporting facilities.
Belmont Common	▪ Picnic facilities ▪ Bird watching ▪ Environmental values ▪ Sporting facilities ▪ Fishing ▪ Boat ramp.
Breakwater Road to the western boundary of Lake Connewarre Reserve	
Geelong Water Ski Club and motor boating zone	▪ Waterskiing access and club rooms ▪ Motorboating.
Reedy Lake	
Lake Connewarre Wildlife Reserve	▪ Bird watching ▪ Environmental values ▪ Walking and cycling.
Reedy Lake and Hospital Swamps – part of the Lake Connewarre State Game Reserve, near Geelong	▪ Bird watching ▪ Environmental values ▪ Duck hunting ▪ Commercial eel fishing[15].

[15] As detailed above on river commercial activities such as commercial eel fishing have been excluded from the analysis - as it was unclear as to what the specific impacts of changing river flow would have on their activity. These values and their expected impact from changed river flows would require further analysis outside the scope of this study.

Current events in central Geelong

The Barwon River through Geelong supports over 50 major events and approximately 1200 smaller organised recreational and sporting events and other smaller private functions each year on its waters and along its riverbank[16].

Events on the Barwon River in central Geelong (between Queens Park Bridge and Breakwater Rd from 13 March 2019 to 13 December 2020 are summarised in Table 4-2 below. This includes some prominent annual events that Geelong is renowned for hosting. For example:

- Head of the School Girls Regatta (10,000 patrons)
- Junior Girls State Champions Regatta (2,000 patrons)
- Sacred Heart, Loreto and Firbank School regattas (between 1,000–2,000 patrons)
- Run 4 Geelong (2,000 patrons)
- River Run – Geelong (1,000 patrons).

Other events, such as Park Runs and waterskiing days[17] regularly attract significant crowds.

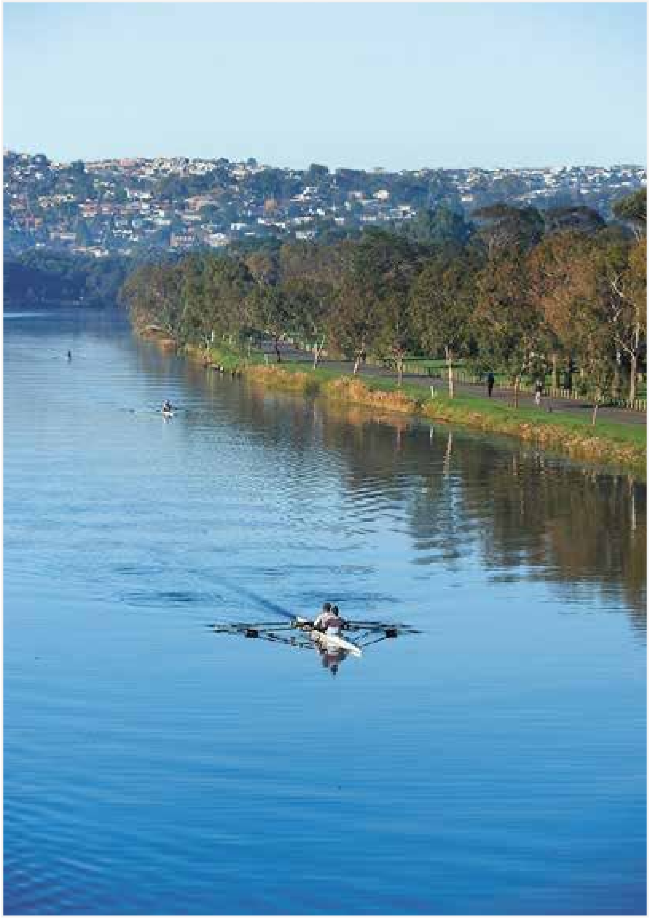

Figure 4-2: Barwon Rowing Mile[18]

16 Surveyed data 2021, RMCG.

17 Use of the Barwon through Geelong for waterskiing in this section of the river, requires temporary re-zoning and requires registration as an event.

18 Source: DELWP, 2019.

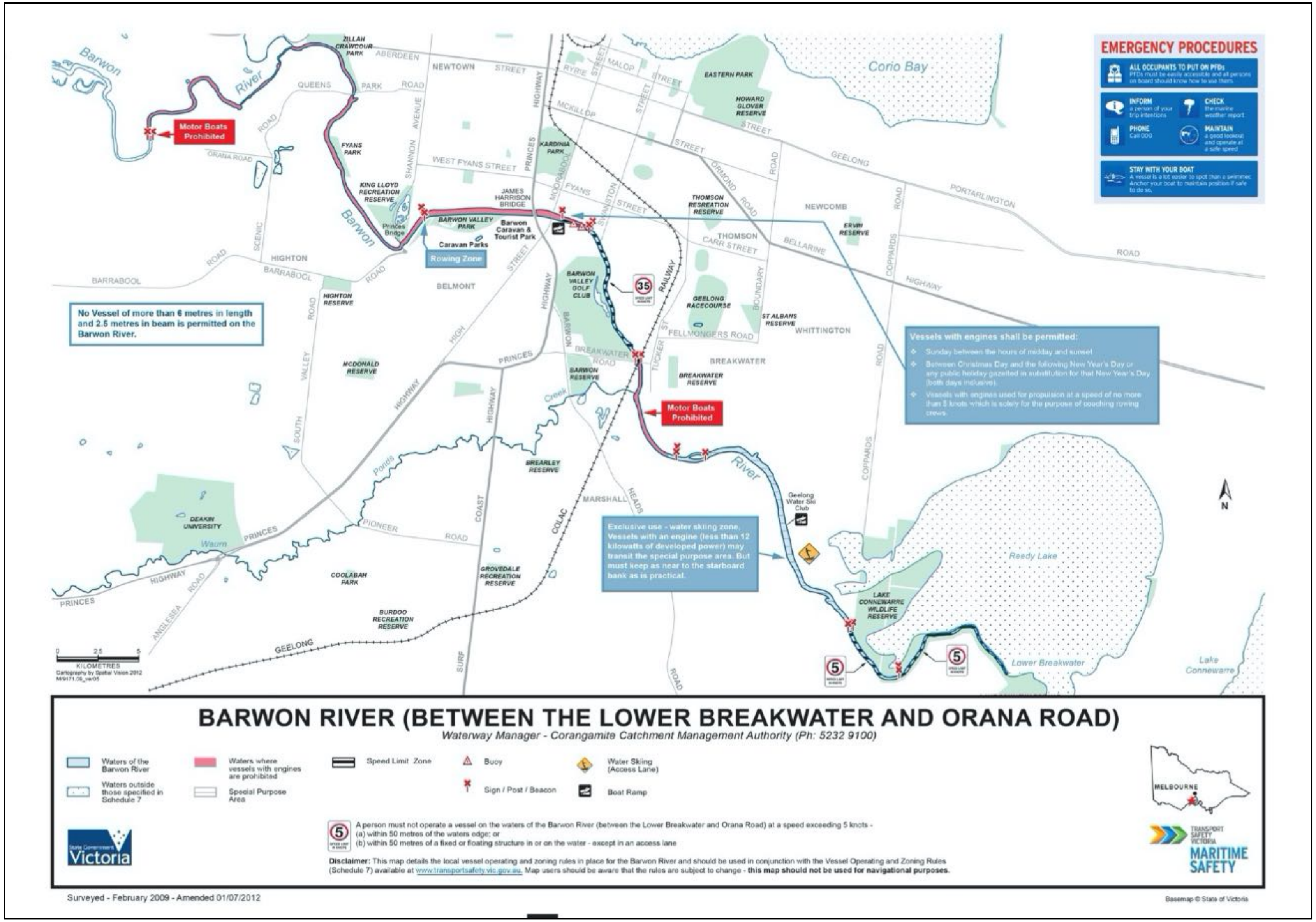

Figure 4-3: Waterway use rules for the Barwon River through Geelong

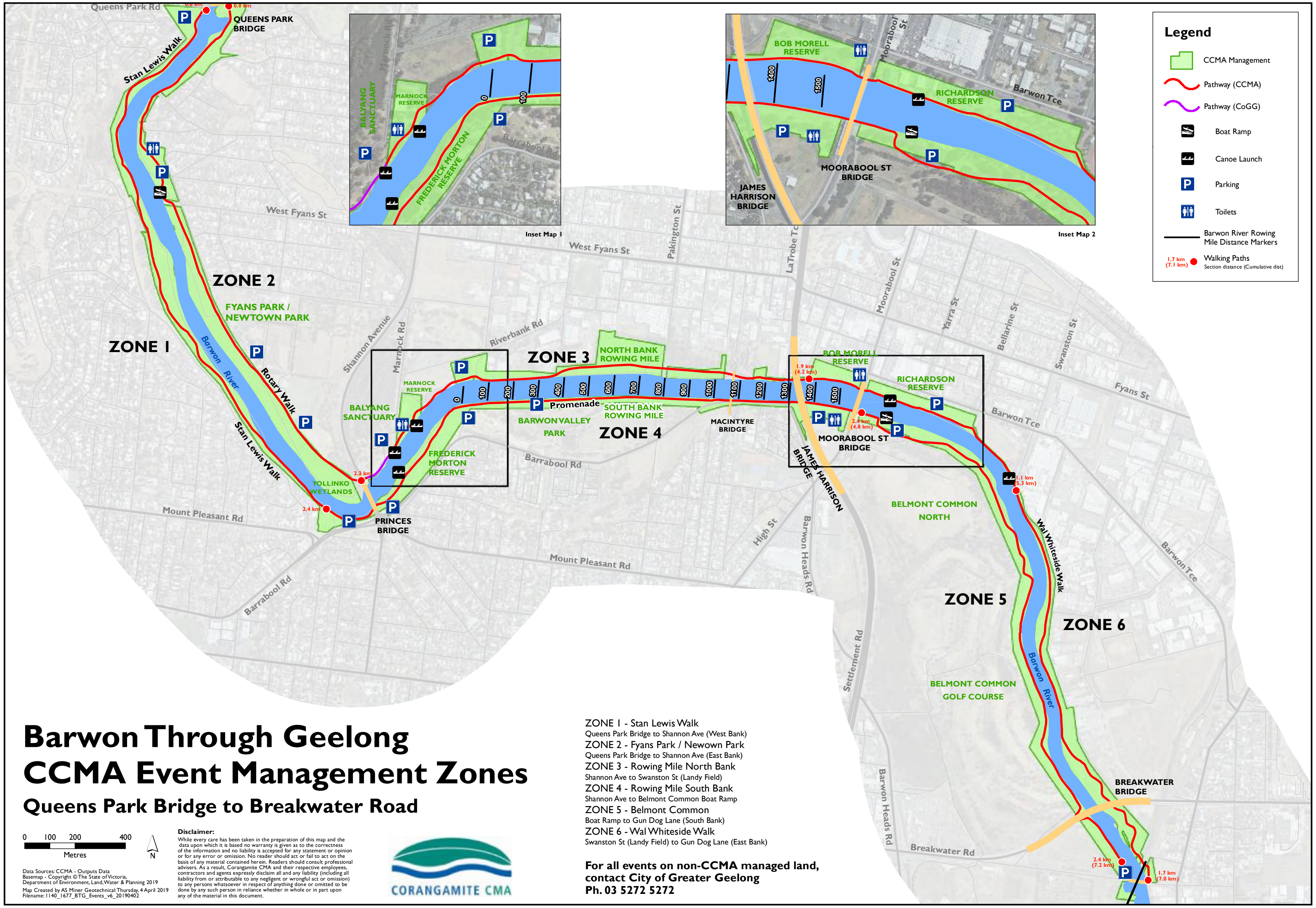

Figure 4-4: Event management zones for central Geelong reaches of Barwon River

Table 4-2: Summary of events held on the Barwon River in central Geelong from March 2019 to December 2020. Source: Corangamite CMA Events Calendar[19]

TYPE OF EVENT	NO. OF EVENTS[20]	LOCATIONS	TOTAL PAX (APPROX.)	TOTAL EVENT HOURS
Rowing regattas	9	Primary: Zones 2–3 Other: Zones 1–6	18,200	79
Paddlesports	3	Primary: Zones 2–3	265	14
Dragon boats	2	Primary: Zones 2–3	350	18
Waterskiing	5	Primary: Zones 4–6 Other: Zones 2–6	42	104
Running events	9	Primary: Zones 1–6	3,850	119
Arts and community	4	Primary: Zones 2–4	226	6[21]
TOTALS	32		22,933	340

Other current uses of the Barwon River through Geelong

In addition to recreational values, the Barwon River through Geelong provides:

- Liveability and amenity value for nearby residents, which can be associated with higher property prices
- Environmental benefits that are valued by the community independent of whether they use the waterway and its parklands.

Anticipated future use

Current population forecasts, project that Geelong will almost double to approximately 569,400 people by 2056[22]. As the population grows there will be pressure for more intensive development in the catchment and greater recreational use of the river and its surrounding area[23].

The Barwon Parklands Strategy (2011), Barwon Strategic Directions Statement[24] and Our living rivers of the Barwon: discussion paper for the future (2019), all speak to a thriving river corridor. This includes the following visions for enhanced use of the river corridor:

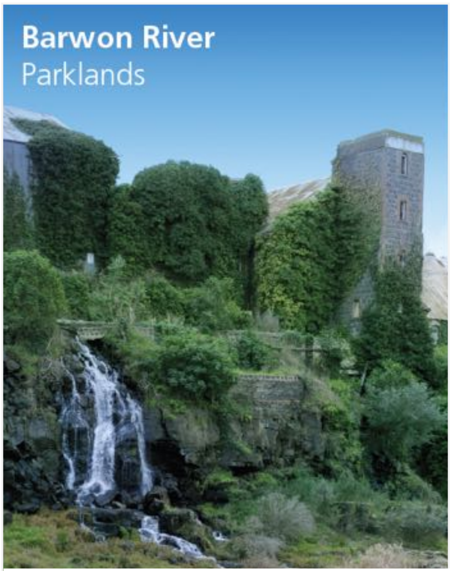

Figure 4-5: Barwon River parklands

- **Kitjarra-dja-bull bullarto langi-ut (Barwon River Parklands)** is an initiative to increase the public amenity of the unique environmental, cultural, and recreational values of the Lower Barwon and Moorabool Rivers. The project area extends from the Moorabool River at Meredith through to where it joins the Barwon River in Geelong and continues through Geelong and onto Barwon Heads. A masterplan for this important river corridor is currently being planned to incorporate the vision of river users, the Wadawaurrung Traditional Owners, public land managers and the general community.

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19 Note that COVID-19 restrictions limited events over March to October 2020.
20 Recurring events (e.g. weekly Park Run events) are counted as a single event.
21 This excludes pop-up installations which are set up for passive recreation and use.
22 https://www.planning.vic.gov.au/__data/assets/pdf_file/0032/332996/Victoria_in_Future_2019.pdf
23 RMCG, 2019
24 DELWP, 2018a

- **Porronggitj Karrong (between Horseshoe bend Rd to Boundary Rd)** includes the heritage-listed Sewer Aqueduct Bridge and adjacent floodplain managed by Barwon Water and the Corangamite CMA. 2007). Barwon Water, the CMA and the Wadawurrung Traditional Owner Aboriginal Corporation are currently working in partnership to further develop the environmental and cultural values of the area and enhanced public access.
- **The Sparrovale Wetland Reserve** – the City of Greater Geelong has acquired 500 hectares of riparian and floodplain land to provide for the capture and treatment of urban stormwater runoff from the Armstrong Creek development area. The natural and constructed wetlands will occupy around 200 hectares with all areas subject to flooding at times from the Barwon River. A Sparrovale Master Plan is currently being prepared for the site.

Figure 4-6: The Barwon through Geelong looking towards the canoe landing[25]

MOORABOOL RIVER

The Moorabool River joins the Barwon River at Fyansford at the western edge of Geelong. Before joining the Barwon, it flows through an area earmarked for development known as the Western Geelong Growth Area. Current recreation activities on the Moorabool through Geelong are mostly limited to the Fyansford area, using the river in the semi-rural region north of Geelong; however, it is expected that the Moorabool River corridor will become an essential focal point for the Western Geelong Growth Area.

Current uses of the Moorabool River

Table 4-3 summarises some of the facilities and current uses of the Moorabool River within the study area. In addition to those listed, other activities along the length of the river include swimming, fishing, bird watching and some bushwalking and horse riding.

[25] Source: DELWP, 2019.

Table 4-3: Facilities and uses of the Moorabool River and its parklands[26][27]

LOCATION / PARKLAND	USES
Lower Moorabool	
Fyansford Common	▪ Walking and cycling ▪ Picnics ▪ Environmental values.
Batesford	▪ Swimming area ▪ Historic attraction (Blue Stone Bridge).
The business associated with direct river use/ visitation	▪ Fyansford Hotel ▪ Batesford Hotel ▪ Truffleduck.

Anticipated future uses of the Moorabool River: West Geelong Growth Area

The Northern and Western Geelong Growth Areas combined are the most significant urban growth project in regional Victoria with the potential to welcome more than 110,000 new Geelong residents. The project will address the long-term growth needs of Geelong, facilitating diverse and affordable housing and employment opportunities for the city over the coming decades. The Northern Geelong Growth Area, in Lovely Banks, is anticipated to deliver up to 18,000 new dwellings for a population of approximately 48,000 residents. The Western Geelong Growth Area in Batesford is expected to deliver up to 22,000 new residences for approximately 62,000 residents. The Western Geelong Growth Area includes more than 20 kilometres of river frontage to the Barwon and Moorabool Rivers and Cowies Creek[28].

The extension of the parklands through this area (the lower Moorabool from Fyansford to Batesford) has been identified as a key opportunity for the planned Barwon Parklands Master Plan[29] and will lead to additional and extended active and passive recreational river side use, including some on river use through paddle sport activities.

4.2 WATERWAY CONDITION REQUIREMENTS

The current and future use described in the previous section can be affected by waterway or riparian conditions. For example, water depths are a safety consideration for motorboat sports such as waterskiing, while blue-green algae must be absent for all water-based activities.

Accordingly, waterway managers often specify waterway rules, such as speed limits or prohibited areas that consider water depths. At the same time, multi-agency coordinating committees help to provide advice to recreational users and manage risks associated with blue-green algae.

Organisers of river-based events also specify minimum water depths or other conditions to ensure consistent depths and safety for participants. Land-based activities may also be impacted by waterway conditions through odour, amenity, or the waterway's capacity to support environmental values such as birdlife.

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26 https://www.geelongaustralia.com.au
27 SKM, 2004
28 DELWP, 2018a
29 RMCG, 2019

Table 4-4 summarises assumptions for minimum conditions, which would limit the use of the rivers for these purposes, based on a range of available desktop resources regarding these management arrangements, and stakeholder interviews with river users (refer section 5.1.4).

Table 4-5 (following page) summarises uses of the Barwon and Moorabool River by season, its central location and the waterway and riparian conditions required for the particular type of use.

The two tables provide the framework for determining what uses will be impacted by flow conditions, taking into consideration the location and seasonality of the activities.

Table 4-4: Minimum conditions for the use of the Barwon and Moorabool Rivers through Geelong, which are flow-dependent

ACTIVITY	CONDITIONS	TIMING	BASIS
High-speed water activities E.g. Waterskiing, motorboats at high speeds.	Water depths >1.6m.	Summer	Water depths are an assumed basis for proposed Lake Burrumbeet Waterway Rule Changes (Ballarat City Council).
Low-speed water activities E.g. Rowing, paddle sports.	Water depths >1.2m.	All	Water depths are an assumed basis for proposed Lake Burrumbeet Waterway Rule Changes (Ballarat City Council).
Rowing regatta events	Water depths >1.9m.	Jan–Mar	Water depth was a driver for dredging of Barwon River rowing mile for regatta events in 2014 (Source to confirmed with the City of Greater Geelong).
All river-contact activities E.g. All watercraft sports, swimming, fishing.	BGA bloom notification threshold triggered*.	Jan–Mar	NHMRC (2008)following with Victorian BGA Circular (DELWP, 2018)*.
Use of adjacent parkland E.g. Walking, running, cycling, art and community events, exercise classes, other passive uses, private events.	BGA bloom notification threshold triggered (due to odour).	Year-round	Varied
Environmental values and amenity E.g. Bird watching, hunting, an amenity for nearby residents.	Too frequent BGA blooms and ceases to flow linked to ecosystem collapse.	Year-round	Varied

Table 4-5: Summary of current uses and waterway conditions

USE	TYPE OF USE	MAIN SEASON	MAIN LOCATIONS	RIVER-BASED ACTIVITY	WATERWAY CONDITIONS	RIPARIAN CONDITIONS
Rowing (incl. dragon boats)	▪ Events ▪ General.	Summer	▪ Central Geelong[30].	Yes	▪ BGA ▪ River level.	▪ Parkland (events).
Paddlesports	▪ Events ▪ General.	Summer	▪ Central Geelong ▪ Reedy Lake.	Yes	▪ BGA ▪ River level.	▪ Parkland (events).
Waterskiing	▪ Events ▪ General.	Summer	▪ Central Geelong ▪ Horseshoe Bend Rd to Lake Connewarre Reserve.	Yes.	▪ BGA ▪ River level.	▪ Parkland (events).
Motorboats	▪ General.	Summer	▪ Horseshoe bend Rd to Lake Connewarre Reserve.	Yes	▪ BGA ▪ River level.	
Walking and running	▪ Events ▪ General.	Year-round	▪ Central Geelong ▪ Ring Road to Queens Park.	No	▪ Odour.	▪ Parkland.
Cycling	▪ Events ▪ General.	Year-round	▪ Central Geelong ▪ Ring Road to Queens Park.	No	▪ Odour.	▪ Parkland.
Fishing	▪ General.	Year-round	▪ Central Geelong ▪ Buckleys Falls and Queens Park ▪ Reedy Lake.	Yes	▪ Fish population ▪ River level ▪ BGA.	▪ Habitat.
Hunting	▪ General.	Autumn	▪ Reedy Lake and Hospital Swamps.	Yes	▪ Duck population	▪ Habitat.
Bird watching	▪ General.	Year-round	▪ Balyang Sanctuary ▪ Reedy Lake and Hospital Swamps.	No	▪ Bird population.	▪ Habitat.

30 Includes Barwon River reach between Queens Park Bridge to Breakwater Road.

USE	TYPE OF USE	MAIN SEASON	MAIN LOCATIONS	RIVER-BASED ACTIVITY	WATERWAY CONDITIONS	RIPARIAN CONDITIONS
Swimming	▪ General.	Summer	▪ Upstream of the Geelong Ring Road ▪ Barwon Heads.	Yes	▪ BGA ▪ River level.	
Exercise classes (e.g. yoga, boot camp)	▪ General	Year-round	▪ Central Geelong ▪ Queens Park.	No	▪ Odour.	▪ Parkland.
Other passive use (e.g. picnics, playgrounds)	▪ General	Spring – Autumn	▪ Central Geelong ▪ Balyang Sanctuary ▪ Belmont Common ▪ Barwon Valley Park ▪ Queens- Zillah Crawcour Parks ▪ Fyansford Common (Moorabool) ▪ Reedy Lake.	No	▪ Odour.	▪ Parkland.
Arts and community events	▪ Events	Spring – Autumn	▪ Central Geelong.	No	▪ Odour.	▪ Parkland.
Private events (e.g. weddings)	▪ Events	Spring – Autumn	▪ Central Geelong ▪ Ring Road to Queens Park.	No	▪ Odour.	▪ Parkland.
Amenity for nearby residents	▪ General	Year-round	▪ Central Geelong ▪ Balyang Sanctuary ▪ Belmont Common ▪ Barwon Valley Park ▪ Queens- Zillah Crawcour Parks ▪ Fyansford Common (Moorabool) ▪ Reedy Lake.	No	▪ Odour.	▪ Parkland.

5 Economic analysis

The analysis identified and (where possible) estimated the economic value of the waterways and riparian zones to communities and businesses within Geelong and its surrounds. An ecosystem services approach was used to link the river system's natural assets to the use of the river. Ecosystem services are the benefits people obtain from the natural environment and are broadly categorised into four types[31]:

- Regulating services: the benefit derived from the regulation of the ecosystem processes providing healthy catchments and water quality, i.e. natural filtration and water treatment, buffering of flood flows, erosion control through water/land interactions
- Provisioning services: products obtained from the ecosystem, i.e. raw water supply
- Cultural services: non-material benefits, i.e. recreation, tourism, aesthetic and spiritual
- Supporting services: supporting ecosystem services that underpin other services, i.e. living spaces (habitat) for plants or animals and maintenance of a (genetic) diversity of plants and animals.

The ecosystem service evaluation method provides a framework through which economic values (benefits and costs) can be assigned to natural assets. The values can then be used to compare the advantages and or disadvantages of management and policy decisions that impact socioeconomic development. This analysis predominantly used cultural services to determine the economic value of the lower Barwon and Moorabool river system within the defined study area (refer Figure 2-1, above)[32].

5.1 APPROACH

The economic analysis first quantified a base case, using ecosystem services, to value the natural capital of the river system today. The analysis included:

- The current value of the waterways
- The impact of climate change, river level, water quality, population growth, community engagement and future use.

The economic value was calculated for a range of water recovery scenarios. Within each scenario we estimated the future use of the river given improved river conditions and the impact this would have on river use and ultimately the economic value. The water recovery scenarios incorporated the same expected climate change, population growth and community behaviour assumptions as were used in the base case. The difference in value between the base case and water recovery scenario represents the marginal benefit of improving river conditions.

The process to develop the economic analysis is outlined in Table 5-1 and further detail on each step is then provided in the sections below.

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31 https://www.fao.org/ecosystem-services-biodiversity/background/supporting-services/en/
32 Due to the limitations and scope of the study we have tended towards conservative estimates for the economic values identified.

Table 5-1: Outline of economic approach

Literature review	• Review existing literature and information on ecosystem services provided by the river system
Stakeholder engagement and mapping	• Engage with river users to test information obtained in the literature review • Using GIS mapping, map and measure the areas providing ecosystem services
Assigning values	• Meta analysis of previous studies that estimate the economic values of ecosystem services
Model	• Based on mapping and unit values aggregate estimates into total value and used to develop a discounted cash flow analysis and marginal benefit for each scenario.

5.1.1 LITERATURE REVIEW

Existing usage information and surveyed data on activity expenditure and usage were used to determine the value and the economic impact associated with the Barwon and Moorabool Rivers through Geelong.

A review of documentation supporting recent investment and planning (2014–19) found the following:

- There is significant support for maintaining and enhancing the Barwon River Parklands, as evidenced by the recent plans, strategies and discussion papers:
  - Barwon Parklands Masterplan development business case. A business case for government investment in a master plan for the Barwon River Parklands from Batesford to Barwon Heads.
  - Barwon Strategic Directions Statement (2018), developed by the Barwon Region Integrated Water Management (IWM) Forum to set out the principles, vision and outcomes for IWM across the Barwon Region. It identifies several opportunities that leverage off the value of the Barwon parklands through Geelong to support sustainable use of the corridor into the future[33].
  - Our living rivers of the Barwon: discussion paper for the future (2019), developed by the Barwon River Ministerial Advisory Committee (MAC) to promote community discussions about opportunities to protect and improve the health and management of the rivers of the Barwon (including Barwon and Moorabool Rivers through Geelong).
- There has been recent and ongoing investment in recreational assets such as:
  - Barwon River access upgrades, October 2018 ($480,000). Six river sites and platforms along the Geelong section of the Barwon River are in the process of being upgraded - all-ability platforms for fishing, paddling, pet-swimming and small boat access to boost visitor experience and bring new people to the River.
  - Upgrade of the Barwon River rowing landing, June 2017 ($850,000). The rowing landing was replaced to improve river access for Geelong's 1,000-strong member rowing community, thousands of rowing regatta competitors, canoe club members and other river users. This was jointly funded by the Victorian Government, Corangamite CMA, City of Greater Geelong and Rowing Geelong.
  - De-silting of the Barwon River rowing mile, 2014 ($550,000). The 'rowing mile' four-lane x 1,500-metre rowing course (Figure 5-1 below) was designed to ensure its fairness for racing. The City of Greater Geelong, Victorian Government and the Corangamite CMA jointly contributed to the dredging works.

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33 DELWP, 2018a

5.1.2 BARWON RIVER REGATTAS

Head of the School Girls Rowing Regatta

The Head of the Schoolgirls (HOSG) Rowing Regatta is the pinnacle event for schoolgirl rowing in Victoria and is the most prestigious female rowing event in the Southern Hemisphere.

Based on unpublished figures from City of Greater Geelong for 2013, the event attracted 2,200 participants from schools throughout Victoria. The HOSG Rowing Regatta meets the Geelong Major Events strategy to promote and support rowing activity on the Barwon River. This event encourages and supports women in sport and the development of young women physically and mentally. The event also attracts local, metropolitan, and intrastate schools and families to the Geelong region. The event is expected to continue to grow, and based on 2013 figures attracted 2,200 participants and 5,300 spectators.

Barwon Regatta

The WH Pincott Barwon Regatta has been run in Geelong since 1876 and is a highlight on the Rowing Victoria and Barwon Rowing calendars. The event is open to all schools or athletes from schools and clubs registered with Rowing Victoria.

Based on unpublished 2013 figures from the City of Greater Geelong, the event attracted 1,200 participants and 2,116 spectators. The Barwon Regatta has strong community support and provides economic benefits to Geelong. The event is held over two days, with overnight stays in Geelong.

Combined, the two events, Barwon Regatta and HOSG Regatta, are estimated to generate economic activity in the order of $2.5 million per annum[34].

Figure 5-1: The Barwon Rowing Club precinct[35]

[34] Greater Geelong City Council - Geelong Major Events Annual Report to Council 2013/2014
[35] Source: RMCG, 2020.

5.1.3 ECONOMIC VALUES

A detailed desktop review of relevant studies was also undertaken to determine the best approach for the economic valuation. As many of the values that are attributable to the river system are non-market-based, two methods were deemed appropriate and used, these were:

- *The benefit transfer method:* Uses information and values from similar existing studies to estimate the economic values in a current study. Specifically, we used values from existing studies that incorporated:[36]
  - The travel cost approach – where the time and cost of traveling to a destination to participate in an activity are used to develop a per trip value of a natural asset.
  - Disability Adjusted Life Year (DALY) – where the impact of recreation is considered to improve the quality and length of life and is reported in monetary terms per unit (in this case per km of cycling, running and walking).
- *The hedonic pricing method:* Where price is determined by internal characteristics and external factors affecting a good.[37] In this case we obtained values that considered the increased value of houses located within close proximity to a river, where residents are willing to pay for a premium for access to natural areas, recreation and amenity.

A summary of the values and methods used is shown below (Table 5-2).

Table 5-2: Economic valuation method

ECOSYSTEM SERVICE	VALUATION METHOD	VALUE	SOURCE
Events (sporting, social)	Travel cost method	$62 per adult (range $49-$87)	Pascoe et al. (2014)
Aesthetic	Hedonic property value	5.6% premium in property prices (range 1.13%-9.31%)	Thomy et al. (2017) Polyakov et al. (2016)
Housing	Median house price within 500 m of the Barwon and Moorabool rivers	$885,000	Realestate.com.au[38]
Recreation (normal exercise, tracks and parks)	DALY	$1.90 – walking (per km) $1.26 – Cycling (per km)	SKM PwC (2011)
Recreation (organised activity)	Travel cost	$20 per adult/ per visit (range $9-$32 depending on duration)	PV and DELWP (2015)

Further detail on each of the economic valuation methods is provided in Appendix 4.

5.1.4 STAKEHOLDER ENGAGEMENT

Once benefit transfer values had been estimated and assigned to relevant activities, a thorough stakeholder engagement program was undertaken with key river user groups. A standard set of questions were asked in a set of interviews designed to increase our understanding and confidence in the assumptions that were being used in the economic model, and to provide "ground truthing" estimates on usage. The engagement was used as a method to understand the extent of community use by prominent user groups. These groups included:

- Geelong Cross-Country Club
- Geelong Rowing association

36 M. Wilson, J. Hoehn, *Valuing environmental goods and services using benefit transfer: The state-of the-art and science.* Ecological economics (2006)

37 O. Ashenfelter, K. Storchmann, *Using hedonic models on solar radiation and weather patterns to assess the economic effect of climate change: the case of Model Valley vineyards.* World scientific, (2010).

38 https://www.realestate.com.au/neighbourhoods/geelong-3220-vic - accessed January 2021

- Geelong Field Naturalists
- Geelong Canoe Club
- Geelong & District Angling Clubs association
- Barwon Valley Water-ski club
- Geelong Outriggers Club
- Geelong Field and Game
- Victorian Fisheries Authority.

A copy of the interview guide and its questions has been included in Appendix 3.

Information on river usage and events, as well as population and development predictions for Geelong was also provided via engagement with the City of Greater Geelong and the Corangamite CMA.

The information obtained from the stakeholder engagement and the literature review was used to consolidate river usage data and predictions on current/planned housing. The housing analysis was also supported by GIS mapping of existing and planned development within 500 metres of the Barwon and Moorabool Rivers.

5.1.5 CURRENT VALUES

The infrastructure, housing and usage/event information outlined in chapters four and five above were consolidated into ‘service’ categories that grouped similar ecosystem services. These service groups were combined with usage data and mapping results to estimate the annual economic value. Specifically, unit values from Table 5-2 (above) were linked to land use data, median house price, and visitation and activities, to estimate the aggregate benefit to the community of Geelong. This estimate should not be considered comprehensive, as many of the benefits were 'transferred values' from existing studies with similar types of natural capital, and specific values that were hard to quantify were excluded (such as commercial fishing). Therefore, the values provided should be treated as indicative only. Table 5-3 shows the ecosystem services and their derived values that are used in the model. We have also included a confidence rating that is based on the quality of the data that was available for this study:

- **High** – high confidence in benefit transfer value and ecosystem services and the impact is easily measured and well understood with data
- **Medium** – medium confidence in benefit transfer value and ecosystem services, and/or impact estimates could be improved, data is minimal
- **Low** – low confidence in benefit transfer value and ecosystem services and/or impact estimates are sparse.

Table 5-3: Annual value of river system 2021[39]

SERVICE	ANNUAL VALUE	DISTRIBUTION OF TOTAL	CONFIDENCE
Major rowing events	$2,667,367	3%	HIGH
Other water events	$46,986	0.1%	LOW
Other events	$185,629	0.2%	LOW
Other recreation	$178,658	0%	LOW
Recreation on water	$2,219,330	3%	LOW
Housing	$17,709,176	92%	MEDIUM
Tracks and parks	$1,697,778	2%	HIGH
Total annual value	$24,704,923	100%	MEDIUM

[39] Note the impact of blue-green algae and low flows have not been applied to these values.

To test the robustness of our results, a sensitivity analysis was performed on the transferred benefit values using the upper and lower bounds that were available in the literature. Results are shown as the estimated value in 2021 (Table 5-4 below).

Table 5-4: Sensitivity analysis – annual value

SERVICE	LOW ESTIMATE	EXPECTED ESTIMATE	HIGH ESTIMATE
Major rowing events	$2,004,167	$2,667,367	$3,334,209
Other water events	$37,701	$46,986	$58,732
Other events	$203,265	$185,629	$232,035
Other recreation	$78,435	$178,658	$223,321
Recreation on water	$974,340	$2,219,330	$2,774,162
Housing	$15,536,777	$17,709,176	$38,738,821
Tracks and parks	$1,122,822	$1,697,778	$1,697,777
Total annual value	**$19,957,507**	**$24,704,924**	**$47,059,057**

The results of the sensitivity testing reinforce the indicative nature of our results. They also highlight the significance of the housing value as a proportion of the total annual value.

In all our assumptions we have tended towards a conservative estimate, and therefore the results presented here should also be considered conservative estimates. To obtain a more accurate representation of the rivers' value for the Geelong community, a more thorough investigation into each of the specific ecosystem services and the value they provide would need to be undertaken.

5.1.6 FUTURE VALUE

A discounted cash flow analysis was used to quantify the economic benefit that the lower Barwon and Moorabool Rivers will deliver to Geelong under a range of the watering scenarios[40]. As agreed with the study's project steering committee, the base climate case and three of the water recovery options (Scenario 3a, 3c and 4) were adopted for the economic benefits analysis. The key outcomes from these modelled scenarios are described here.

Scenario 3a – releasing water to the reaches immediately downstream of each storage (increased environmental entitlements in Lal Lal and West Barwon Reservoirs). This scenario (which approximates to the 3,380 ML/year water recovery target from Lal Lal Reservoir[41]) slightly reduces the number of weeks of low river flows at Geelong, can provide a more significant reduction in the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing. It also provides local ecological benefits in the reaches immediately downstream of the storages.

Scenario 3c – releasing higher volumes of water (further increase in environmental entitlements in Lal Lal and West Barwon Reservoirs) over summer and winter to improve more constant flow through Geelong. This scenario, (which approximates to the 5,140 ML/year water recovery target from Lal Lal Reservoir and 3,773 ML/year water recovery target at West Barwon Reservoir[42]), significantly decreases the number of weeks of low flow at Geelong and the frequency of algal blooms. It also provides the best results in terms of the ability to maintain critical rowing depth. It also provides ecological benefits throughout both basins in the reaches downstream of the storages all the way down to Geelong.

[40] R. Hubbard *et al. Microeconomics 4th edition.* Pearson (2018)
[41] Jacobs, 2015
[42] Alluvium, 2019

Scenario 4 – environmental water recovery with optimised wastewater treatment releases. This scenario, which combines the manipulation of Ballarat South Wastewater Treatment Plant discharge with an increased environmental entitlement (which approximates to the higher 6,150 ML/year water recovery target from Lal Lal Reservoir[43]), also successfully reduced the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing.

Each scenario has unique values that were derived from combining the annual socioeconomic values with river flow and algal bloom data to calculate a Net Present Value (NPV). Each scenario's NPV was compared to the base case to determine a marginal economic benefit of providing extra water into the river system.

The assumptions that were standard across each scenario are detailed in Table 5-.

Table 5-5: Model assumptions

ASSUMPTION	VALUE
Population growth	1.7% annual growth
Social discount rate	4%
Time frame	40 years

For each scenario, an economic value was derived for the following costs and benefits:

- The benefit of reduced algae blooms
- The benefit of increased events and recreational use
- Increased housing value
- Reduced low flow.

A summary of how each value was calculated is provided in Table 5-7 below.

[43] Jacobs, 2015

Table 5-7: Derived economic values

VALUE	ALGAE BLOOMS	LOW FLOW
Recreation	The percentage of days per year for each modelled scenario was linked directly to passive and active river use on and around the river. For example, if 3 per cent of days had algae blooms, then 3 per cent of the annual value would be counted as a cost relative to the base case	The percentage of low flow days per year that impacted recreation for each modelled scenario was linked directly to passive and active river use on and around the river. For example, if 3 per cent of days had low flow, then 3 per cent of the annual value would be counted as a cost relative to the base case
Events	Using historical data, a statistical approach was developed to combine the probability of algae events occurring at the time of a planned event. For example, if there were a 50 per cent chance that the river would experience algae blooms or low flows during a rowing event, 50 per cent of the value would be counted as a cost	Using historical data, a statistical approach was developed to combine the probability of a significant low flow occurring at the time of a planned event. For example, if there were a 50 per cent chance that the river would experience a significant low flows during a rowing event, 50 per cent of the value would be counted as a cost.
Housing	Housing value was calculated as a benefit. A 5.7 per cent premium was calculated for houses within 500m of the riverbanks (median house price in Geelong is $885,000, so the residential premium for a particular property is $50,445). For sections of the river where sustained algae events were avoided, a direct benefit was used, i.e., a 3 per cent reduction in algae blooms would see a 3% improvement in housing impact. The value of low flows was also added to scenario 3c in years where the river would cease to flow. Scenario 3c is the only scenario where there was a distinctive difference when compared to the base case.	The value of low flows was only deemed to impact housing values if sustained cessation of river flows were experienced. Scenario 3c was the only scenario where there was a notable difference in cessation relative to the base case.

5.2 RESULTS OF ECONOMIC ANALYSIS

MARGINAL NET PRESENT VALUE

This analysis has estimated the socioeconomic impact of three alternative water recovery scenarios, estimating both market and non-market values. The benefit of having extra water available in the system within the scenarios ranged from $42 million to $95 million over the 40-year period, relative to the base case where no extra water is available (Table 5-9).

From our analysis it was determined that Scenario 3c has the highest marginal benefit since it provides:

- The lowest number of algae events
- The lowest number of lost river event (e.g. rowing regattas)
- The highest benefit to housing value
- The second lowest number of low-flow events.

Table 5-5 shows the relative impacts (expressed as percentages of occurrence) that were used to calculate the costs and benefits for each scenario. These values are also ranked according to marginal benefit.

Table 5-5: Ecosystem services – percentage of days impacted per year

SCENARIO	OCCURRENCE OF ALGAE EVENTS	OCCURRENCE OF LOW FLOW OR ALGAE AT EVENT	PERCENTAGE INCREASE IN HOUSING VALUE	OCCURRENCE OF LOW FLOW	RANK
Base case	7.6%	46.2%	-	18.9%	-
3a	3.4%	36.3%	4.1%	12.3%	3
3c	**0.3%**	**6.3%**	**7.2%**	**3.6%**	**1**
4	1.8%	18.3%	5.8%	2.2%	2

Table 5-6: Results discounted cashflow analysis – 40-year time frame[44]

SCENARIO	COST OF ALGAE	COST OF LOST EVENTS	HOUSING VALUE	COST OF LOW FLOW	MARGINAL BENEFIT
Base case	$4.2 M	$24.7 M	$-	$10.2 M	-
3a	$1.9 M	$19.3 M	$31.3 M	$6.9 M	$42.4 M
3c	**$0.1 M**	**$4.0 M**	**$55 M**	**$2.2 M**	**$95.1 M**
4	$1.2 M	$9.7 M	$44 M	$1.4 M	$70.9 M

This study has shown the socioeconomic benefits of increased water availability. It is, however, important to recognise that:

1. The cost associated with acquiring or recovering the additional water has not been included and will likely play a significant role in the feasibility of realising the socioeconomic values stated in this report.
2. The modelling assumes both current climate (post 1975 climate conditions) and levels of consumptive demand, therefore does not account for expected changes in demand and climate change within this time period.

The marginal benefit of the three scenarios that were tested, relative to the base case, is also shown as a time series in Figure 5-2 below. The base case in this graph is represented as the horizontal axis, with zero marginal benefit. The results indicate:

- Scenario 3c has the highest marginal benefit with a marginal NPV over 40 years of $95.1 million (commencing in 2021 at $3.8 million). The graph indicates that, over time, the cumulative benefits of 3c clearly outstrip the other scenarios. This is mainly driven by decreased algae events.
- Scenario 4 has a marginal NPV of $70.9 million (commencing in 2021 at $2.8 million). This scenario showed the increased cost of algae events relative to scenario 3c.
- Scenario 3a has a marginal NPV of $42.4 million (commencing in 2021 at $1.2 million). This scenario showed the largest impact of lost events, and impact on housing. Although, relative to the base case, it is a significant improvement in river condition.

44 Results are rounded to the nearest hundred thousand

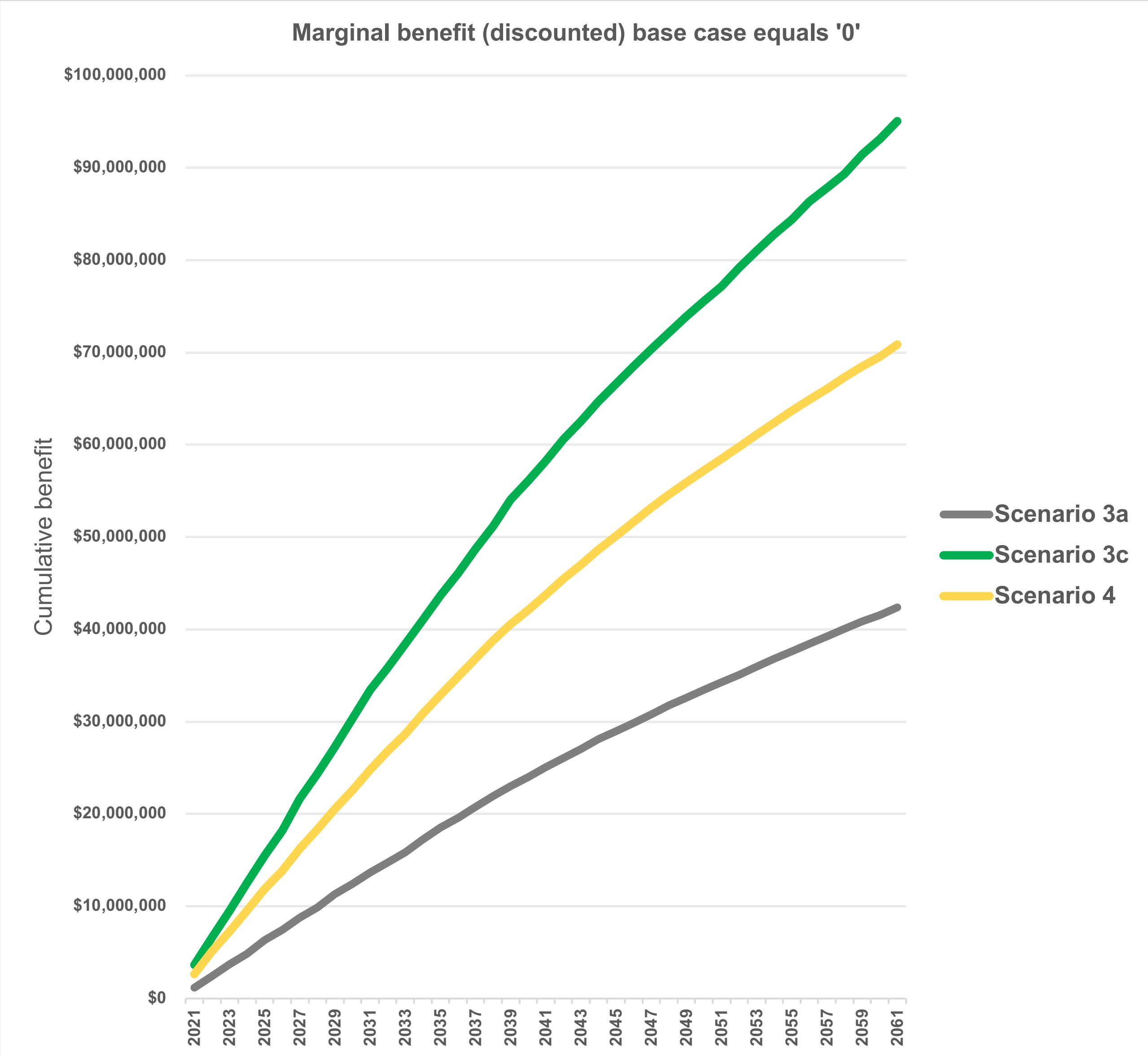


Figure 5-2: Time series – marginal cumulative NPV of river management scenarios relative to the base case

AVERAGE ANNUAL BENEFIT

The river currently provides an annual value of approximately $24.7 million to the Geelong community, assuming no impact from low water levels or algal blooms.

Applying the base case flow scenario *(post 1975 climate conditions)*, the annual average value is estimated to be $19.9 million (a benefit reduction of $4.8 million per year). With planned housing development and population growth, it is estimated that this value will increase to approximately $76.6 million annually over a 40-year period, assuming a continuation of the current climate and levels of consumptive demand.

The change in average annual benefit for each of the modelled water scenarios is provided in Table 5-10 below. The modelling shows that if the 3c water management scenario is adopted there would be an immediate $3.8 million increase in benefit relative to the base case (*post 1975 climate conditions*) to an annual average value of $23.7 million. The annual average value increases to a total of $86.3 million at the end of the 40-year period. This represents an annual benefit of $9.7 million per year relative to the base case. The results are shown below in Figure 5-3 as a time series of the average annual benefit of each scenario.[45]

Table 5-7: Results of the average annual benefits – 40-year time frame[46]

SCENARIO	ANNUAL VALUES (*BENEFIT*) 2021	ANNUAL VALUES (*BENEFIT*) 2041	ANNUAL VALUES (*BENEFIT*) 2061
Base case	$19.9 M	$50.7 M	$76.6 M
3a (*Annual benefit*)	$21.2 M (*$1.3 M*)	$53.1 M (*$2.4 M*)	$80.6 M (*$4.0 M*)
3c (*Annual benefit*)	**$23.7 M (*$3.8 M*)**	**$55.6 M (*$4.9 M*)**	**$86.3 M (*$9.7 M*)**
4 (*Annual benefit*)	$22.7 M (*$2.8 M*)	$54.4 M (*$3.7 M*)	$83.1 M (*$6.5 M*)

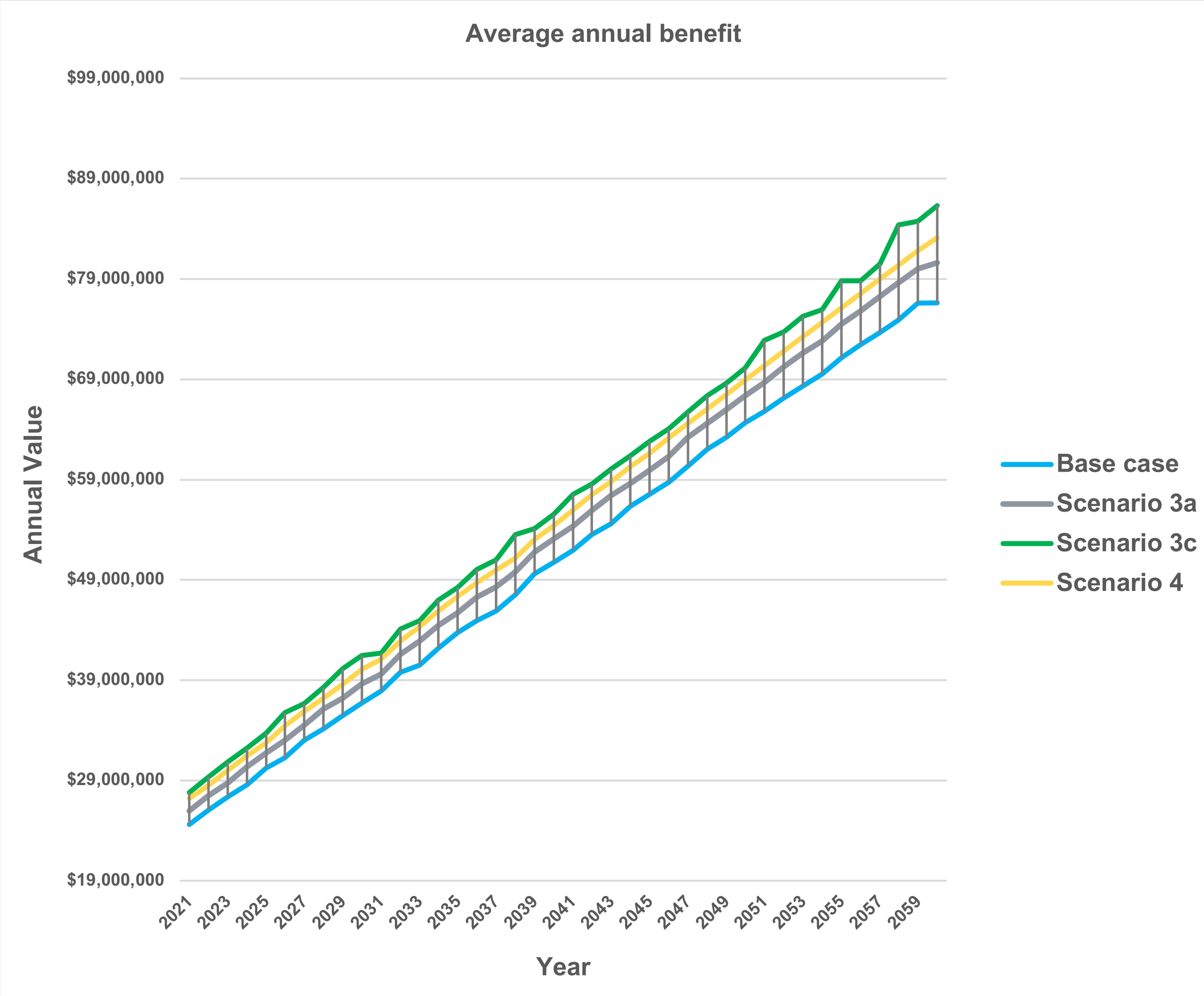


Figure 5-3: Average annual values of river management scenarios relative to the base case

**Please note that the average annual benefit the river provides for each of the water recovery scenarios (3a, 3c and 4) in 2041 and 2061 have been modelled relative to the base case climate scenario – and so assume a continuation of the current climate (post 1975 climate conditions) and levels of consumptive demand. These*

45 Note that these values are the unadjusted nominal values.

46 Results are rounded to the nearest hundred thousand

estimates therefore represent the likely average annual values, assuming no impact in future climate change and or consumptive demands.

Climate change and projected demand considerations

All the projections of future economic benefit from the water recovery scenarios analysed assume a continuation of current climate conditions and consumptive demand. However, climate change and increases in consumptive use from population growth are expected to impact river flows relative to those modelled in this study. A more accurate assessment of the future economic benefit of additional water recovery would therefore require further analysis of the impact on flows of future climate change and projected consumptive demand. These considerations are detailed further below.

The ‘base case post 75 climate’ modelling scenario represents current climate conditions. All the water recovery scenario modelling results were run with current climate conditions, which are directly comparable to results for the ‘base case post 75 climate’ modelling scenario.

As detailed in the water resource modelling (Section 3.4.3 and Appendix 2), the performance of the base case was also sensitivity tested under other climate cases. This included:

1. Step climate change case based on post 1997 climatic conditions
2. High climate change projection for 2065 assuming a high emissions scenario taken from the DELWP climate change guidelines (the magnitude of urban consumptive demands for Ballarat and Geelong were also updated to correspond to 2065 growth projections).

Whilst not subject of explicit economic modelling under this report – the higher climate change / demand projections would be expected to yield a slight improvement in annual net benefit relative to current climatic conditions. This is due to the benefit of the reduction in algal blooms being greater than the impact on water depth for these climate scenarios. As detailed in the water resource modelling (Appendix 2), both the post-1997 adjustment for climate change scenario and 2065 high climate change scenario reduces the algal blooms over the 90-year modelled period to 18 days/year compared to current climate average of 27 days/year. This is due to a drop in nutrient-laden catchment inflows, which offsets the effect of the flow reduction on algal blooms.

Further analysis (through additional water resource model runs) would be required for each of the water recovery scenarios relative to the ‘post 1997 climatic conditions’ and the ‘high climate change / demand projection for 2065’, in order to gauge a more accurate impact of each of the scenarios on flow, agal blooms and the marginal net economic benefit over time.

6 Summary of key findings

6.1 EFFECT OF CLIMATE AND WATER RECOVERY SCENARIOS

A series of three climate scenarios and nine water recovery scenarios (including the base case) were modelled to see which options produced the best outcomes (refer Table 6-1).

CLIMATE SCENARIOS

The ‘base case post 75 climate’ modelling scenario represents current climate conditions. The scenario ‘post-97 climate’ represents an alternate, more pessimistic representation of current climate where it is assumed that climate conditions that have occurred since 1997 will continue. The scenario ‘2065 high climate change’ shows results under a future (2065) climate assuming a high emissions scenario. Corresponding 2065 level of development demands are used for this modelling scenario.

Flow and algal bloom modelling showed that under current climate and levels of development algal blooms occur in Geelong for an average of 27 days per year, and critical rowing depths for regattas are expected to be met in around one third of years. Flow conditions worsen under demand growth and climate change, which impact the river’s overall amenity and its capacity to support river events, however, the effect of the flow reduction on algal blooms is offset by a drop in nutrient-laden catchment inflows.[47]

Table 6-1: Summary of modelling results

SCENARIO	AVG NO WEEKS PER YEAR < 140 ML/ WEEK	AVG NO DAYS PER YEAR ALGAL BLOOMS	% OF YEARS ABOVE CRITICAL DEPTH FOR ROWING	
			HEAD OF SCHOOLGIRLS REGATTA	BARWON REGATTA
Base case (current post 1975 climate)	12	27	29%	37%
Post 1997 climate case	17	18	21%	30%
Future 2065 high climate change case	23	18	9%	16%
1a: WWTP discharge reduced to 2 GL	17	6	15%	20%
1b: WWTP discharge zero	18	3	11%	16%
1c: WWTP discharge pattern changed	8	7	67%	81%
2a: Quarry discharge halved	12	33	27%	34%
2b: Quarry discharge zero	15	38	26%	27%
3a: Min water recovery target	11	12	34%	45%
3b: Higher water recovery target	11	12	35%	45%
3c: Enviro water recovery lower reaches	3	1	90%	88%
4: Water recovery optimised	8	6	64%	79%

47 Both the post-1997 adjustment for climate change scenario and 2065 high climate change scenario reduces the algal blooms over the 90-year modelled period to 18 days/year compared to current climate average of 27 days/year. This is due to a drop in nutrient-laden catchment inflows, which offsets the effect of the flow reduction on algal blooms.

WATER RECOVERY OPTIONS

The scenario modelling results presented in Table 6-1 were all run with current climate conditions, which are directly comparable to results for the 'base case post 75 climate' modelling scenario.

For Scenario 1 model runs, the Ballarat South WWTP was shown to deliver a significant volume of water that helps maintain river depths in Geelong, but also a significant nutrient load that can drive algal blooms. The frequency with which this nutrient load creates algal blooms can largely be negated by manipulating the pattern of WWTP discharge to maintain flows above 20 ML/day in Geelong.

For Scenario 2 model runs, Batesford quarry discharge only contributes a small volume of flow to the river but was shown to have an important dilution effect, reducing nutrient load and hence algal blooms.

Scenario 3 runs depend on recovering additional stored water for the environment in both the West Barwon and Lal Lal Reservoirs (refer below and Section 3.4.4 of this report for further details on each of these scenarios and their approximate water recover targets). Providing most required environmental flow components for the reaches immediately downstream of West Barwon and Lal Lal Reservoirs provides good local environmental benefit but, due to losses along the river, has limited impact on reducing algal blooms or maintaining critical flow depth in Geelong. Targeting environmental flow provision to low flow requirements in the lower reaches of the Barwon and Moorabool rivers instead provided the largest reduction in the incidence of algal blooms and the best maintenance of critical river depth in Geelong compared to the base case. Modelling also showed combined environmental flow provision and manipulation of WWTP discharge is also successful. While not analysed for this study, it is noted that recovery of additional stored water for the environment provides a wide range of additional environmental benefits throughout both basins, in addition to mitigating algal blooms and maintaining depth at Geelong.

On the basis of these results, it is recommended that quarry discharges be maintained into the future, and that options to deliver low flows and manipulate WWTP discharge patterns be explored further. The provision of low flow requirements requires extra water but provides a wide range of additional environmental and recreational benefits throughout the system. There would be benefit in exploring all these options further, including the combined manipulation of WWTP discharge patterns and the provision of low flow requirements via additional stored environmental entitlements to maximise benefits and minimise costs.

SCENARIOS SELECTED FOR ECONOMIC ANALYSIS

As agreed with the study's project steering committee, the base climate case and three of the nine modelled water recovery options (Scenario 3a, 3c and 4) were adopted for the economic benefits analysis:

- **Scenario 3a –** releasing water to the reaches immediately downstream of each storage (increased environmental entitlements in Lal Lal and West Barwon Reservoirs). This scenario (which approximates to the 3,380 ML/year water recovery target from Lal Lal Reservoir[48]) slightly reduces the number of weeks of low river flows at Geelong, can provide a more significant reduction in the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing. It also provides local ecological benefits in the reaches immediately downstream of the storages.
- **Scenario 3c –** releasing higher volumes of water (further increase in environmental entitlements in Lal Lal and West Barwon Reservoirs) over summer and winter to improve more constant flow through Geelong. This scenario, (which approximates to the 5,140 ML/year water recovery target from Lal Lal Reservoir and a 3,773 ML/year water recovery target from the West Barwon Reservoir[49]), significantly decreases the number of weeks of low flow at Geelong and the frequency of algal blooms. It also provides the best results

[48] Jacobs, 2015
[49] Alluvium, 2019

in terms of the ability to maintain critical rowing depth. It also provides ecological benefits throughout both basins in the reaches downstream of the storages all the way down to Geelong.

- **Scenario 4 –** environmental water recovery with optimised wastewater treatment releases. This scenario, which combines the manipulation of Ballarat South Wastewater Treatment Plant discharge with an increased environmental entitlement (which approximates to the higher 6,150 ML/year water recovery target from Lal Lal Reservoir[50]), also successfully reduced the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing.

6.2 SOCIAL AND ECONOMIC IMPACT

The economic value was established using an ecosystem system services approach. Values from existing literature and consultation were used to derive the annual direct and indirect benefits associated with the river system and surrounding area. The values included were:

- Events
- Recreation
- Increased housing prices
- Infrastructure.

On-river commercial activities such as commercial eel fishing, however, were not included in the study, and would require further analysis. The cultural and Aboriginal water values of the river to the Wadawurrung People were also not included in this study.

Once the annual value was established, the ability to access and participate in recreational and social events and an individual's willingness to pay for housing located within proximity to the river was linked to river depth, annual flow and blue-green algae events under a range of water recovery scenarios. Key findings include:

- The river currently provides an annual value of approximately $24.7 million to the Geelong community, assuming a continuation of the current climate and levels of consumptive demand. The benefits are largely driven by land use surrounding the river, for example, recreation, aesthetic and social events as well as the willingness for housing in a more natural riverine environment.
- When considering the predicted frequency of low river levels and algal events, the average annual value of the river is reduced to $19.9 million per year (a $4.8 million per year reduction). With planned housing development and population growth, it is estimated that this figure will increase to approximately $76.6 million annually over a 40-year period[51].
- When considering the optimal flow scenario 3c (which approximates to the 5,140 ML/year water recovery target from Lal Lal Reservoir and 3,773 ML/year water recovery target from West Barwon Reservoir) the current average annual value of the river is estimated to be increased to $23.7 million per year (a $3.8 million per year increase).
- With planned housing development and projected population growth this value increases to $86.3 million at the end of the 40-year period. This represents an annual benefit of $9.7 million per year relative to the base case, assuming the continuation of the current climate and consumptive demands.

These estimates (which are highlighted in Table 6.2 and Figure 6-1) demonstrate the importance of environmental water recovery and increased environmental entitlements for improving river flows and supporting the social and economic values of the Barwon and Moorabool Rivers through Geelong.

[50] Jacobs, 2015

[51] *These estimates for 2061 represent the likely maximum annual net benefits, assuming no impact in future climate change and or consumptive demands.*

Table 6-2: Results of the annual benefit – 40-year time frame[52]

SCENARIO	ANNUAL VALUES (*BENEFIT*) 2021	ANNUAL VALUES (*BENEFIT*) 2041	ANNUAL VALUES (*BENEFIT*) 2061
Base case	$19.9 M	$50.7 M	$76.6 M
3a (*Annual benefit*)	$21.2 M (*$1.3 M*)	$53.1 M (*$2.4 M*)	$80.6 M (*$4.0 M*)
3c (*Annual benefit*)	**$23.7 M (*$3.8 M*)**	**$55.6 M (*$4.9 M*)**	**$86.3 M (*$9.7 M*)**
4 (*Annual benefit*)	$22.7 M (*$2.8 M*)	$54.4 M (*$3.7 M*)	$83.1 M (*$6.5 M*)

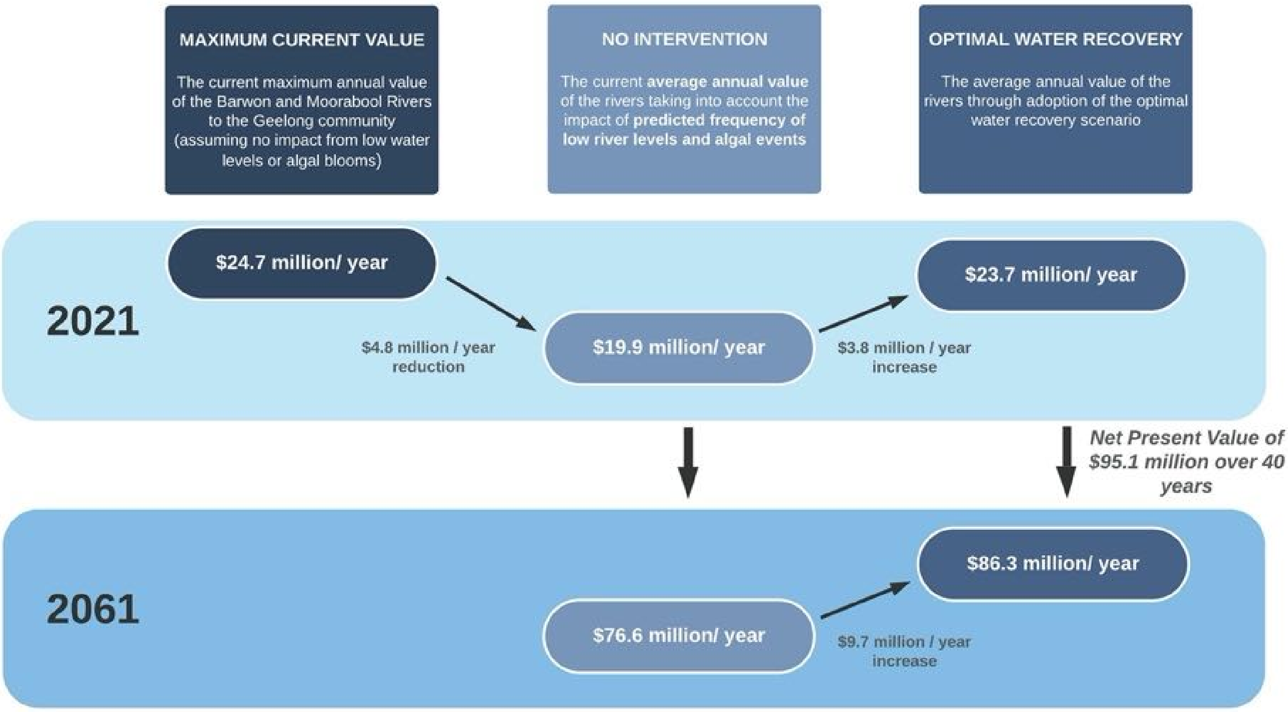


Figure 6-1: Summary of the annual average value of the Barwon and Moorabool Rivers to the community in response to low flows and optimal water recovery

[52] Results are rounded to the nearest hundred thousand

6.3 LIMITATIONS AND FURTHER INVESTIGATION

This study has shown the socio-economic benefits of increased water availability, which can be used as an input to guide future water recovery decisions for the Barwon and Moorabool Rivers, and subsequent studies into increased environmental entitlements. It is important to note, however, that the feasibility and costs associated with acquiring or recovering additional water has not been included in this study, and will be important factors in realising the socio-economic values estimated in this report.

The estimates of annual benefit the river provides for each of the water recovery scenarios (3a, 3c and 4) in 2041 and 2061 (Table 6-2) have been modelled relative to the base case climate scenario, and so assume a continuation of both current climate (post 1975 climate conditions) and levels of consumptive demand. A more accurate assessment of the future economic benefit of additional water recovery would therefore require further analysis of the impact on flows of future climate change and consumptive demand, for example, additional modelling of the water recovery scenarios relative to the post 1997 climatic conditions and/or the 2065 high climate change and demand projections.

As outlined in the project scope in Section 2.2, this study has not explicitly examined ecological flow requirements nor Aboriginal water values and associated flow requirements, both of which are also critical considerations of any future management of flows within this stretch of the Barwon and Moorabool Rivers.

As noted throughout this report, the water quality modelling undertaken is simplified and does not represent the decay of WWTP nutrient loads as they pass downstream or any sediment fluxes. It is recommended that more detailed water modelling be undertaken to take into account these effects. It was also noted that there was no useful data on stormwater discharges from the Geelong urban area into the lower Barwon River or estuary. Gauging and monitoring of stormwater discharges would assist to quantify the stormwater contribution to flows and loads now and in the future.

Water resource modelling was carried out on a weekly timestep and a daily pattern applied for the purposes of algal bloom modelling. DELWP is currently undertaking a project to create a daily timestep Source model of the Barwon-Moorabool system. Creation of this model will include a rederivation of reach inflows, lags and losses and the representation and prioritisation of environmental flow requirements by individual flow component. This will allow for the modelling of a more accurate daily time series at Geelong and hence more accurate algal bloom modelling. It will also allow for the targeting and reporting of the compliance of individual flow components in each reach. The Source model can also factor in future climate change and future estimates of consumptive demand. It is recommended that scenarios be re-run in the daily Source model once it is available to further explore the benefits of each of the water recovery scenarios.

References

Alluvium (2019). Upper Barwon, Yarrowee and Leigh rivers FLOWS study update. Report prepared by Alluvium Consulting Australia for Corangamite Catchment Management Authority, Colac.

Ashenfelter O. and Storchmann K. (2010). Using hedonic models on solar radiation and weather patterns to assess the economic effect of climate change: the case of Model Valley vineyards. World scientific.

Binney J., Buncle A., Dr Thomy B. and Tait J. (2018). Economic benefits of the Yarra River. Report to Melbourne Water April 2018.

City of Greater Geelong (2020). Northern and Western Geelong Growth Areas: Framework plan – August 2020.

Corangamite CMA (2007). Barwon (through Geelong) Management Plan: Final Report. Report prepared for Corangamite CMA by Thompson Berrill Landscape Design Pty Ltd in association with Ecology Partners P/L.

Corangamite CMA (2019). Barwon through Geelong CCMA Event Management Zones: Queens Park Bridge to Breakwater Road. Available at: https://ccma.vic.gov.au/what-we-do/barwon-through-geelong/.

DELWP (2018a). Barwon Strategic Directions Statement. Developed by the Barwon Integrated Water Management Forum.

DELWP (2018b). Blue-Green Algae Circular: Algal Management Framework. Available at: https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/blue-green-algae.

Dolichospermum in Naturalist [accessed 9 December 2020] https://www.inaturalist.org/guide_taxa/707293.

Freeman, K.S. (2010). Harmful algal blooms: musty warnings of toxicity. *Environ Health Perspectives.* 118(11): A473

HARC (2021). Analysis of the social and economic values dependent on a flowing Barwon River through Geelong and lower Moorabool River - Modelling summary report. Hydrology and Risk Consulting Pty Ltd, Blackburn, Victoria.

Hubbard R. et al. (2018). Microeconomics 4th edition. Pearson.

Jacobs (2015). Moorabool River FLOWS Study Update, Report prepared by Jacobs for Corangamite Catchment Management Authority, Colac.

Maritime Safety Victoria (2012). Barwon River (Between the Lower Breakwater and Orana Road) Waterway Rule Map. Available at: https://ccma.vic.gov.au/what-we-do/barwon-through-geelong/.

Mazzotta MJ, Besedin E, and Speers AE (2014). A meta-analysis of hedonic studies to assess the property value effects of low impact development. Resources, 3(1), 31-61.

National Health and Medical Research Council (NHMRC) (2008). Guidelines for Managing Risks in Recreational Water. Available at: https://www.nhmrc.gov.au/about-us/publications/guidelines-managing-risks-recreational-water.

Parks Victoria and DELWP (2015). Valuing Victoria's Parks: Accounting for ecosystem services and valuing their benefits, Parks Victoria and the Department of Environment, Land Water and Planning

Polyakov M, Fogarty J, Zhang F, Pandit R, Pannell DJ (2017). The value of restoring urban drains to living streams. Water Resources and Economics, 17, 42-55.

Reynolds C.S. & Maberly S.C. (2002). A simple method for approximating the supportive capacities and metabolic constraints in lakes and reservoirs. Freshwater Biology 47: 1183–1188.

RMCG (2019). Our living river of the Barwon: A discussion paper for the future. Report prepared for Barwon Ministerial Advisory Committee (MAC).

RMCG (2020). Analysis of the social and economic values dependent on a flowing Barwon River through Geelong and lower Moorabool River - Scoping Paper. RM Consulting Group Pty Ltd. Torquay, Victoria.

SKM (2004). Moorabool River Water Resource Assessment. Report prepared for Corangamite CMA October 2004.

Thomy B, Morrison M, Duncan R, Bark RH, Boyle KJ, Parton KA, Birtles P (2016). Estimating the amenity value of urban stream improvements for local residents: A hedonic approach investigation. Charles Sturt University.

Wilson, M. Hoehn J. (2006). Valuing environmental goods and services using benefit transfer: The state-of the-art and science. Ecological economics.

https://www.atap.gov.au/mode-specific-guidance/active-travel/5-estimation-of-benefits - Accessed 15th October 2021

https://corporatefinanceinstitute.com/resources/knowledge/valuation/hedonic-pricing/ - accessed 15th October 2021

https://www.geelongaustralia.com.au – accessed 2020.

Appendix 1: Environmental watering priorities

Table A1-1: Priorities used at Lal Lal for recent SWS modelling (WaterRes, 2020)

DOWNSTREAM OF LAL LAL	
Drought flows	If the environmental share of storage is less than 1000 ML at the start of the water year the only releases to be made in that water year are to maintain up to 5 ML/day downstream of Lal Lal to allow carryover for the following year.
Low flows	If the drought trigger is not in place, the provision of Summer low flows (December – May) and Winter low flows (June – November) is made. If a water year is classified as dry*, this release increases the total release from Lal Lal to 5 ML/day, if the water year is classified as average or wet, the total release is increased to 10 ML/day.
Freshes	The available resource^ is then assessed to determine which if any of the fresh events can be delivered. The priorities for delivery of the events in order of time of delivery in each water year are based on defined event reserve volumes being met on a given week for event delivery as follows: ▪ July Freshes delivery (2nd priority, deliver in week 31) ▪ Sep-Nov (October) Fresh delivery (1st priority, deliver in week 44) ▪ Sep-Nov (November) Fresh 2nd event delivery (5th priority, deliver in week 48) ▪ Jan/Feb freshes delivery (4th priority, deliver in week 9) ▪ Feb/Mar Little Summer Fresh delivery (6th priority, deliver in week 13) ▪ April/May Freshes delivery (3rd priority, deliver in week 22).

*Water year classification - each water year as dry, average or wet based on the annual flow being less than 33 percentile flow (dry), between 33 and 67 percentile (average) and above 67 percentile (wet). This is similar to the classification used in the FLOWS study (Jacobs, 2015) which was based on rainfall and divided years up into the three categories each with an equal number of years. Streamflow, rather than rainfall was used because the streamflow has been transformed to current climate.

^ Available resource - defined as the minimum of

- environmental storage minus a drought reserve of 1000 ML and
- three year use limit of 7,500 ML

zero resource is available for freshes if the drought trigger is in place.

The basis for the prioritisation for the SWS modelling (WaterRes, 2020) was to forecast the water required for the remainder of the water year for each priority. If there is sufficient water in storage to supply the first priority, then the second priority is supplied up to the maximum value. If there is sufficient water available to fully supply priority two, then water is available for priority three. It was noted that the sum of potential watering of priority 1, 2 and 3 far exceeds the average available environmental water.

Table A1-2: Priorities used at West Barwon for recent SWS modelling (WaterRes, 2020)

DOWNSTREAM OF WEST BARWON DAM	
Priority 1	Maintain Upper Barwon east branch low flows of 0.5-5 ML/day between December to May. It has been assumed that this watering actions will supplement the existing passing flow on the Upper Barwon east branch up to a maximum of 5 ML/day.
Priority 2	Release 2 x 9 - 35ML/day freshes in the Upper Barwon east branch over two days between December and May. It is assumed that the target flow release rate for this event is only 9 ML/day due to downstream capacity constraints.
Priority 3	When water is available: ▪ Maintain Upper Barwon west branch low flows of up to 30 ML/day between December and May. The rule for delivery of priority 3 is to estimate water availability for the remainder of the water year and supply that available daily flow rate between December and May inclusive to the Upper Barwon west branch up to a maximum of 30 ML/day to supplement the passing flow of 4 ML/day (5 ML/day in December if storage volume in West Barwon and Wurdee Boluc reservoirs is greater than 40,000ML).

Appendix 2: Water modelling report

HARC

Analysis of the social and economic values dependent on a flowing Barwon River through Geelong and lower Moorabool River

Modelling summary report

Final 3.1

6 June 2021

Document status

Client	Corangamite CMA
Project	Analysis of the social and economic values dependent on a flowing Barwon River through Geelong and lower Moorabool River
Report title	Modelling summary report
Version	Final 3.1
Authors	Kate Austin, Phillip Jordan, Bonnie Bonneville, Katherine Szabo
Project manager	Kate Austin
File name	COR00003_HARC modelling report_f3.docx
Project number	COR00003

Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	24/12/20	P Jordan	P Jordan	Sharon Blum-Caon (CCMA) Phil Mitchell (DELWP)	Includes results only for the base case and first six scenarios (1a, 1b, 1c, 2a, 2b and 3a)
Final 1	11/03/21	K Austin	P Jordan	Andrew Harrison (CCMA) Jayden Woolley (CCMA) Phil Mitchell (DELWP) Trent Wallis (RMCG)	Includes updated results for scenario 3a and results for Scenario 3b and Scenario 4, climate change and water level results
Final 2	09/04/21	K Austin, B.Bonneville	P Jordan	Andrew Harrison (CCMA) Jayden Woolley (CCMA) Phil Mitchell (DELWP) Trent Wallis (RMCG)	Addressing comments on Final 1 version
Final 3	28/05/21	P Jordan	P Jordan	Trent Wallis (RMCG)	Including additional scenario 3 run
Final 3.1	6/06/21	Trent Wallis (RMCG)		Andrew Harrison (CCMA) Jayden Woolley (CCMA) Phil Mitchell (DELWP)	Including additional BGA events table and
Final 3.2	18/06/21	K Austin T Wallis (RMCG)		Andrew Harrison (CCMA)	Additional DELWP edits and map corrections
Final 3.3	18/11/21	K Austin		Andrew Harrison (CCMA)	Report corrections

Contents

1. Overview

The Corangamite Catchment Management Authority (CCMA) has commissioned an independent study by RMCG in partnership with HARC to understand the full suite of economic and social benefits derived from a flowing Barwon River through Geelong and lower Moorabool River, and the risks posed by climate change to river flows and the identified values. This will be used to support informed decision making through the upcoming Central and Gippsland Region Sustainable Water Strategy (SWS) process, with the aim of working towards an allocation of water that will maintain the economic and social values of the rivers identified in the study.

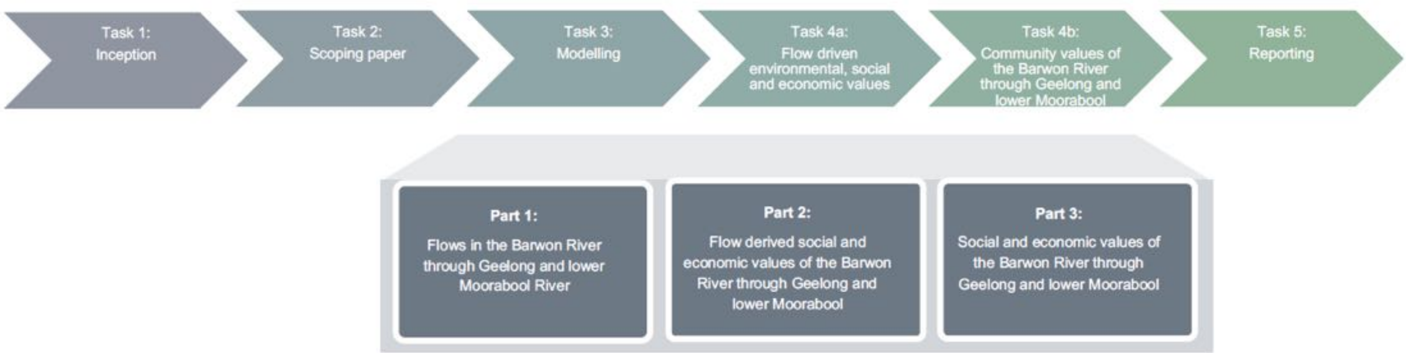


Figure 1-1: Task diagram

The overall project is being delivered across five tasks as outlined in Figure 1-1 above. This modelling summary report documents the outcome of Task 3, which seeks to outline the approach taken to and results of water resource and algal bloom modelling.

2. Terminology and concepts

Key terminology and concepts are defined below (and are referred to throughout the text):

Base case model

- The base case model to represent current system operations over a long-term climatic sequence.

Climate cases

- Model inputs based on long term historical climate are referred to as the **historical climate case**
- Historical climate is adjusted to represent current climate conditions, referred to as the **baseline climate** case. To do this historical data prior to 1975 is adjusted to have the same characteristics as data post 1975 in accordance with the DELWP Climate Change Guidelines (DELWP, 2016).
- Climate adjusted to post 1997 conditions is referred to at the **step climate change** case
- Baseline climate is adjusted using factors from global climate models to create the future **2040 and 2065 climate** cases.

Levels of development

- Most model runs have been undertaken with demands at “current” levels of development, factored to match usage in recent years. These represent the demands that would have been experienced with current levels of population, crop areas and crop types and current infrastructure generated over a long-term climate sequence.
- One run was undertaken at future (2065) levels of development with demands adjusted for expected population growth and projected climate change by 2065.

Yield

- The yield of a given system is the average annual demand that can be supplied at the desired level of service (usually frequency of restrictions). Current levels of development demands are often factored up to determine system yield.

3. Water resources modelling

A base case water resources model was created and run under current (baseline) climate conditions and climate change, then a range of water recover scenarios were run under current climate and the results compared. Runs are summarised in Table 3-1.

Table 3-1: Summary of scenarios modelled

Run No	1	2	3	4	5	6	7	8	9	10	11	12
Baseline (post 75) climate case	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Post 97 climate case		✓										
High 2065 climate case			✓									
Current level of development	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
2065 level of development			✓									
Base case	✓	✓	✓									
Scn 1a: Ballarat South Wastewater Treatment Plant (WWTP) discharge reduced to 2 GL (As per SWS commitment)				✓								
Scn 1b: Ballarat South WWTP discharge turned off (Scn 1 worst case)					✓							
Scn 1c: Ballarat South WWTP discharge pattern manipulated (Scn 1 best case)						✓						
Scn 2a: Batesford quarry discharge reduced by 50% (Test impact of no winter discharge)							✓					
Scn 2b: Batesford quarry discharge turned off (Scn 2 worst case)								✓				
Scn 3a: Minimum environmental water recovery target (refer Section 3.3.3): Approximates to 3,380ML/yr (including current EE[1]) in Lal Lal									✓			
Scn 3b: Higher water recovery target (refer Section 3.3.3): Approximates to 6,150ML/yr in Lal Lal (including current EE)										✓		
Scn 3c: environmental water recovery for lower reaches (refer Section 3.3.3): Approximates to 5,140ML/yr (including current EE) in Lal Lal and 3,773ML/yr in West Barwon (including current EE)											✓	
Scn 4 (1c+3b): Ballarat South WWTP discharge pattern manipulated and Higher water recovery target (Combined best case)												✓

[1] EE = Environmental Entitlement

3.1 Model changes to create a base case model

DELWP provided a copy of the most up to date Barwon-Moorabool Resource Allocation (REALM) model (bm_curr_12.sys) recently used for the Central Region Sustainable Water Strategy (SWS) modelling (WaterRes, 2020). The following changes were made to the model to create a base case suitable for use for this project:

- Explicit representation of Batesford quarry discharge to lower Moorabool River
- Reducing demands and discharges from yield to current levels of development
- Recalibration of model losses to better represent low flows at Geelong.

Batesford Quarry discharge was assumed to be 3,500 ML/yr spread evenly throughout the year, which was based upon gauged discharges over recent years.

3.1.1 Urban demands and discharges at current level of development

The urban demands and Ballarat South Wastewater Treatment Plant (WWTP) discharge inputs to the model are currently set at yield for SWS modelling purposes. These were factored down to create current levels of development demands and discharges.

Table 3-2: Factors to create current level of development demands and discharges

Input	In SWS model	Current	Factor	Comment
Ballarat South WWTP discharge	11.2 GL	7.8 GL	0.70	Current discharge level based on recent recorded data
Geelong demand	40.4 GL	33.8 GL	0.84	Current urban demand based on Geelong Source model^
Ballarat demand	20.9 GL	12.0 GL	0.57	Current urban demand based on average of last 5 years as reported in Central Highlands Water 2019/20 Annual Report

^ most up to date version provided by Barwon Water in November 2020 (Geelong Colac - Mar 2020.rsproj)

3.1.2 Recalibration of Barwon and Moorabool River losses

When the SWS version of the REALM model provided by DELWP was run, it was found that the model performed poorly at reproducing historic flows in Barwon River at Geelong (233217). River losses in the model (losses to groundwater) were last calibrated in 2006. The plot of flows at Pollocksford on a log scale shows how loss characteristics have changed since the Millennium Drought, as shown in Figure 3- and Figure 3-.

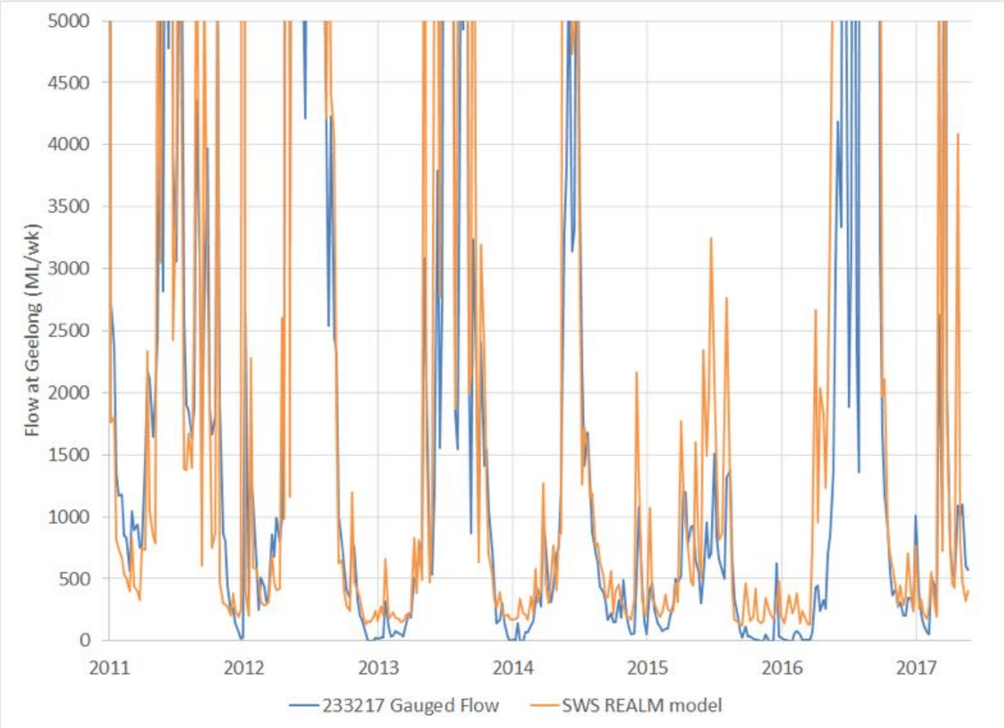


Figure 3-1: SWS model fit at Geelong (233217)

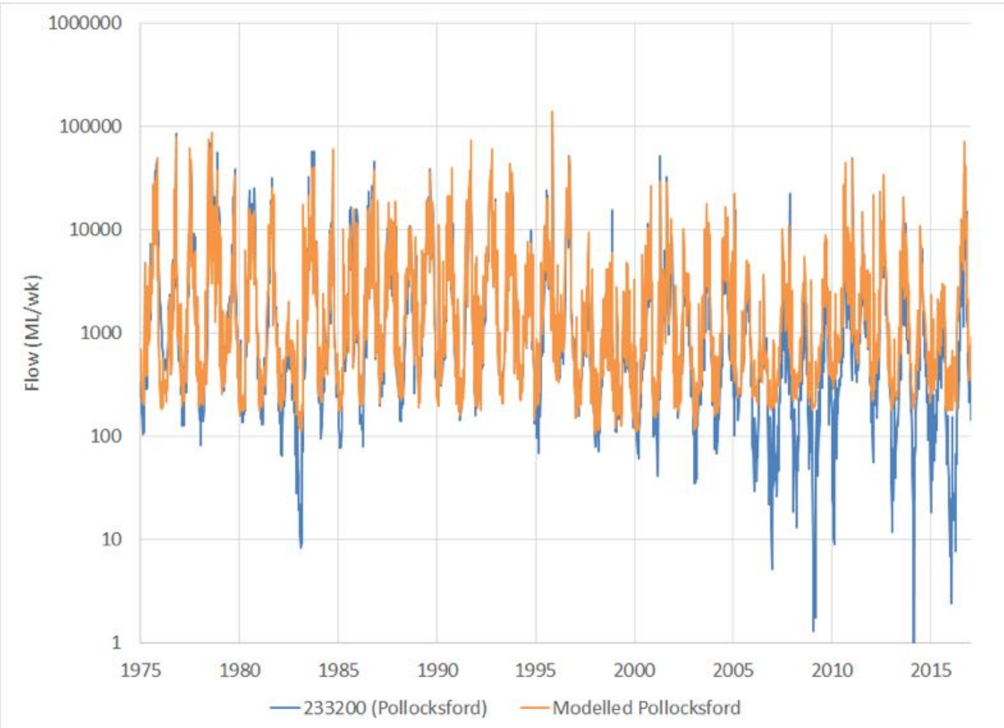


Figure 3-2: SWS model fit at Pollocksford (233200)

Losses are represented in the model:

- in the Barwon River upstream of Conns Lane (233224),
- between Conns Lane and Inverleigh (233218),
- between Inverleigh and Pollocksford (233200), and
- between the Moorabool River at Batesford (232202) and the Barwon River at Geelong.

Historic inflows were forced in the model at Batesford and at Conns Lane, and loss and gain functions adjusted to get a better match to gauged flows at Inverleigh, Pollocksford and Geelong. The improvement in the fit to the low flow periods from adjustment to the losses are shown in Figure 3-, Figure 3- and Figure 3-.

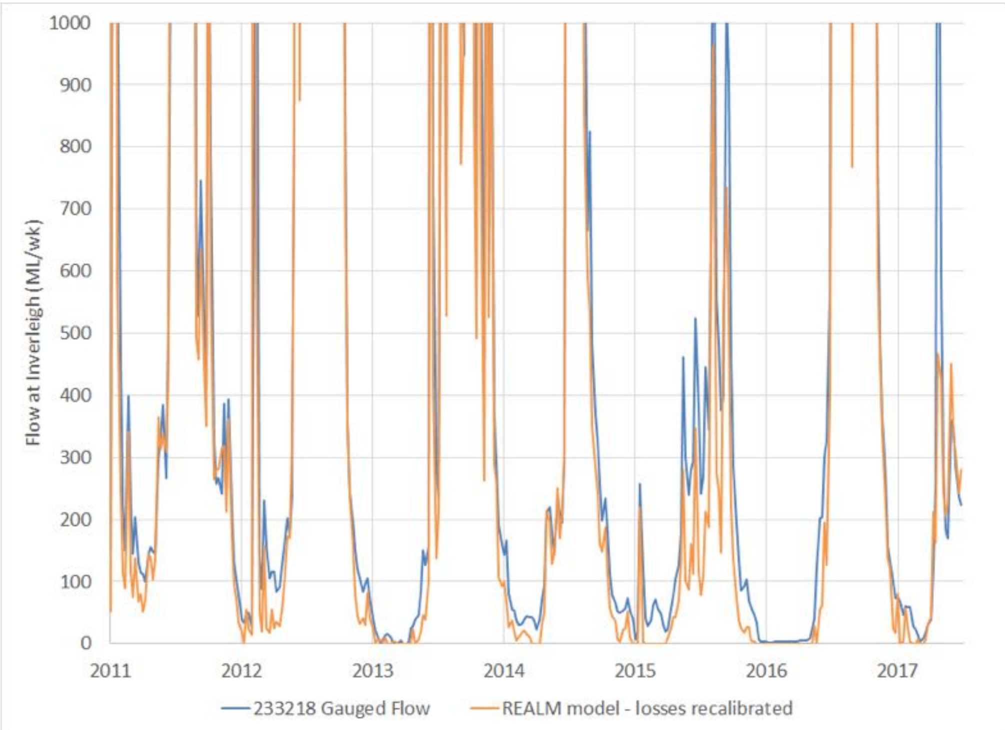


Figure 3-3: Model fit at Inverleigh (233218) with losses recalibrated

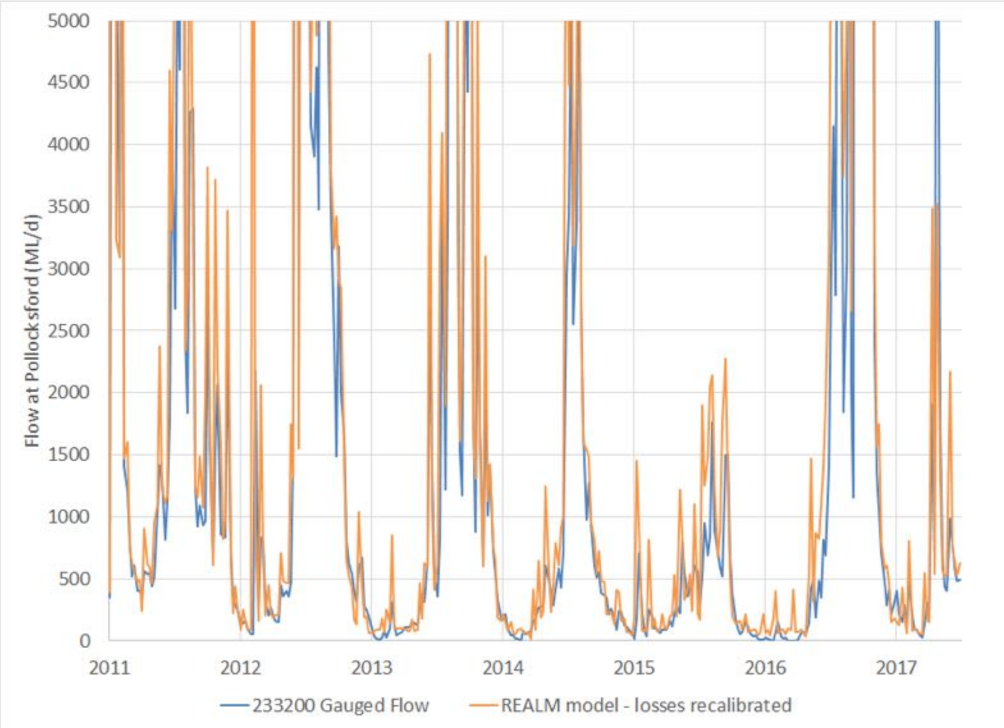


Figure 3-4: Model fit at Pollocksford (233200) with losses recalibrated

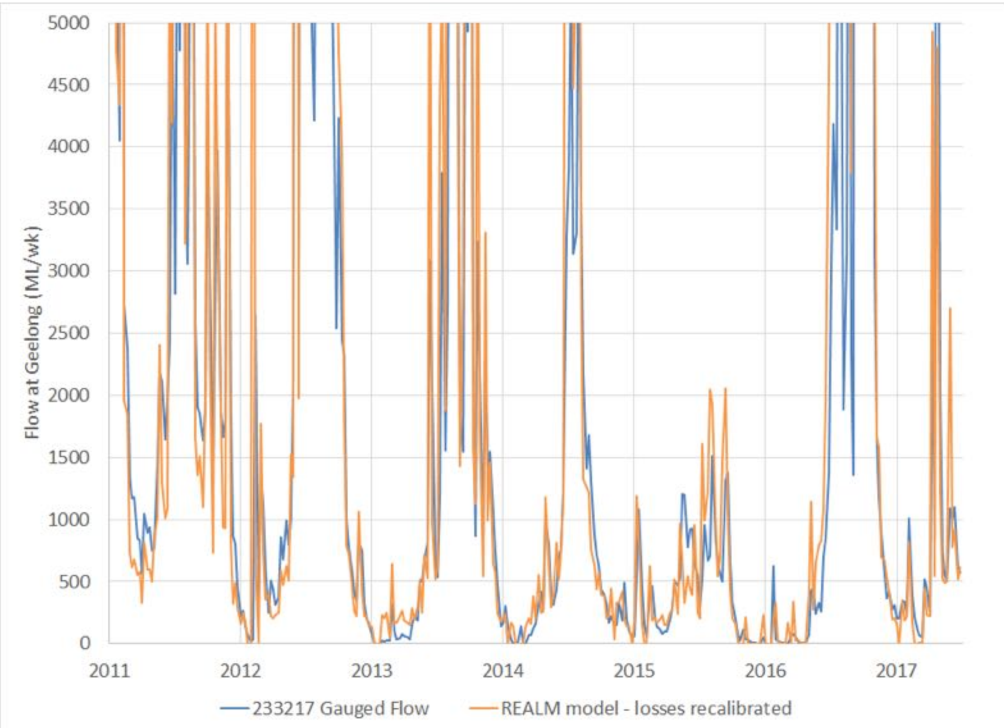


Figure 3-5: Model fit at Geelong (233217) with losses recalibrated

Following this re-fit of losses with historic upstream flows forced, the model was run again with forcing removed. This tested how model behaviour, including releases from storage, impact results at Geelong.

Plots of flow showed that modelled flows at Batesford are lower than historic flows, while modelled flows in the Barwon River, at and downstream of Conns Lane, are higher than historic, which in turn impacts flows at Geelong. Modelled releases from West Barwon Dam generally show a good fit to historic data, as shown in Figure 3-, however it can be seen that passing flow requirements are sometimes not maintained. This level of accuracy was felt to be sufficient for the purposes of this project.

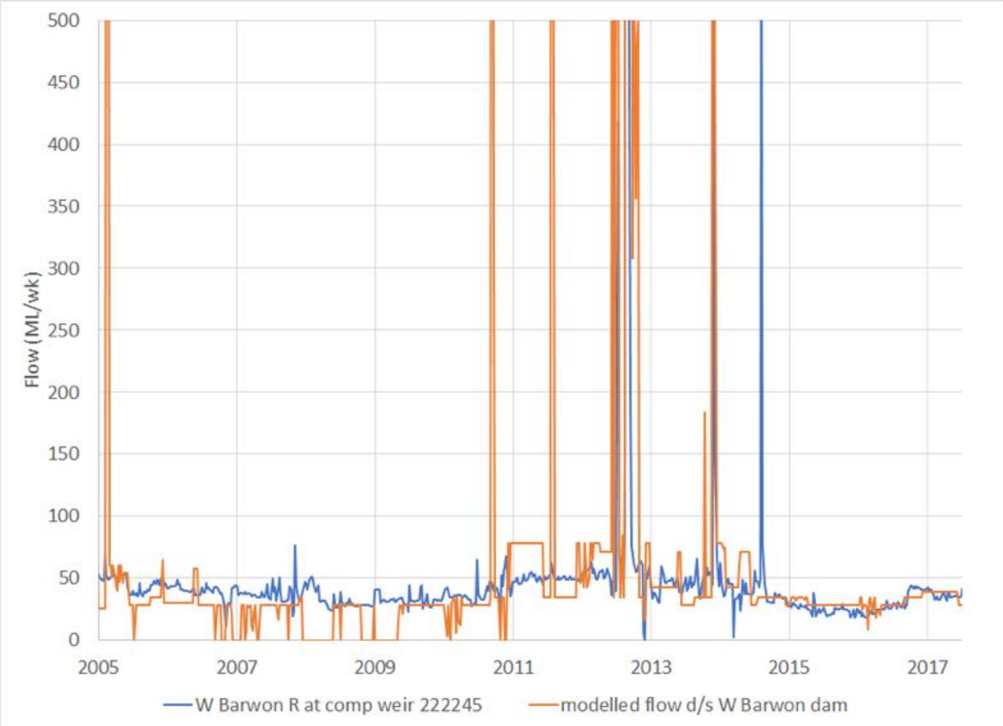


Figure 3-6: Model fit downstream West Barwon Dam

Based on the above analysis, it was concluded that the losses upstream of Conns Lane needed adjustment. The updated fit and its impact on flows downstream is shown in the following plots. The model fit was concentrated on the period post Millennium Drought, in an attempt to capture the changed loss response in the catchment. The comparison between gauged flows and flows from the REALM model at Conns Lane, Inverleigh, Pollocksford and Geelong are shown in Figure 3- to Figure 3-.

This base case with recalibrated losses gives a much-improved fit with historic flows at Geelong (233217) as can be seen in comparing Figure 2-10 with Figure 2-1 and was adopted for scenario modelling.

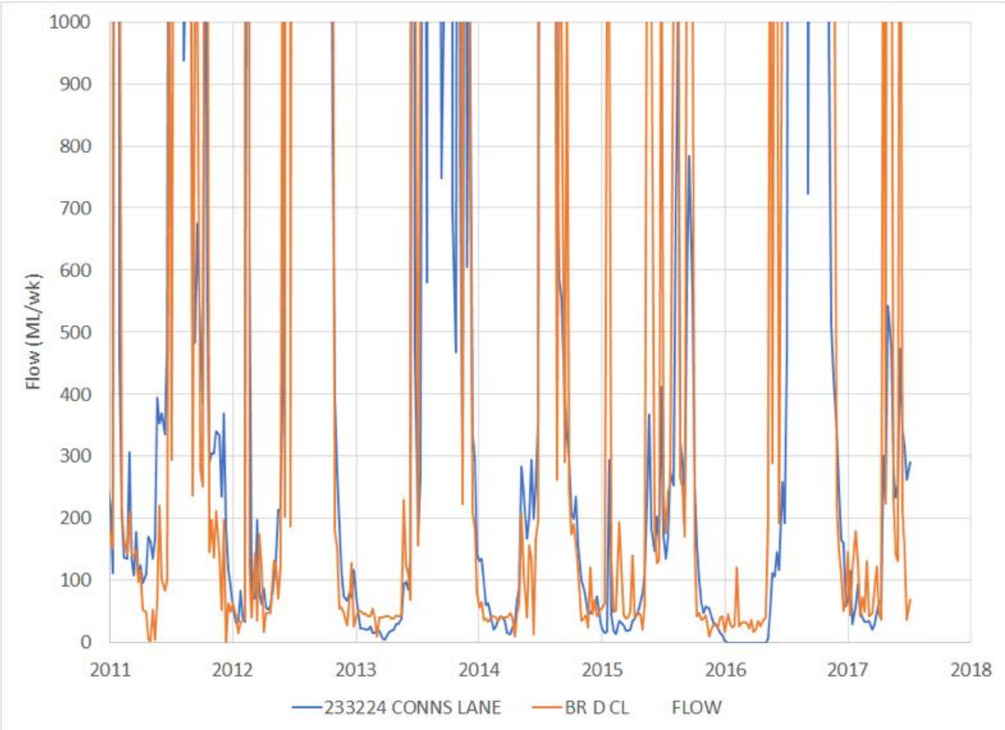


Figure 3-7: Model fit at Conns Lane (233224) with losses recalibrated - unforced

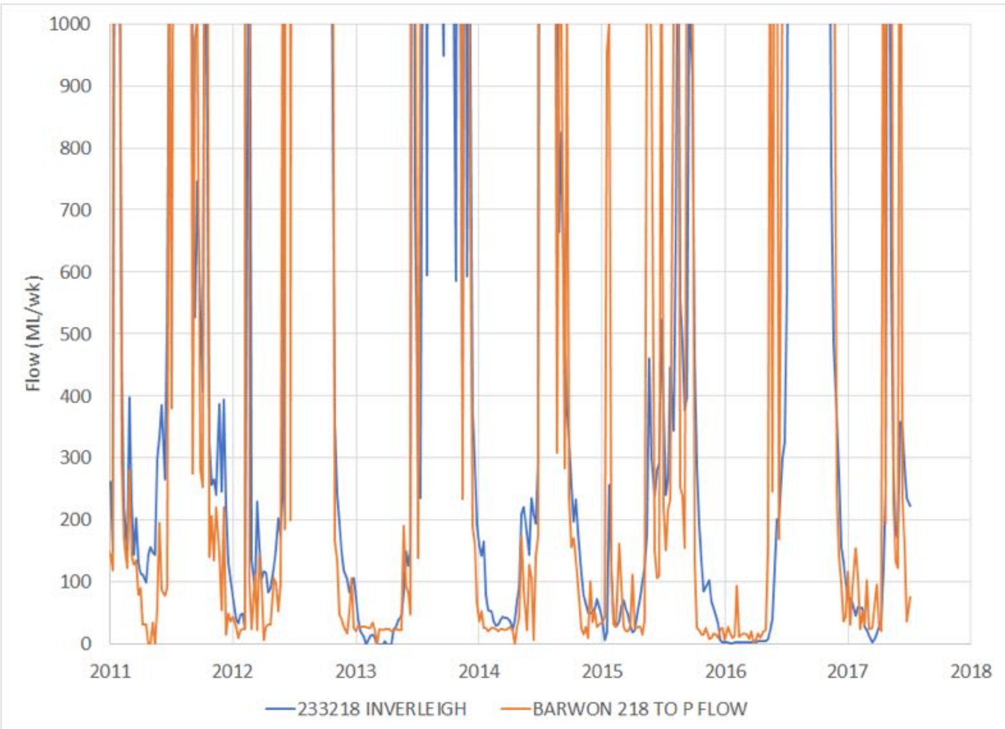


Figure 3-8: Model fit at Inverleigh (233218) with losses recalibrated – unforced

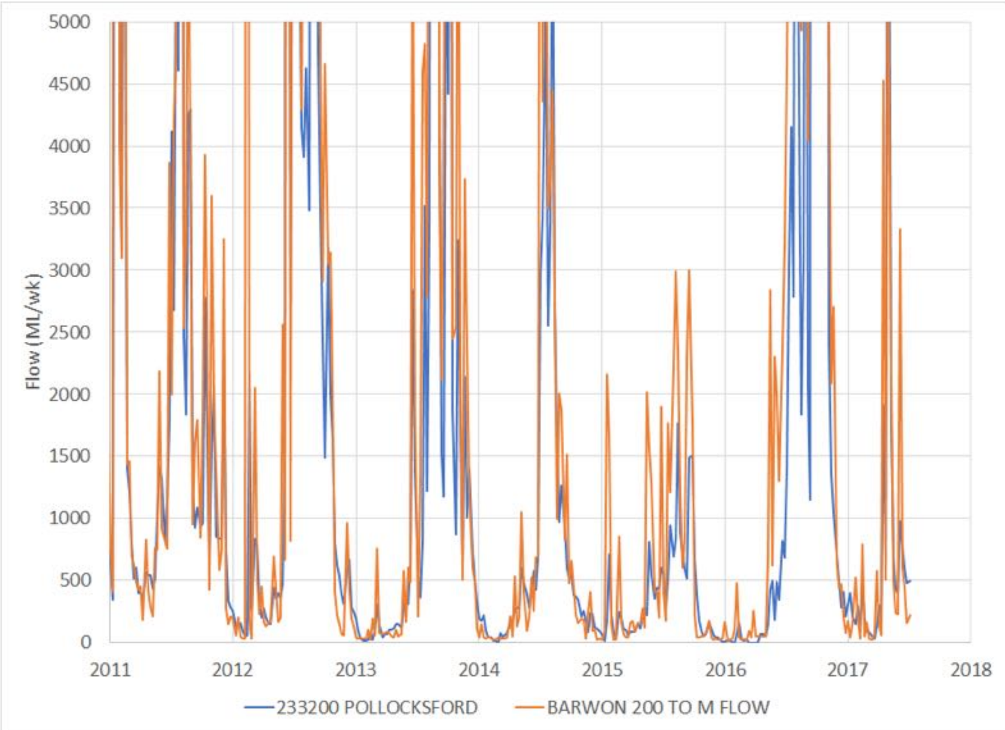


Figure 3-9: Model fit at Pollocksford (233200) with losses recalibrated - unforced

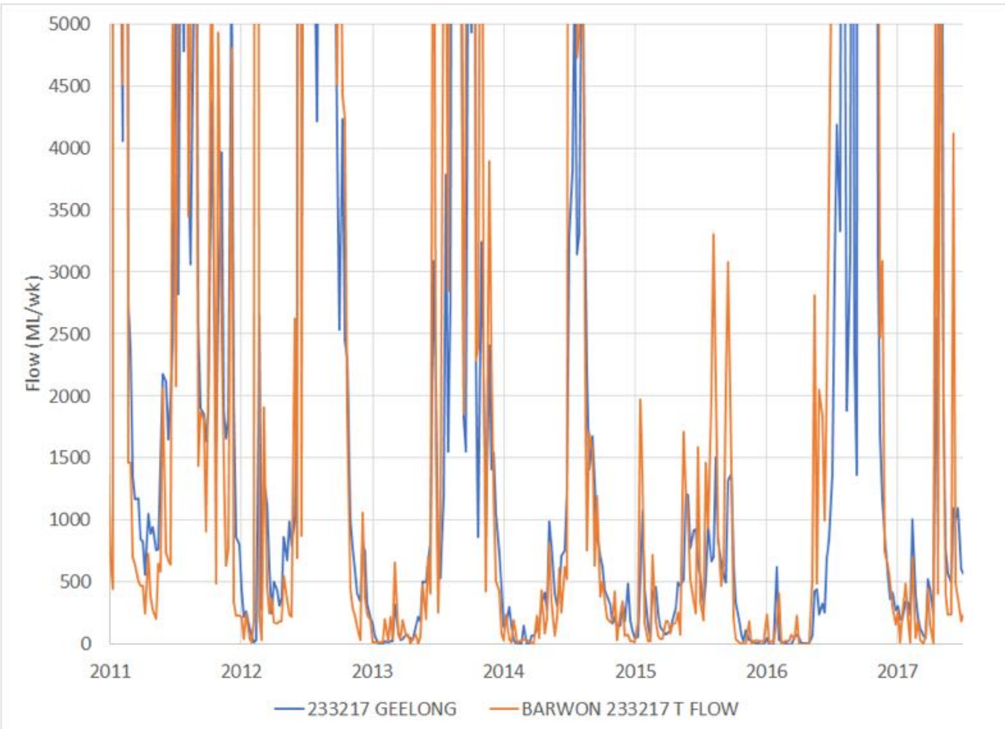


Figure 3-10: Model fit at Geelong (233217) with losses recalibrated – unforced

3.1.3 Climate inputs: historic climate and projected climate change

Models are run over a long-term climate sequence to see how the system performs over a range of climate conditions and extended drought periods. Use of a long climate sequence also enables risk-based results to be reported, for example the probability of an algal bloom occurring in any given year.

The DELWP climate change guidelines provide advice on deriving a “baseline” climate sequence that represents the current climate change signature. To create this series historic inflows and climate inputs prior to 1975 are adjusted via annual decile scaling so that they have the same statistical characteristics as inflows and climate post-1975, the period felt to be representative of current climate.

Baseline climate was used for all base case and scenario modelling. The climate resilience of the base case and selected water scenarios have been tested under other climate cases. The step climate change case is based on post-1997 climatic conditions derived via annual decile scaling, while the high climate change projection for 2065 is based on projections of global climate models, taken from the DELWP climate change guidelines.

It is recognised that the DELWP climate change guidelines have recently been updated, however the climate change inputs used for this project are based on the 2016 DELWP climate change guidelines to be consistent with those applied for the Long-Term Water Resource Assessment (LTWRA) and recent SWS modelling. It is noted that flows under the current climate case would be lower if the 2020 guidelines were applied as they take into account the shift in climate from the post 1975 baseline to 2020. The guidelines indicate a 3-4% reduction in runoff in the Barwon and Moorabool catchments by 2020 using the medium climate change projection.

3.1.4 Updating demands to 2065 level of development

When running the model under 2065 climate conditions, the magnitude of the urban demands for Ballarat and Geelong were updated to correspond to 2065 growth projections. The Central Highlands Water (CHW) 2017 Urban Water Strategy predicted Ballarat demand in 2065 of around 23 GL, as shown in Figure 3-. The Barwon Water 2017 Urban Water Strategy predicted Geelong demand in 2065 of around 53 GL, as shown in Figure 3-.

Figure 29 Future water supply-demand balance for the Ballarat system

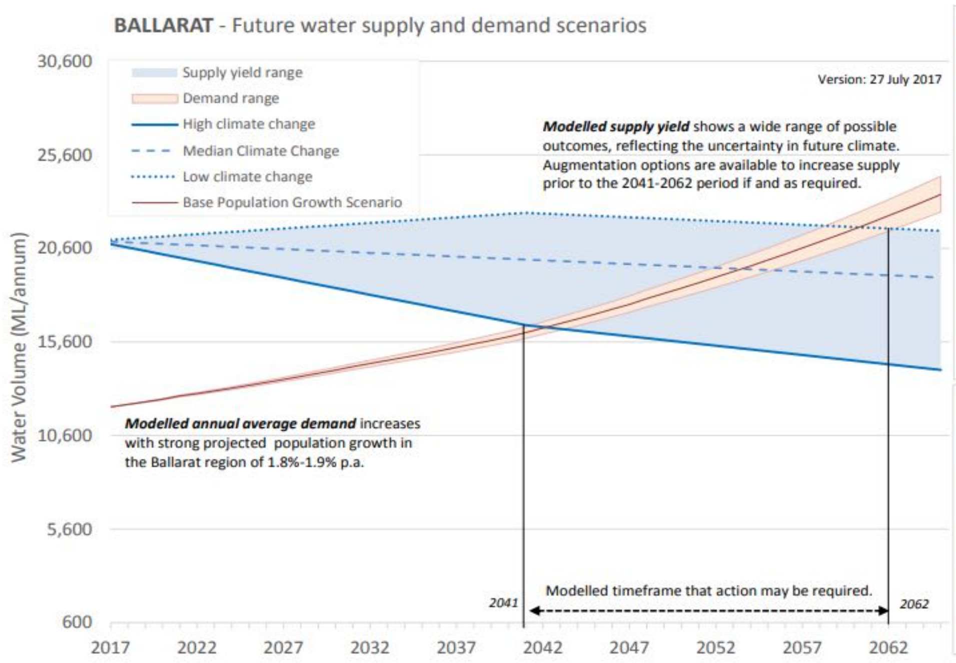


Figure 3-11: Supply-demand curve for Ballarat (from Central Highlands Water, 2017)

Figure 19: Forecast balance between water supply and demand for the Greater Geelong system

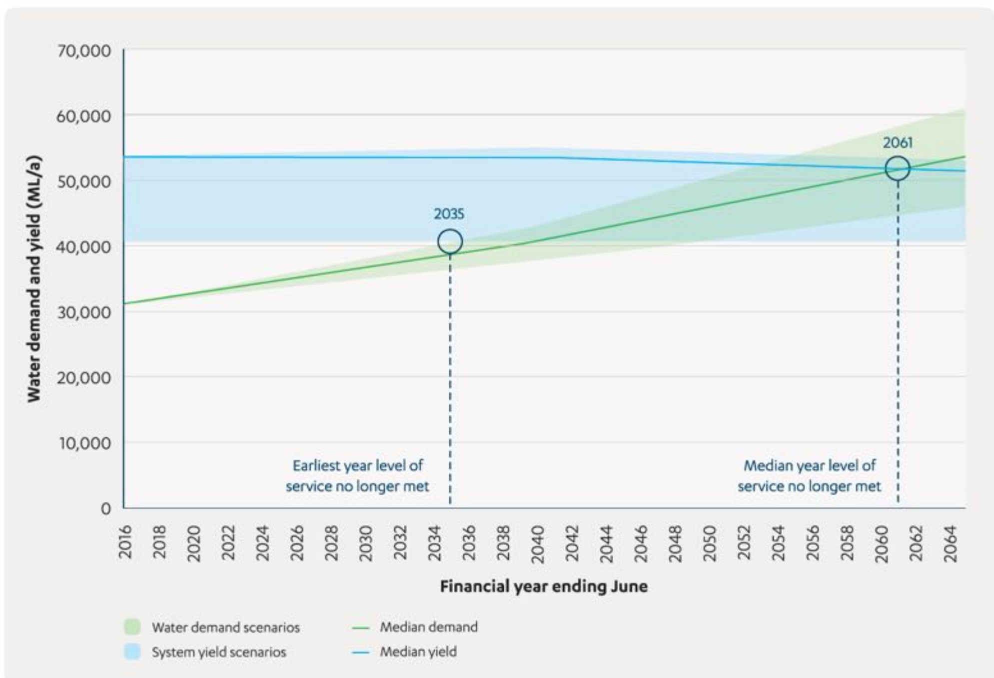


Figure 3-12: Supply-demand curve for Geelong (from Barwon Water, 2017)

3.1.5 Model correction following initial model runs

In the process of undertaking model runs for Scenario 3b for input to the draft report an error was discovered in the specification of the West Barwon Dam release to satisfy the Priority 3 flow (upper Barwon River West branch low flows between December and May).

A check was undertaken of the base case run and it was found that the corrected model version made only a small difference to results, so these were not updated in this report. The model correction does however make a significant difference to Scenario 3a results, so these were updated for the current study.

3.2 Base case modelling results

3.2.1 Current climate

The base case model was run with post 1975 climate conditions, using adjusted climate data for the period from 1927 to 2017. Flows were extracted at key locations to enable the derivation of daily inputs to the algal bloom model (refer Section 5).

As noted in the project's Scoping Paper (RMCG, 2020), investigations showed that flows in Geelong less than 20 ML/d are favourable for algal growth. Analysis showed that flows are below 140 ML/wk (i.e. 20 ML/d) on average 12 weeks per year, with the worst case being 28 weeks.

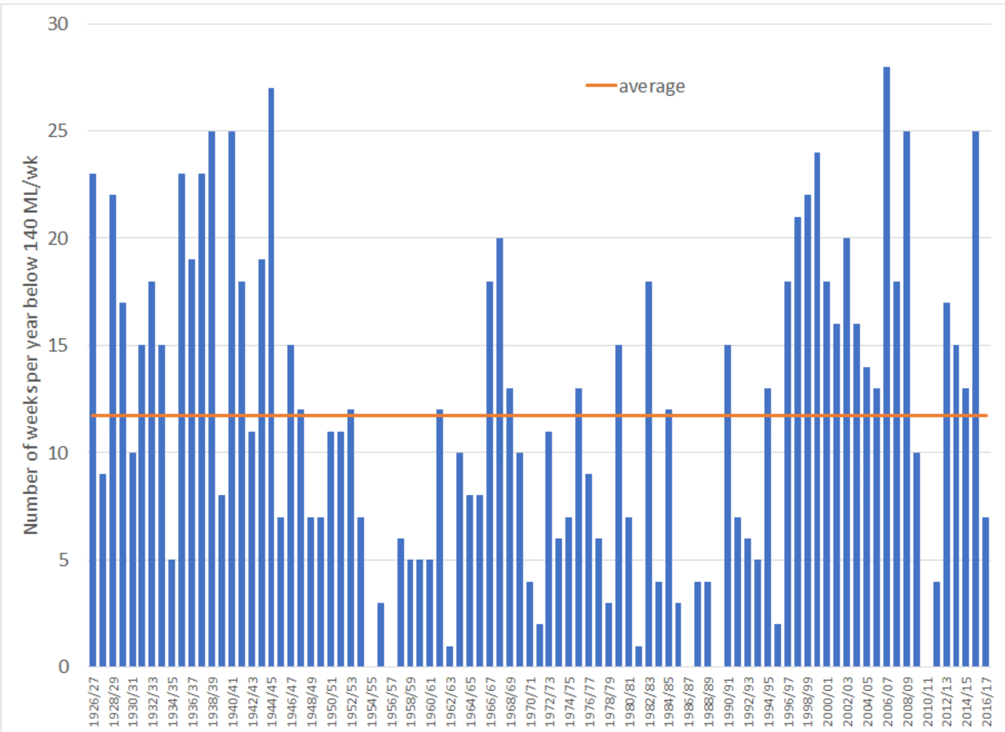


Figure 3-13: Base case post 75 climate – number of weeks per year below 140 ML per week

3.2.2 Climate change

The base case model was also run for two climate change scenarios: pre-1997 adjusted step climate change and 2065 High climate change scenario. The inflow and demand inputs for these climate change scenarios first developed for the LTWRA were adopted.

New climate impacted demands and WWTP discharges were derived. Demands were updated as discussed in Section 3.1.4, and WWTP discharges were calculated by running climate change impacted climate through the WWTP discharge wet weather component rainfall runoff model developed by Jacobs (2020) and adjusting the WWTP discharge dry weather component for population in 2065.

Results showed that under post 1997 and 2065 climate conditions the average number of weeks where flows are less than 140 ML/wk (20ML/d) increased from 11.7 weeks (post 75 case) to 16.8 weeks (post 97 case) and 22.8 weeks (2065 case).

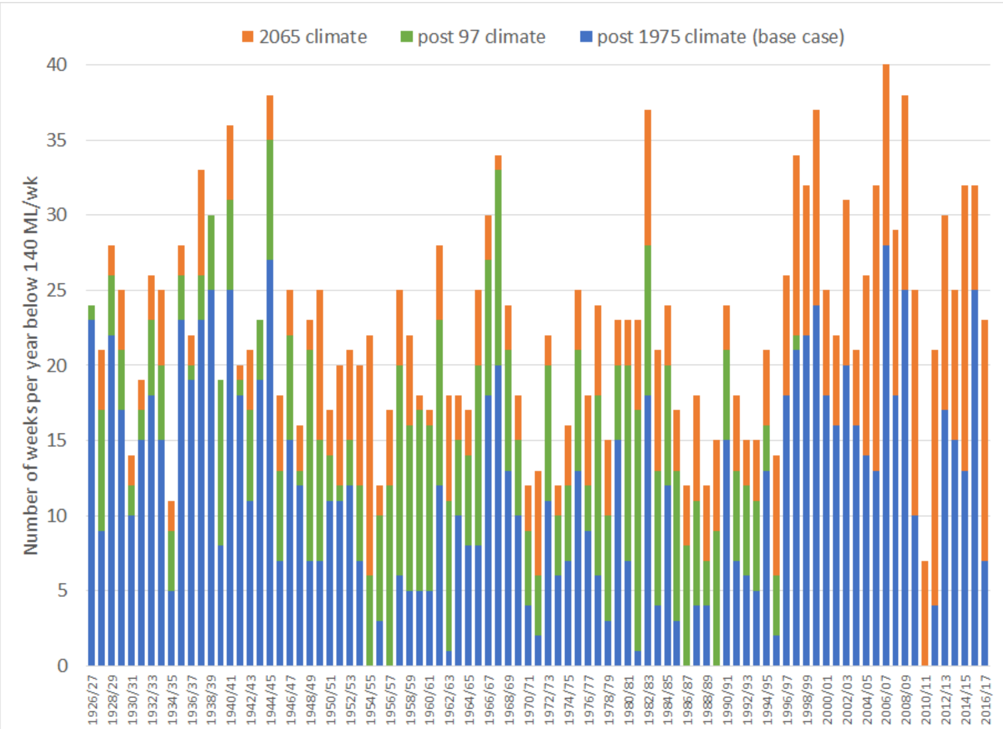


Figure 3-3: Base case – number of weeks per year below 140 ML per week under different climate cases

3.3 Scenario modelling

All scenarios were run with current levels of development demands and current (baseline) climate.

3.3.1 Scenario 1: Changes to Ballarat South WWTP discharge

The Ballarat South WWTP currently discharges around 7.8 GL annually to the Upper Leigh River. Scenario 1a involves reducing that to 2 GL/yr to correspond with the recommendation in the existing Central Region SWS (DSE, 2005) which states that Corangamite CMA and CHW should work together to ensure 2 GL/yr continues to be discharged from Ballarat South WWTP to address environmental water needs.

Scenario 1b is run with WWTP discharges switched off to show the contribution they make to flows at Geelong. Scenario 1c involves storing some of the WWTP discharge so greater volumes can be discharged at times when Geelong flows are low.

As noted in the project's Scoping Paper (RMCG, 2020), investigations showed that flows in Geelong less than 20 ML/d are favourable for algal growth. Results show that when WWTP discharge reduces to 2 GL per year the average number of weeks when flows in Geelong are less than 140 ML/wk increases from 12 to 17 weeks per year. When WWTP discharge is removed altogether the average number of weeks when flows in Geelong are less than 140 ML/wk increases further to 18 weeks per year.

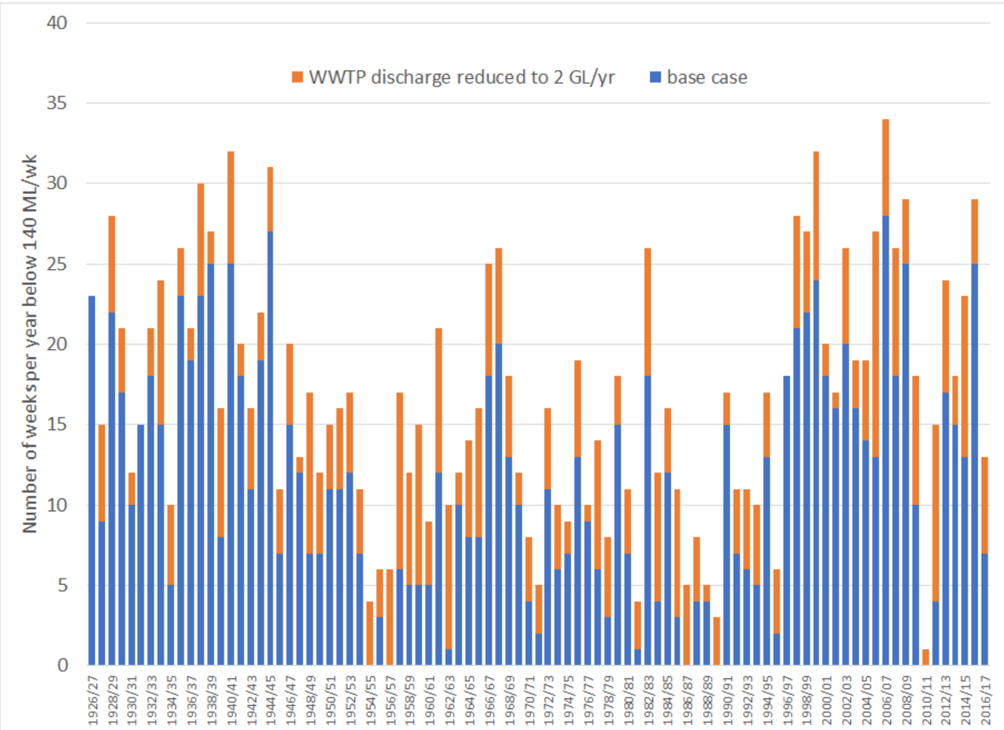


Figure 3-15: Base case and Scenario 1a post 75 climate – number of weeks per year below 140 ML per week

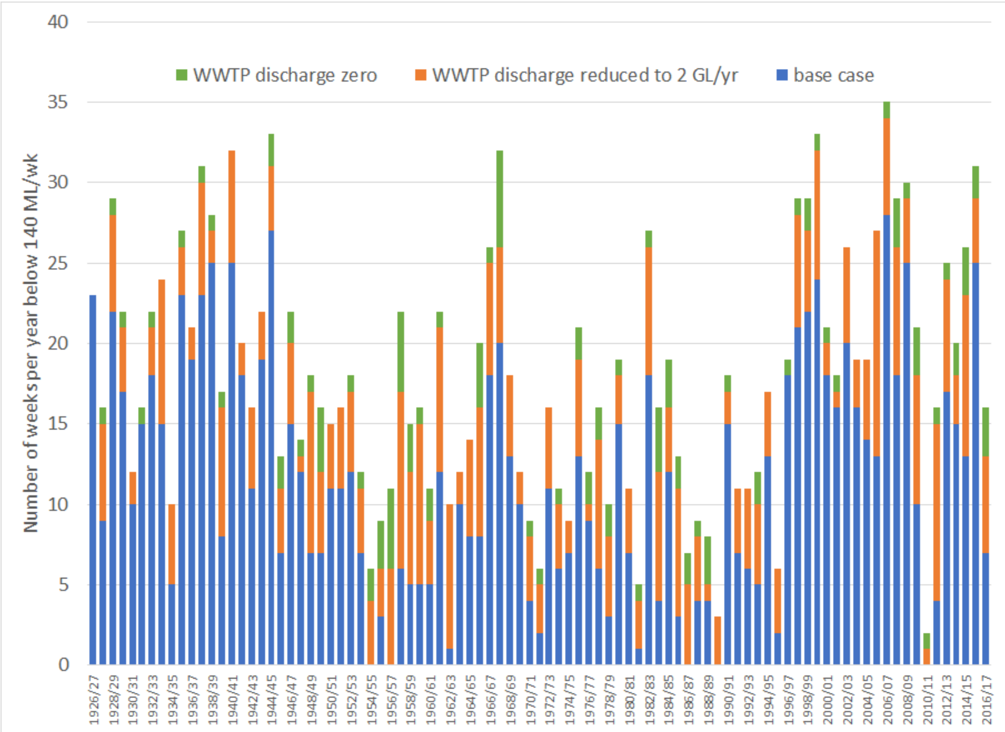


Figure 3-4: Base case, Scenario 1a and Scenario 1b post 75 climate – number of weeks per year below 140 ML per week

Manipulating the pattern of discharge using a notional storage (Scenario 1c) was able to reduce the average number of weeks less than 140 ML/wk from 12 weeks to 8 weeks per year. Looking at results for December through to March all the benefit occurs in this period, reducing the average number of weeks below 140 ML/wk for December to March from 8 to 4 weeks per year.

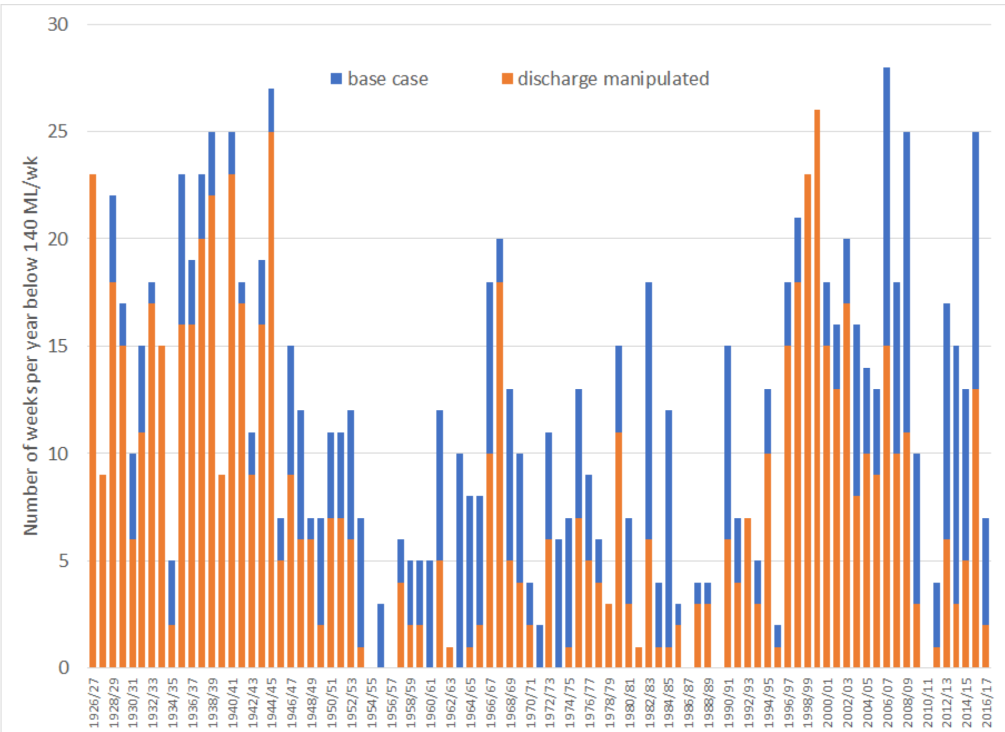


Figure 3-5: Base case and Scenario 1c post 75 climate – number of weeks per year below 140 ML per week

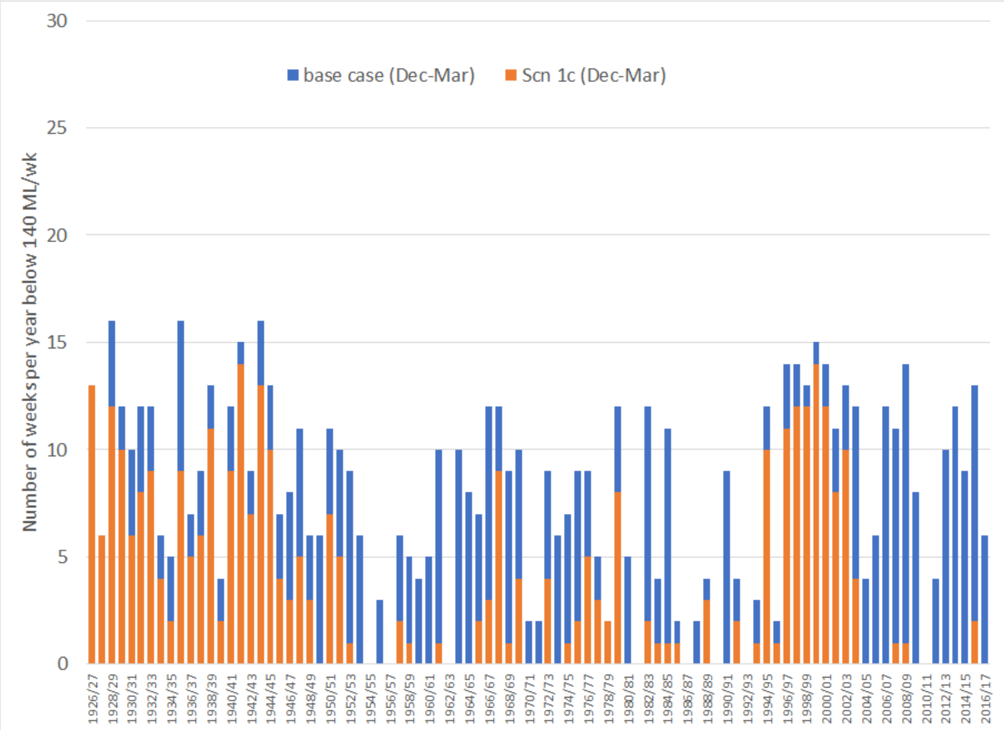


Figure 3-18: Base case and Scenario 1c post 75 climate – number of weeks Dec-Mar below 140 ML per week

3.3.2 Scenario 2: Changes to Batesford Quarry discharge

Batesford Quarry currently discharges around 3.5 GL annually to the Moorabool River below Batesford. Scenario 2a involves reducing that by 50%, while Scenario 2b was run with quarry discharges switched off, to show the contribution they make to flows at Geelong. As stated in the scoping paper, the future of discharges from the quarry is uncertain with its closure planned in 2029.

As noted in the project's Scoping Paper (RMCG, 2020), investigations showed that flows in Geelong less than 20 ML/d are favourable for algal growth. Results show that when quarry discharge reduces by 50% the average number of weeks when flows in Geelong are less than 140 ML/wk increases slightly from 11.7 to 12.3 weeks per year. When quarry discharge is removed altogether the average number of weeks when flows in Geelong are less than 140 ML/wk increases further to 15 weeks per year.

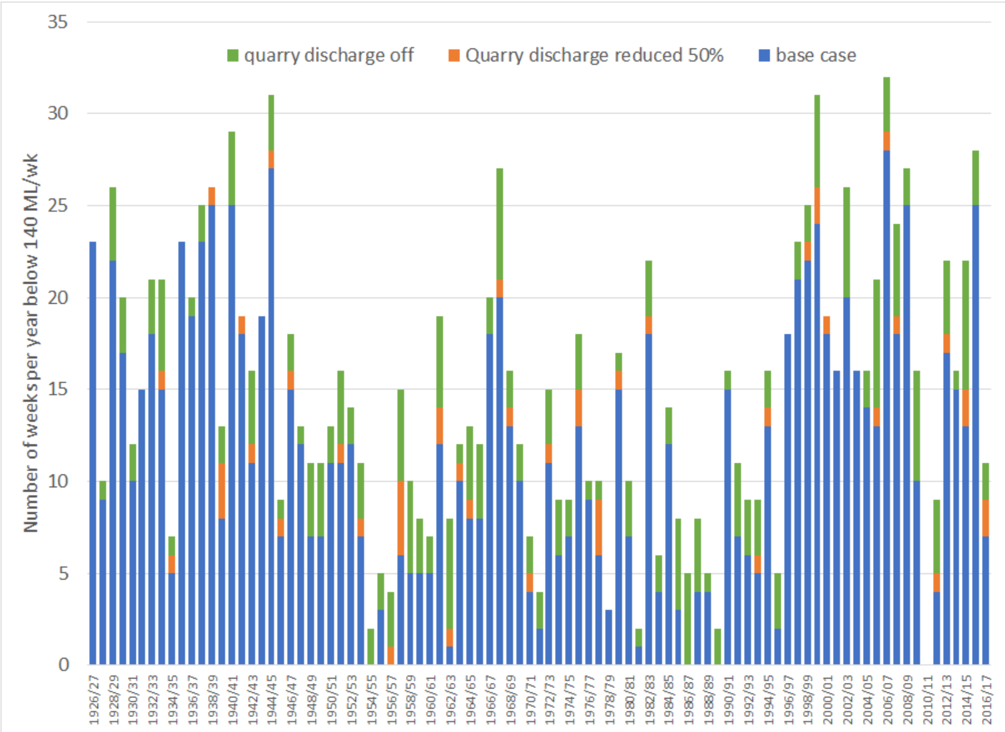


Figure 3-6: Base case, Scenario 2a and Scenario 2b post 75 climate – number of weeks per year below 140 ML per week

3.3.3 Scenario 3: Meeting water recovery targets

Three scenarios were run increasing the environmental share in Lal Lal and West Barwon reservoirs in order to meet environmental flow targets. A minimum (Scenario 3a) and a higher (Scenario 3b) target were modelled for meeting flow recommendations immediately downstream of the storage. A third case (Scenario 3c) was run aiming to meet dry (Dec-May) and wet (Jun-Nov) season low flow recommendations in the Barwon River at Pollocksford and the Moorabool River at Batesford.

Based on previous FLOWS studies, Jacobs (2015) and Alluvium (2019), the minimum water recovery target for Lal Lal Reservoir is 5,140 ML and for West Barwon Dam is 3,336 ML. These volumes correspond to the volume required to meet summer/autumn and winter/spring low flows and selected freshes required under "dry" conditions.

The higher water recovery target for Lal Lal Reservoir is 9,000 ML and for West Barwon Dam is 19,301 ML. These volumes correspond to the volume required to meet summer/autumn and winter/spring low flows and selected fresh requirements under "wet/average" conditions and include additional freshes.

3.3.3.1 Location of water recovery targets – Scenario 3a and 3b

Moorabool

The Lal Lal Reservoir water recovery target volume corresponds to flow requirements in Reach 3b and Reach 4 which are the Moorabool River from the confluence of the east and west Moorabool rivers downstream to the Barwon River confluence. However, in REALM, environmental flow releases are modelled based on the requirements of the upstream Reach 3a, which is the West Moorabool River between Lal Lal Reservoir and the East Moorabool River confluence. This reach has lower corresponding water recovery targets of 3,380 ML/yr for the minimum case and 6,150 ML/yr for the higher water recovery case.

In the existing REALM model recently configured and used for SWS modelling (WaterRes, 2020) Reach 3a flows are prioritised as follows:

1. If the environmental share of storage is less than 1,000 ML at the start of the water year, the only releases to be made in that water year are to maintain up to 5ML/day downstream of Lal Lal Reservoir to allow carryover for the following year.

2. If the drought trigger is not in place, the provision of summer low flows (December – May) and winter low flows (June – November) is made. If a water year is classified as dry, the release from Lal Lal Reservoir remains 5 ML/day, if the water year is classified as average or wet, the total release is increased to 10 ML/day (the years with the lowest 1/3 of inflows are classed as dry).

3. The available resource (with 1,000 ML set aside as a drought reserve) is then assessed to determine which, if any, of the fresh events can be delivered.

   - July Freshes delivery (2nd priority, deliver in week 31)
   - Sep-Nov (October) Fresh delivery (1st priority, deliver in week 44)
   - Sep-Nov (November) Fresh 2nd event delivery (5th priority, deliver in week 48)
   - Jan/Feb Freshes delivery (4th priority, deliver in week 9)
   - Feb/Mar Little Summer Fresh delivery (6th priority, deliver in week 13)
   - April/May Freshes delivery (3rd priority, deliver in week 22)

The prioritised flows are summarised in Table 3-7.

Table 3-7: Reach 3a prioritised flow components in REALM (WaterRes, 2020)

Priority	Event	Threshold (ML)	Duration (Days)	Frequency		Event Volume (ML)		
				Dry	Average/Wet	20 ML/day passing	5 ML/d passing	If natural = 1 ML/d passing
1	Priority 1 – Trigger based freshes (if needed)	N/A	N/A	As needed	N/A	Up to 250ML/yr	Up to 250ML/yr	Up to 250ML/yr
2	Priority 2 – Summer low flows	5 (Dry) 10 (Avg/Wet)	182	Every year if possible	Every year if possible			
3	Priority 3 - Maintain winter base flows	5 (Dry) 10 (Avg/Wet)	183	Every year if possible	Every year if possible			
4	Priority 4 – October spring fresh	80	5	At least one per year	At least two per year	383	566	685
5	Priority 5 - July winter fresh	80	5	At least one per year	At least one per year	383	566	685
6	Priority 6 - April/May Autumn fresh	60	5	1 in every 2-3 years	Every year	252	424	478
7	Priority 7 - Jan/Feb Summer fresh	60	5	Not Required	Every year	252	424	478
8	Priority 8 - September spring fresh	80	5	At least one per year	At least two per year	383	566	685
9	Priority 9 - Feb/March little Summer Fresh	30	3	Not Required	At least one per year if possible	31	128	171

It is noted that achievement of flow components in Reach 3a does not mean flow components are met in downstream reaches 3b and 4.

Upper Barwon

The West Barwon Dam water recovery targets correspond to Reach 9 which is the Barwon River from Birregurra Creek to the Leigh River confluence. Environmental flow releases in REALM are however based on flow requirements for Barwon River East Branch and West Branch, i.e.:

- Priority 1: Maintain Upper Barwon east branch low flows of between 0.5 and 5 ML/day between December to May. It was assumed that this watering action will supplement the existing passing flow on the Upper Barwon east branch, up to a maximum of 5 ML/day.
- Priority 2: Release 2 x 9-35 ML/day freshes in the Upper Barwon east branch over two days between December and May inclusive. It is assumed that the target flow release rate for this event is only 9 ML/day, due to downstream capacity constraints.
- Priority 3: Maintain Upper Barwon west branch low flows of up to 30 ML/day between December and May. The rule for delivery of priority 3 is to estimate water availability for the remainder of the water years and supply that available daily flow rate between December and May (inclusive) to the Upper Barwon west branch: up to a maximum of 30 ML/day and to supplement the passing flow of 4 ML/day (5 ML/day in December if storage volume of West Barwon and Wurdee Boluc is greater than 40,000ML). This supply of 26 ML/day for six month is up to around 4,700 ML.

3.3.3.2 Water recovery targets – Scenario 3c

Scenario 3c aims to satisfy wet and dry season low flow requirements in the Barwon River at Pollocksford and Moorabool River at Batesford. This was done using minimum flow requirement arcs at Pollocksford and Batesford.

Caps were also placed on maximum annual releases at 18,301 ML/yr from West Barwon Dam and 9,000 ML/yr from Lal Lal Reservoir, corresponding with the higher water recovery targets mentioned earlier. This was to ensure these targets were not exceeded. These are summarised below.

Table 3-4: Low flow requirements

Compliance point	Dry season low flow requirement	Wet season low flow requirement	Cap on reservoir releases
Barwon River at Pollocksford	70 ML/d	280 ML/d	18,301 ML/yr
Moorabool River at Batesford	20 ML/d	86 ML/d	9,000 ML/yr

3.3.3.3 Contribution from other sources

As mentioned for the Upper Barwon case above, flow components can be partially satisfied by flows other than releases from stored environmental entitlements. In the case of the Upper Barwon these include Bulk Entitlement (BE) passing flow requirements on the East and West Barwon Rivers, as well as local catchment inflows downstream of the storages. In the case of Lal Lal Reservoir these are BE passing flow requirements plus releases by Barwon Water to transfer water to She Oaks for urban supply (which contribute to environmental outcomes above Barwon Water's diversion point at She Oaks). It is important to note the model removes the transferred consumptive water which is extracted by Barwon Water at She Oaks).

Therefore, the amount of water that needs to be delivered from the environmental share of Lal Lal and West Barwon reservoirs is only a part of the total flow requirement.

3.3.3.4 Scenario modelling approach – Scenario 3a and 3b

The modelling approach for these scenarios involved increasing the environmental share of Lal Lal and West Barwon reservoirs such that prioritised flow components were met.

Moorabool

Results of the base case model run showed that with the existing environmental share in Lal Lal Reservoir:

- Almost 100% of priority 1, 2 and 3 flows in Reach 3a can be supplied.
- 76% of priority 4 flows in Reach 3a can be supplied.
- Between 78 and 92% of priority 5, 6, 7, 8 and 9 flows in Reach 3a can be supplied.

Note – these results do not assume Barwon Water covers all required baseflows over their operational release period. The model combines the releases from the environmental entitlement share with the operational release from Barwon Water's share of Lal Lal, and compares this flow with the prioritised flow requirements.

<u>Scenario 3a</u> aimed to provide all of the required Priority 1, 2, 3 and 4 flows in Reach 3a. <u>Scenario 3b</u> aimed to provide all flow components in Reach 3a.

Table 3-5: Base case model – Percentage of flow components that can be supplied

Priority		Vol required	Total required	% supplied
1	Drought flow	5 ML/d in drought years	60 ML	99%
2	Summer low	5 ML/d in dry years, 10 ML/d in avg/wet years	3,048 ML	100%
3	Winter low	5 ML/d in dry years, 10 ML/d in avg/wet years		99%
4	October fresh	591 ML 1 per year	591 ML	76%
5	July fresh	591 ML 1 per year	591 ML	80%
6	Apr/May fresh	449 ML 1 in 2 (in dry years) 1 per yr (in avg/wet years)	375 ML	80%
7	Jan/Feb fresh	449 ML 0 (in dry years) or 1 (in avg/wet years) per yr	301 ML	92%
8	Sept fresh	591 ML 1 (in dry years) or 2 (in avg/wet years) per yr	987 ML	78%
9	Feb/Mar fresh	153 ML 0 (in dry years) or 1 (in avg/wet years) per yr	103 ML	92%

Upper Barwon

Results of the base case model run showed that with the existing environmental share in West Barwon Dam:

- 97% (by volume) of priority 1 flow requirements can be supplied (by volume).
- 100% of priority 2 flow requirements can be supplied.
- 31% of priority 3 flow requirements can be supplied

Scenario 3a aimed to provide all of the required Priority 1, 2 and 3 flows. Scenario 3b aimed to provide all of these plus the wet period fresh included in the Reach 9 higher target (3 events of 750 ML/d for 5 days).

3.3.3.5 Scenario modelling approach – Scenario 3c

As for scenarios 3a and 3b, the scenario modelling approach involved increasing the environmental share of Lal Lal and West Barwon reservoirs, such that dry and wet season low flows are satisfied. This was done using minimum flows requirement arcs at Pollocksford and Batesford.

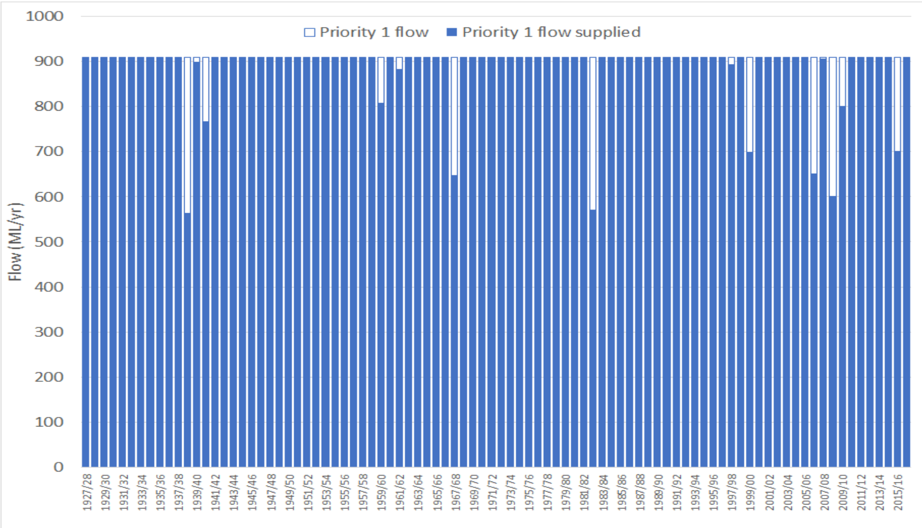
Caps were also set on maximum annual releases of 18,301 ML/yr for West Barwon Dam and 9,000 ML/yr for Lal Lal Reservoir, which corresponded to the higher water recovery targets mentioned earlier. This was to ensure these targets were not exceeded.

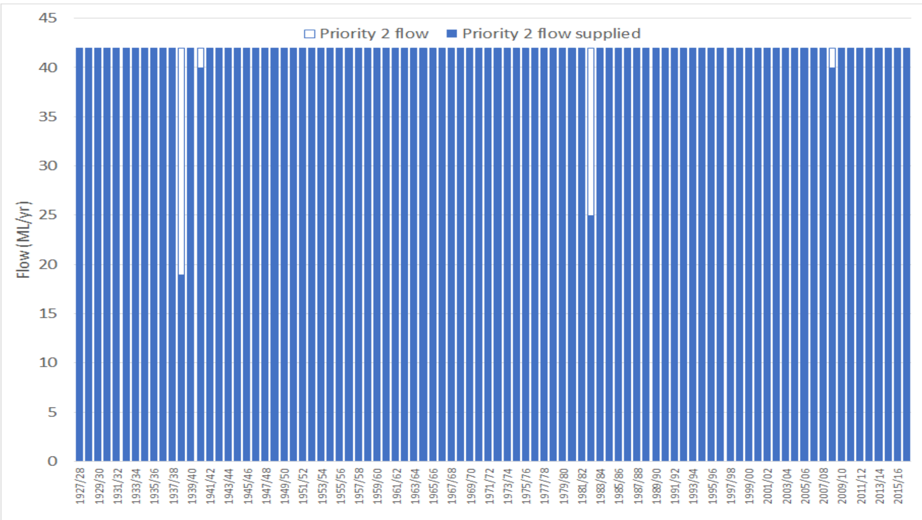
In addition, extra water was released from the environmental share of Lal Lal in coordination with Barwon Water's releases if extra volume was required to meet 40 ML/wk flow requirements at She Oaks during the dry season.

3.3.3.6 Scenario 3a results

Upper Barwon

Scenario 3a aimed to provide all of the required Priority 1, 2 and 3 flows in the Upper Barwon. It was found that increasing the environmental share in West Barwon Dam to 9,000[2] ML with a corresponding increase in inflow (existing share multiplied by 4.5) allowed for 99% of priority 1, 2 and 3 flows to be suppled. Supply of flows compared to the base case are shown below.





[2] This storage increase has been used in order to meet the recommendations in the more upstream reach, as configured in the WaterRes model.

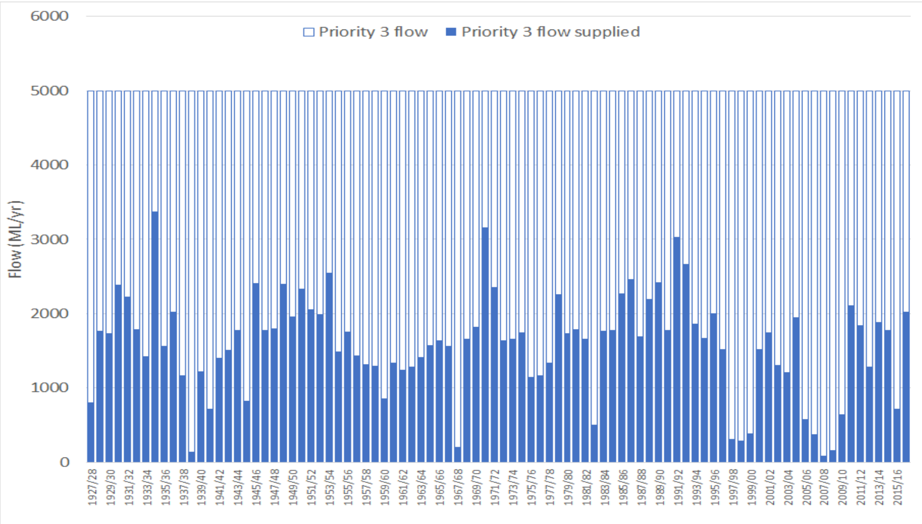
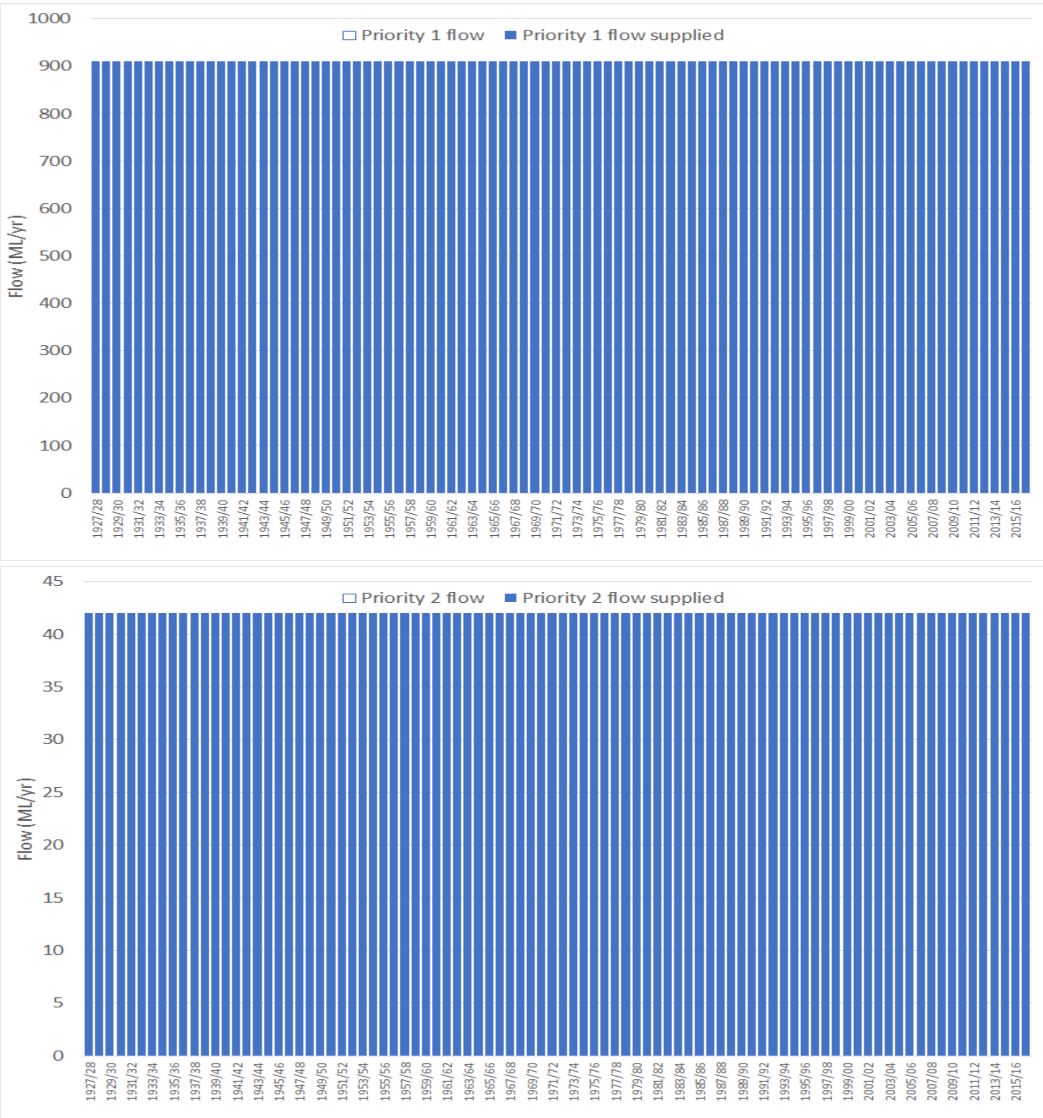


Figure 3-8: Upper Barwon Priority 1, 2 and 3 flows supplied – base case



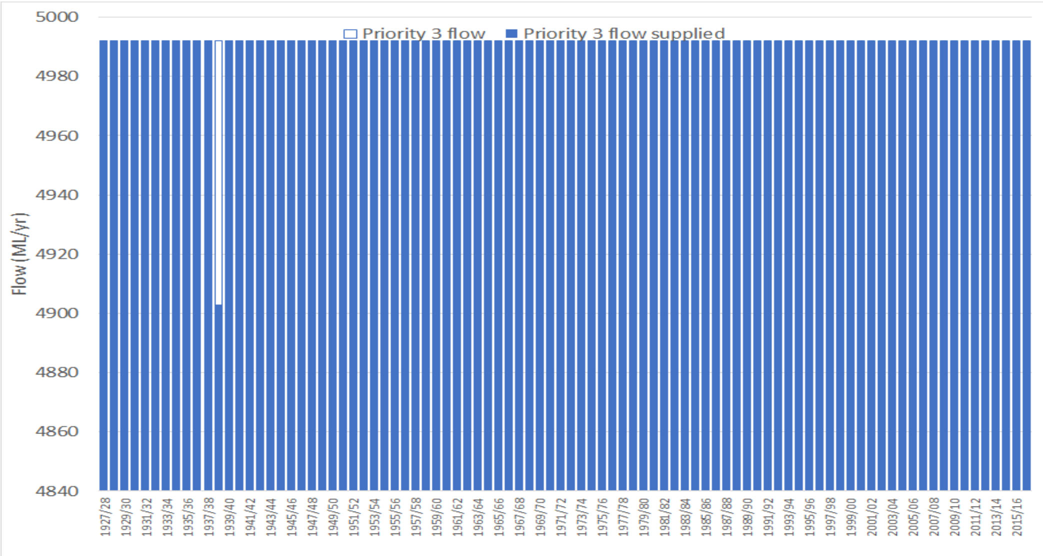


Figure 3-9: Upper Barwon Priority 1, 2 and 3 flows supplied – Scenario 3a

Moorabool

Given that all prioritised flow components in Reach 3a were already fairly close to being supplied in the base case, scenario 3a aimed to supply all prioritised flow components rather than just 1 to 4, noting this does not relate to downstream reaches 3b or 4.

The existing Moorabool River Environmental entitlement comprises 11.9% of inflows and 11.9% of storage in Lal Lal Reservoir (average entitlement volume of 2,500 ML/year). It was found that increasing the environments share of Lal Lal Reservoir from 11.9% to 20% allowed for 99% of prioritised flow components to be supplied. Supply of flows compared to the base case are shown below.

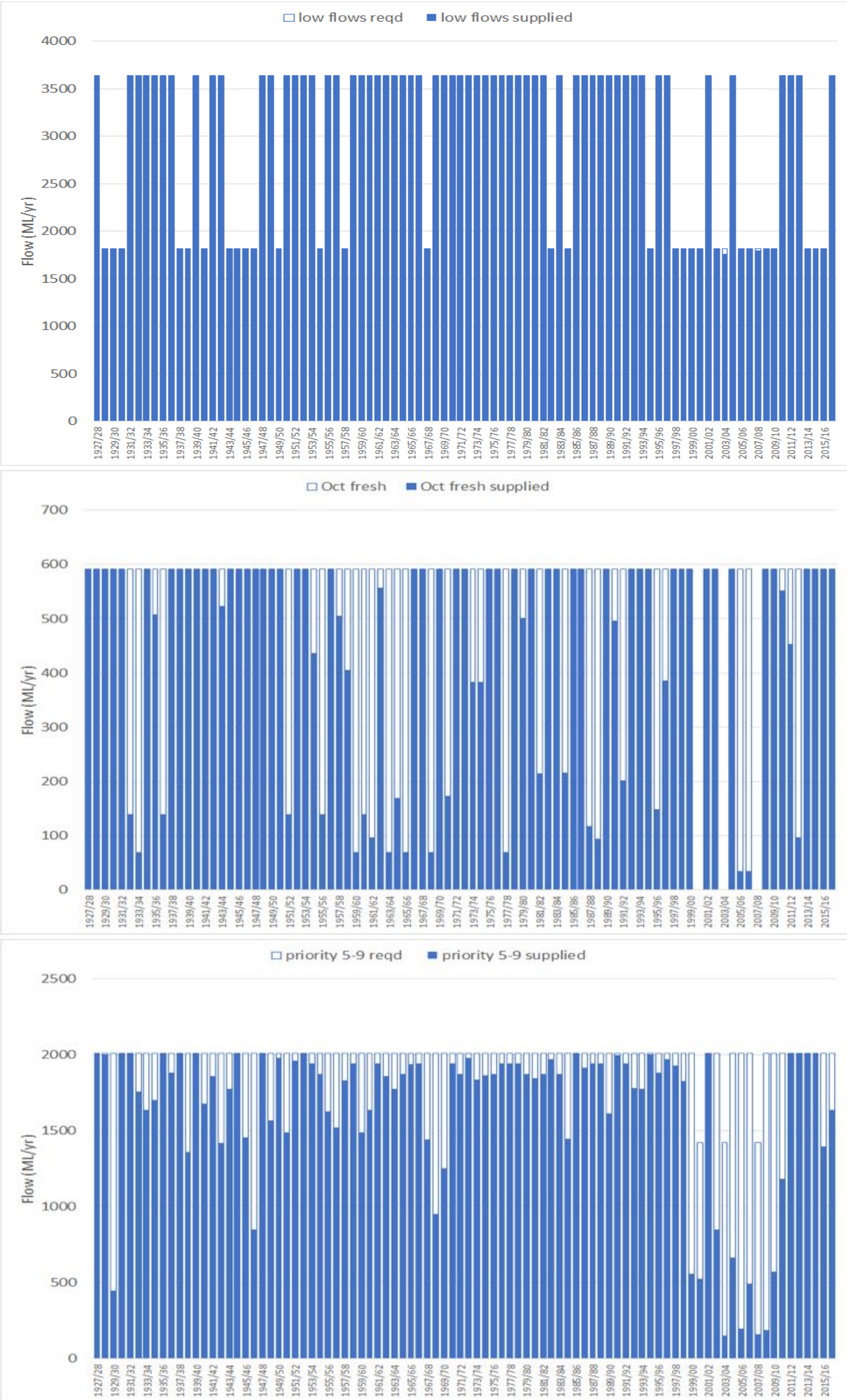


Figure 3-10: Moorabool Reach 3a priority flows supplied – base case

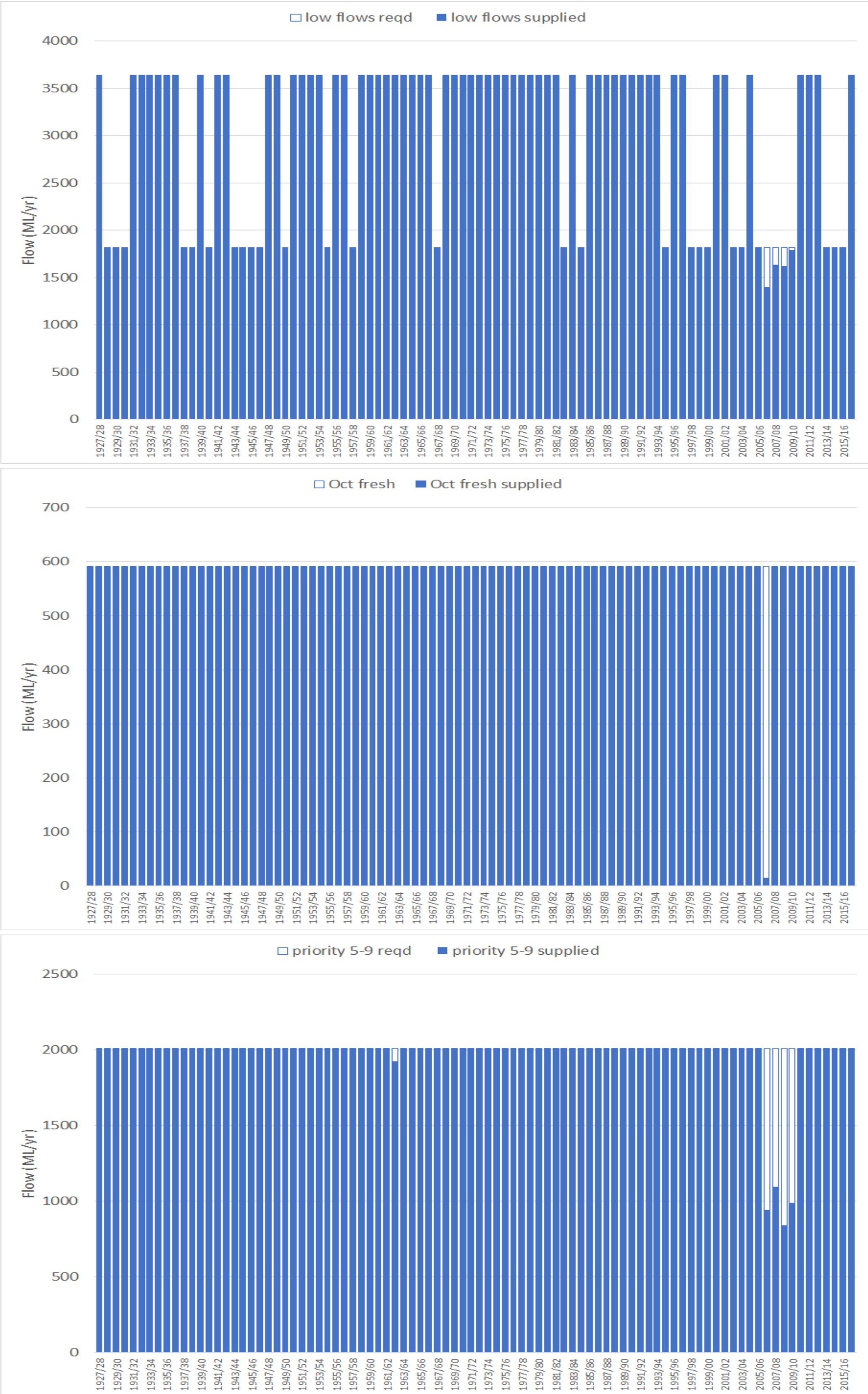


Figure 3-11: Moorabool Reach 3a priority flows supplied – Scenario 3a

Results also show that under Scenario 3a average number of weeks when flows in Geelong are less than 140 ML/wk decreases from 11.7 to 10.9 weeks per year.

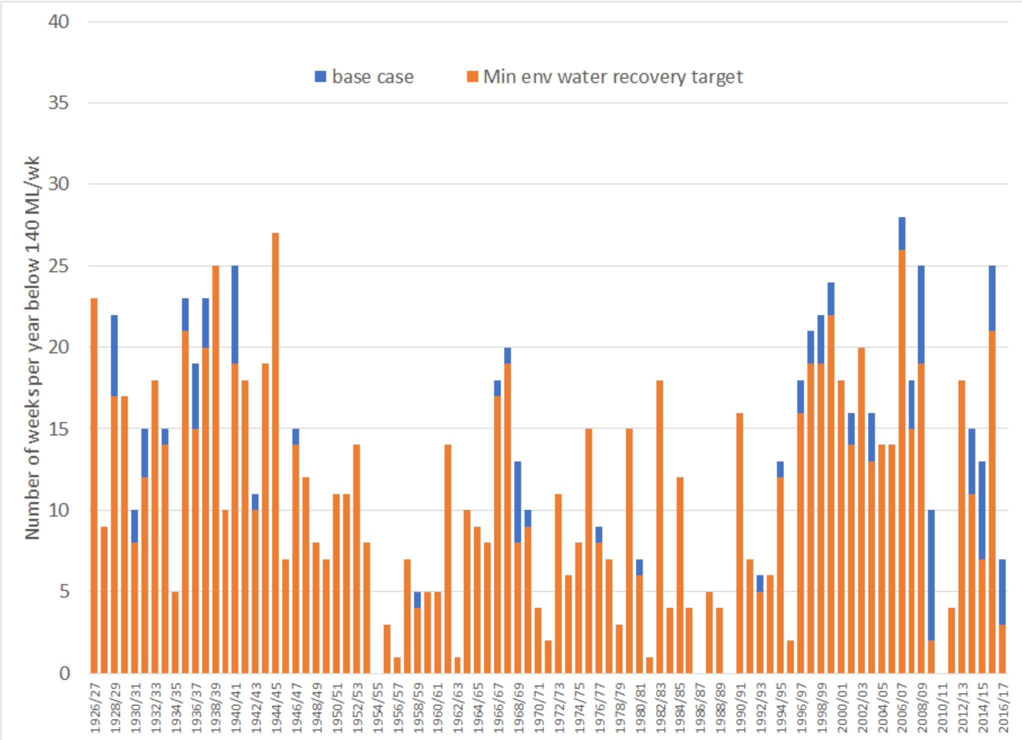


Figure 3-12: Base case and Scenario 3a post 75 climate – number of weeks per year below 140 ML per week

3.3.3.7 Scenario 3b results

Upper Barwon

Scenario 3b aimed to provide all of the required Priority 1, 2 and 3 flows in the Upper Barwon plus the wet period fresh included in the Reach 9 higher target (3 events of 750 ML/d for 5 days). It was found that if the environmental share of West Barwon Dam is increased to 12,000 ML, the additional fresh in the wet period (three events of 750 ML/d, each for 5 days) can be supplied in all years of the run, except for 1967/68.

Moorabool

If the environment's share of Lal Lal Reservoir is increased to 25% then all required flow components in Reach 3a can be supplied in all years. Again, it is noted that achievement of flow components in Reach 3a does not mean flow components are met in downstream reaches 3b and 4.

Results also show that under Scenario 3b average number of weeks when flows in Geelong are less than 140 ML/wk decreases from 11.7 to 11 weeks per year.

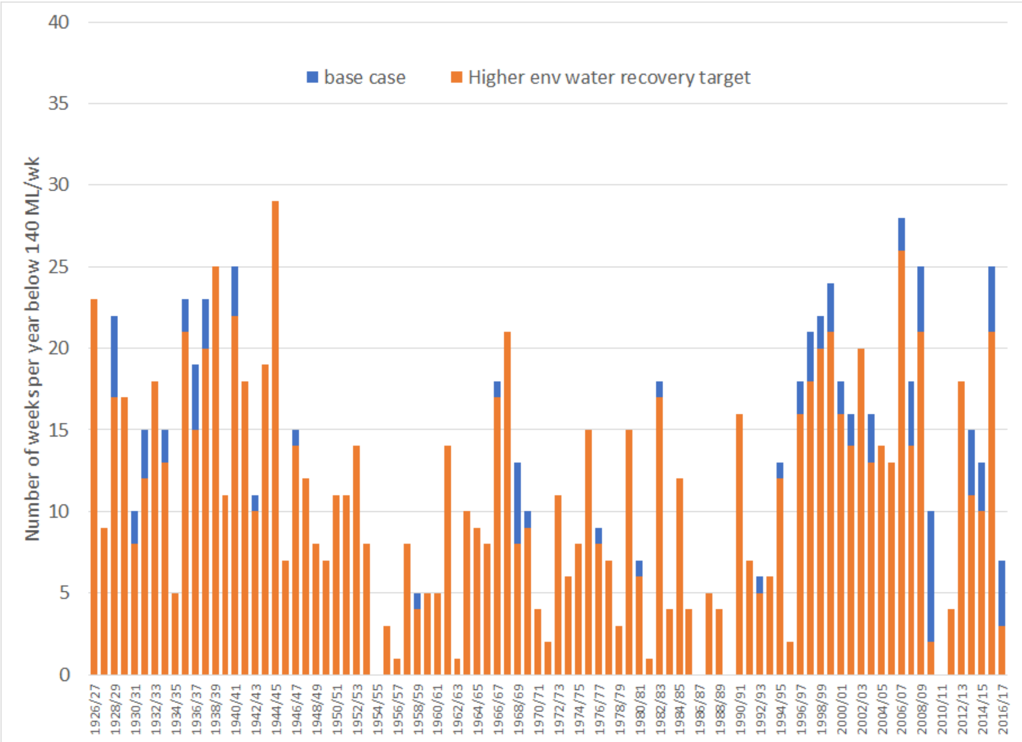


Figure 3-13: Base case and Scenario 3b post 75 climate – number of weeks per year below 140 ML per week

3.3.3.8 Scenario 3c results

West Barwon

Results show that if the environmental share of West Barwon Dam is increased to 18,000 ML capacity and 34% of inflows, then wet and dry period low flows can be supplied in 84% of weeks, compared to 45% of weeks for the base case.

Volumetrically this equates to 88% of the required dry period low flow volume and 89% of the required wet period low flow volume. Average annual release from the environmental share of West Barwon Dam is 13,736 ML.

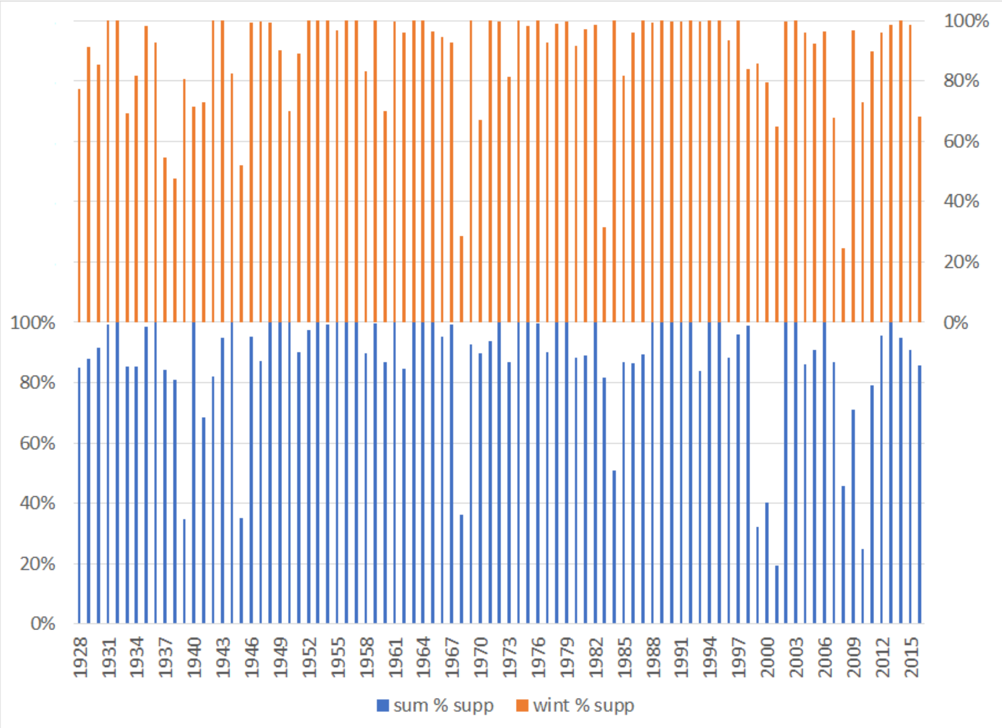


Figure 3-14: Proportion of required low flow supplied by year - Pollocksford

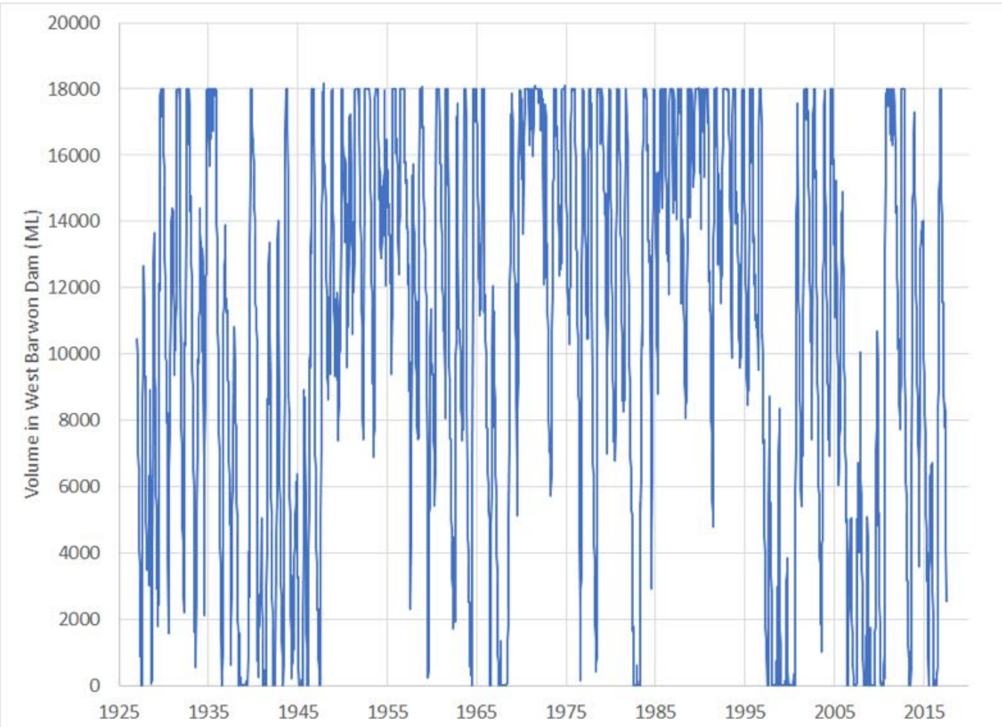


Figure 3-27: West Barwon Dam environmental share

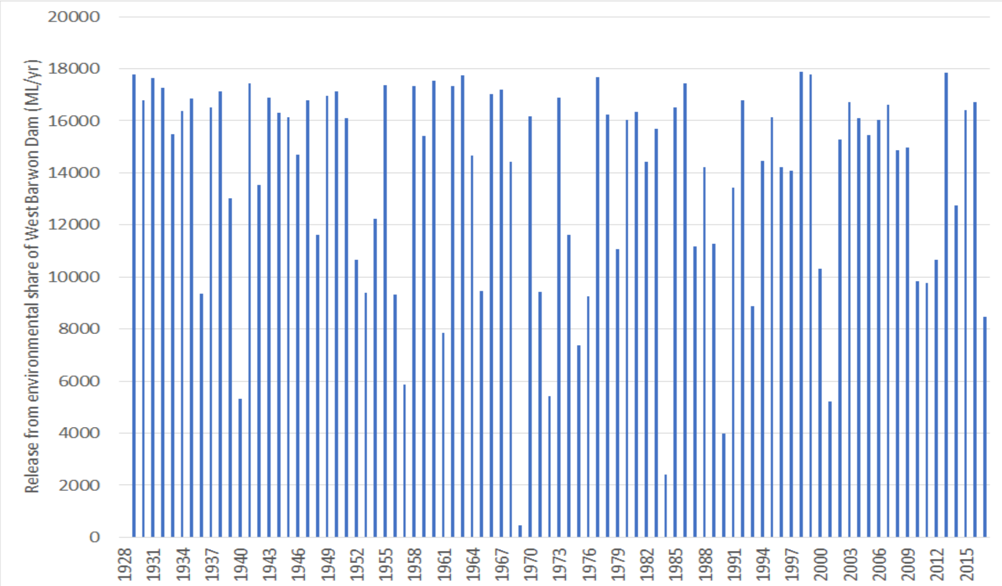


Figure 3-28: Release from environmental share of West Barwon Dam

Lal Lal

Results show that if the environmental share of Lal Lal Reservoir is increased to 23,820 ML capacity and 40% of inflows then wet and dry period low flows can be supplied in 83% of weeks, compared to 26% of weeks for the base case.

Volumetrically this equates to 88% of the required dry period low flow volume and 76% of the required wet period low flow volume. Average annual release from the environmental share of Lal Lal Reservoir is 7,674 ML.

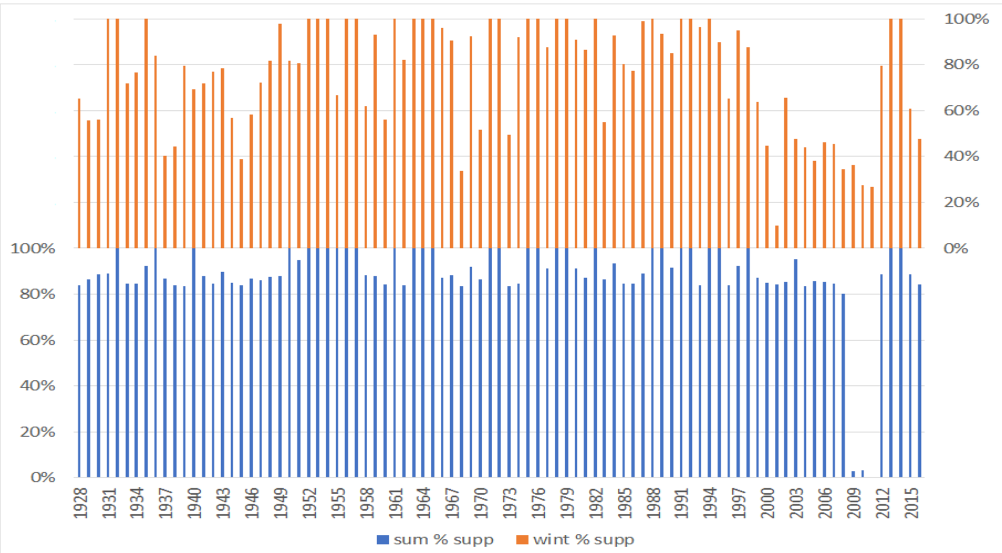


Figure 3-29: Proportion of required low flow supplied by year - Batesford

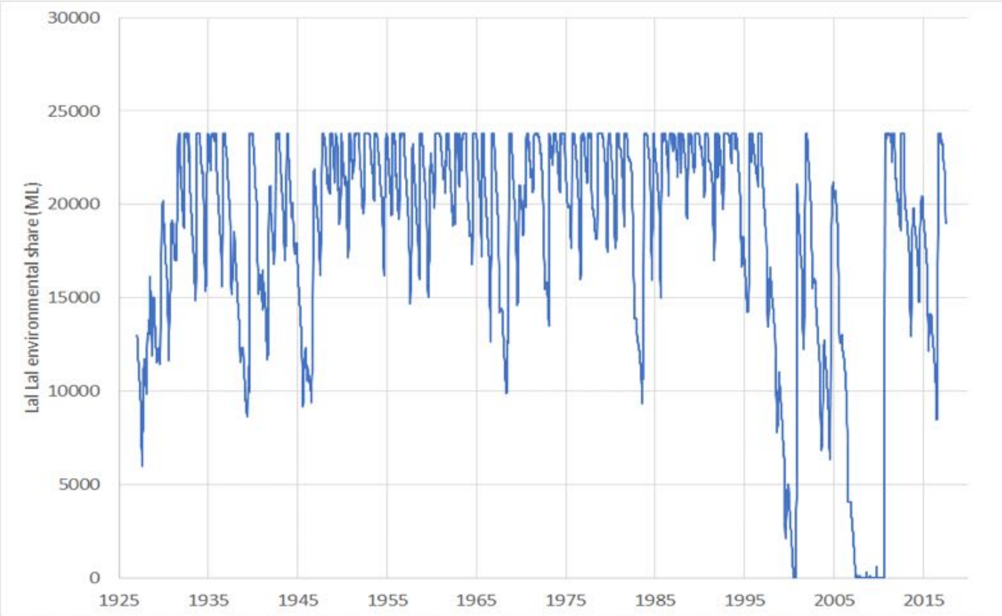


Figure 3-30: Lal Lal Reservoir environmental share

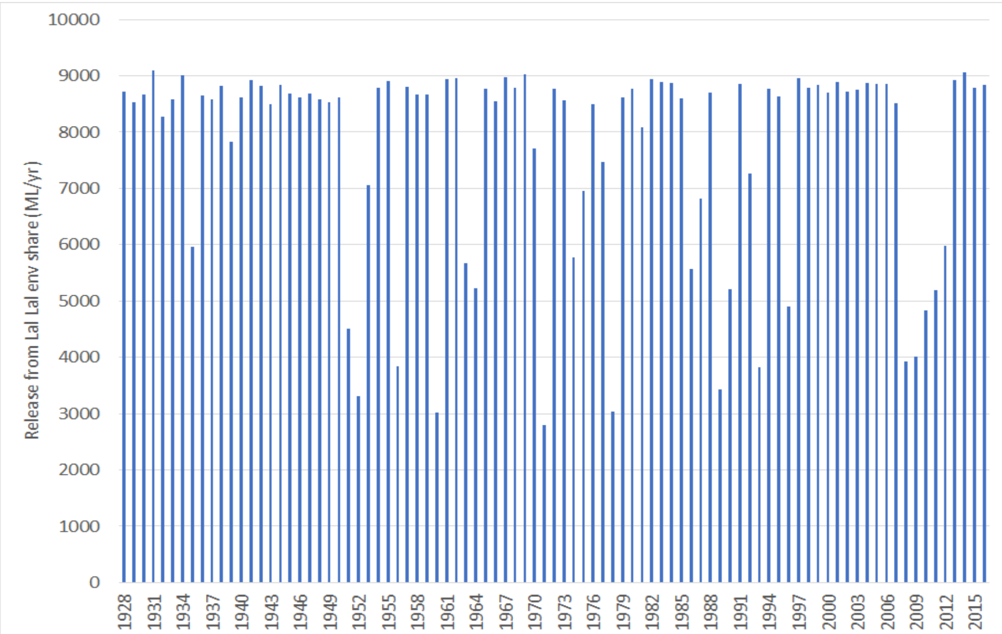


Figure 3-15: Release from environmental share of Lal Lal Reservoir

Flow at Geelong

As noted in the Scoping Paper, investigations showed that flows in Geelong less than 20 ML/d are favourable for algal growth. Analysis showed that flows are below 140 ML/wk (i.e. 20 ML/d) on average 12 weeks per year under the base case run. This reduces to 3 weeks per year under Scenario 3c.

3.3.4 Scenario 4 (combined scenario): Ballarat WWTP discharge pattern manipulated and higher water recovery target

This scenario combined Scenario 1c (Ballarat WWTP discharge pattern manipulated) and Scenario 3b (Higher water recovery target for the environment).

Results also show that under Scenario 4 the average number of weeks when flows in Geelong are less than 140 ML/wk decreases substantially from 11.7 to 7.9 weeks per year.

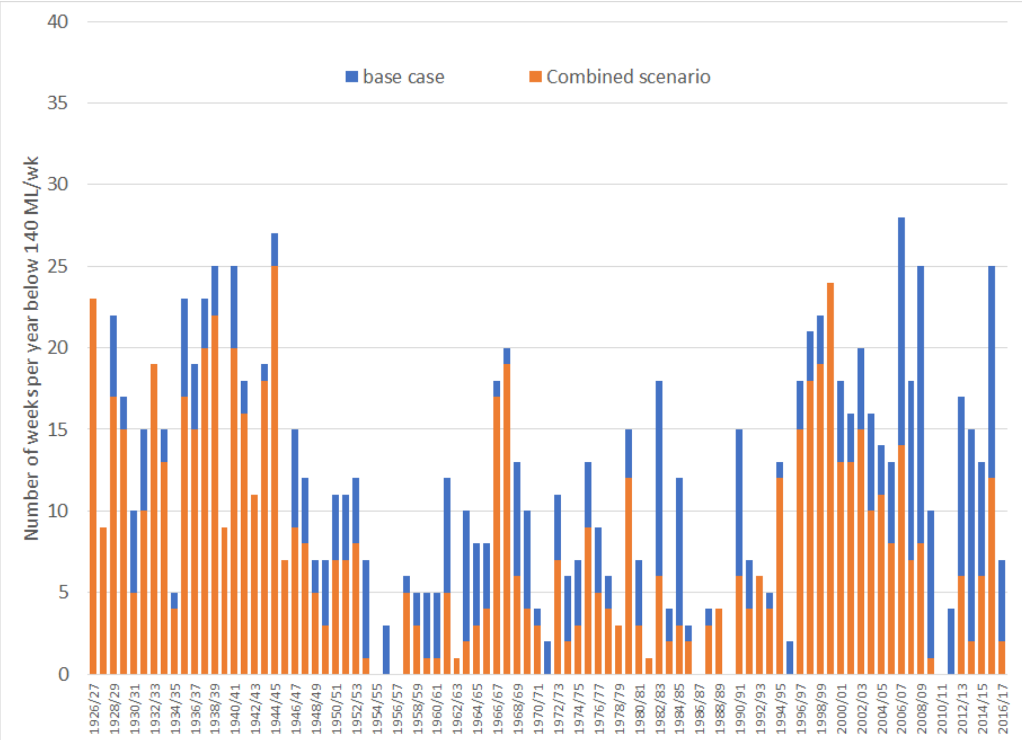


Figure 3-16: Base case and Scenario 4 post 75 climate – number of weeks per year below 140 ML per week

4. Water levels at Geelong

Modelled time series of water levels at Geelong were inferred from the modelled flows at Geelong. These modelled water level time series were then analysed to check the depth in this reach of the Barwon River, particularly during periods of each year when this reach of river is used for rowing and other on river events and recreational use. The key events considered were:

- Barwon Regatta (Australia day weekend in January)
- Head of the School Girls Regatta (second weekend of March).

As outlined in GHD (2013), the entire extent of the rowing lanes require a minimum water depth of 1.9 metres for events to be held. As outlined in GHD (2013) this translates to a water level of 0.85 m AHD.

Levels at the 232217 gauge (Barwon River at Geelong) where converted to AHD using survey data taken in 2015. This showed that a survey height at the gauge of 0.926 m AHD corresponded to a gauge height of 0.935m.

The modelled flows at Geelong for each scenario were converted to water levels using the rating table (extract from the Water Measurement Information System (WMIS)) for the gauge in the Barwon River at Geelong (232317), and converted to AHD using the adjustment described above.

The analysis for the minimum river level for rowing targeted the key rowing dates outlined above. To give a reasonable indication of water level over a run period of 1927 to 2017, these were assumed to be approximately over the fixed dates of 25-27 January and 18-20 March each year respectively[3]. The results are summarised in Table 4-1 and plotted in Figure 4-1 and Figure 4-2.

It is evident that the WWTP discharges are important for maintaining river levels, and manipulating the pattern of discharge gives a significant improvement in results over the base case. Provision of environmental water for the lower reaches results in the greatest improvement in maintaining river levels.

The impact of climate change is evident on key rowing depths with a reduction of the percentage of years above critical depth of up to 21% for the Barwon Regatta and 20% for the Head of School Girls Regatta.

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[3] Assuming that results over these fixed three day periods would be relatively representative of the nominated weekends for the events, which can move by a few days in each year

Table 4-1 Number of years critical rowing depth is reached for each scenario

Scenario*	Barwon Regatta (Australia Day)		Head of School Girls Regatta (March)	
	Number of years above critical depth	% of years from 1927 to 2017	Number of years above critical depth	% of years from 1927 to 2017
Base case post 75 climate	34	37%	26	29%
Base case post-97 climate	27	30%	19	21%
Base case 2065 High climate change	15	16%	8	9%
Scn 1a: Ballarat South WWTP discharge reduced to 2 GL	18	20%	14	15%
Scn 1b: Ballarat South WWTP discharge turned off (Scn 1 worst case)	15	16%	10	11%
Scn 1c: Ballarat South WWTP discharge pattern manipulated (Scn 1 best case)	74	81%	61	67%
Scn 2a: Batesford quarry discharge reduced by 50% (Test impact of no winter discharge)	31	34%	25	27%
Scn 2b: Batesford quarry discharge turned off (Scn 2 worst case)	25	27%	24	26%
Scn 3a: Min enviro water recovery target	41	45%	31	34%
Scn 3b: Higher enviro water recovery target	41	45%	32	35%
Scn 3c: environmental water recovery for lower reaches	82	90%	80	88%
Scn 4: Ballarat South WWTP discharge pattern manipulated and Higher water recovery target	72	79%	58	64%

*Note these results assume no dredging or other intervention works are undertaken to improve river depths.

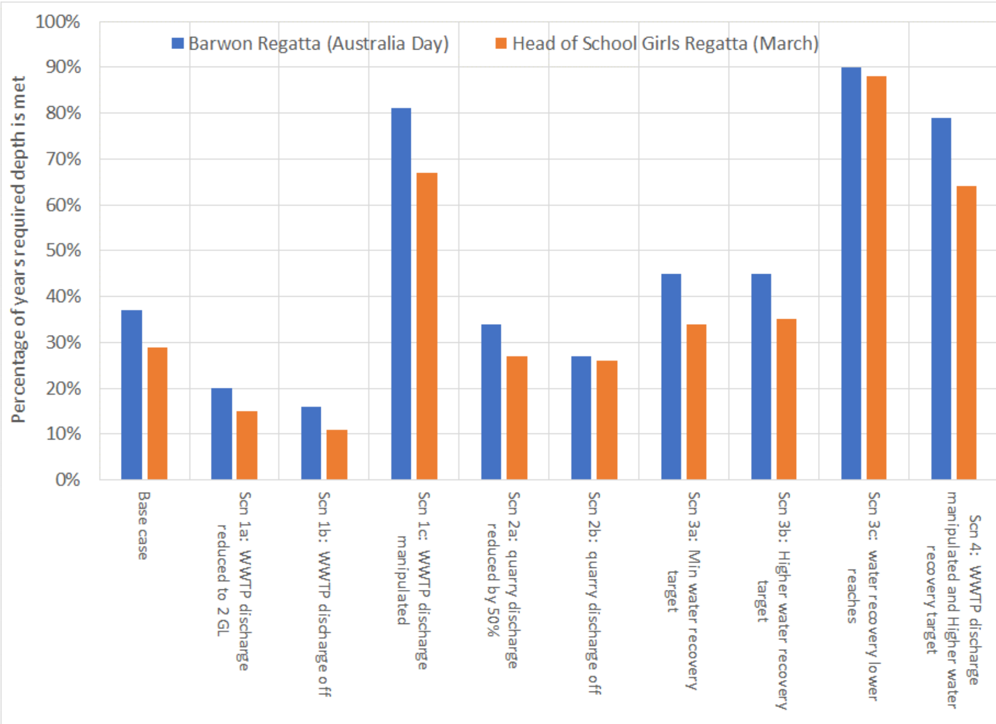

Figure 4-1: Percentage of years required rowing depth can be met for key events

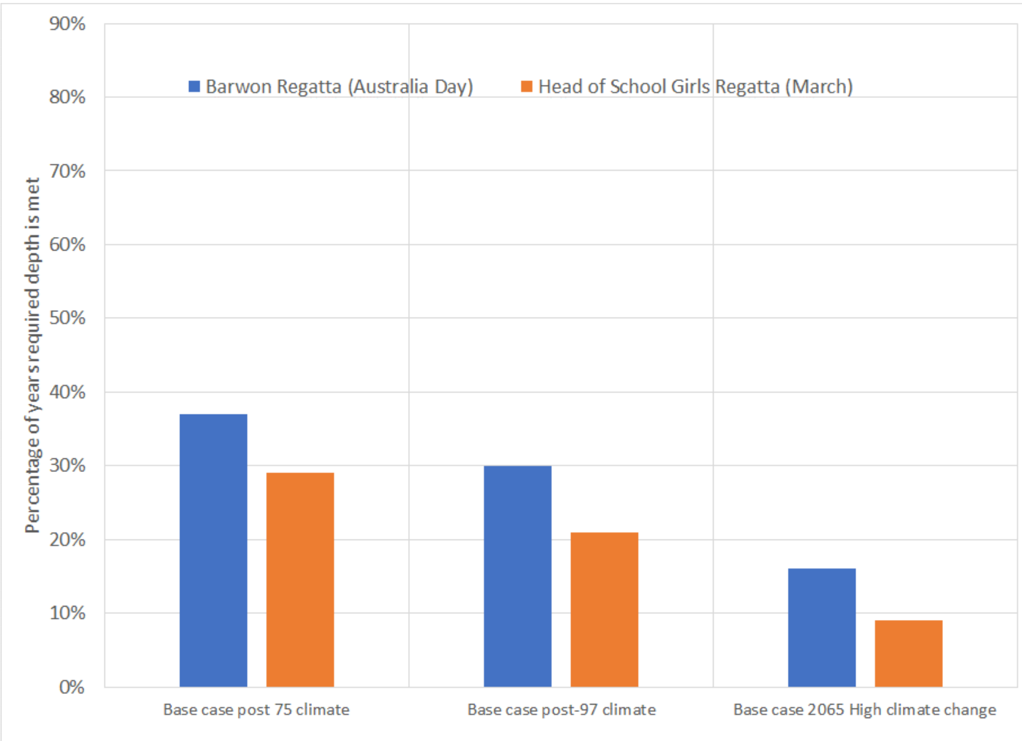

Figure 4-2: Impact of climate change on percentage of years required rowing depth can be met for key events

5. Creating inputs to the algal bloom model

5.1 Conceptual model of flow and water quality inputs

As discussed in the project's Scoping Report, water quality in the lower Barwon River is influenced by the volumes and quality of water flowing into the reach from upstream sources. In this report, several scenarios were considered that would modify the volumes of water that would be derived from various sources. Changes in the volume of water derived from different sources would also cause changes in the loads of total suspended solids (TSS) and nutrients that would be delivered into the Lower Barwon River. To test the impact of the scenarios for changes in water management in the catchment, relationships were first developed for the sediment and nutrient concentrations that are associated with each of the major sources of water.

An algal growth model was established for the Lower Barwon River, as discussed in the Scoping Report and in Section 6. The conceptual model of flow and water quality generated from the catchment is shown in Figure 5-1. There are two significant point source inputs:

- Ballarat South Wastewater Treatment Plant (WWTP)
- Batesford Quarry.

and four subcatchments providing diffuse inputs:

- Leigh River
- Upper Barwon River (to the confluence with the Leigh River)
- Moorabool River
- Barwon River, downstream of the confluence with the Leigh River.

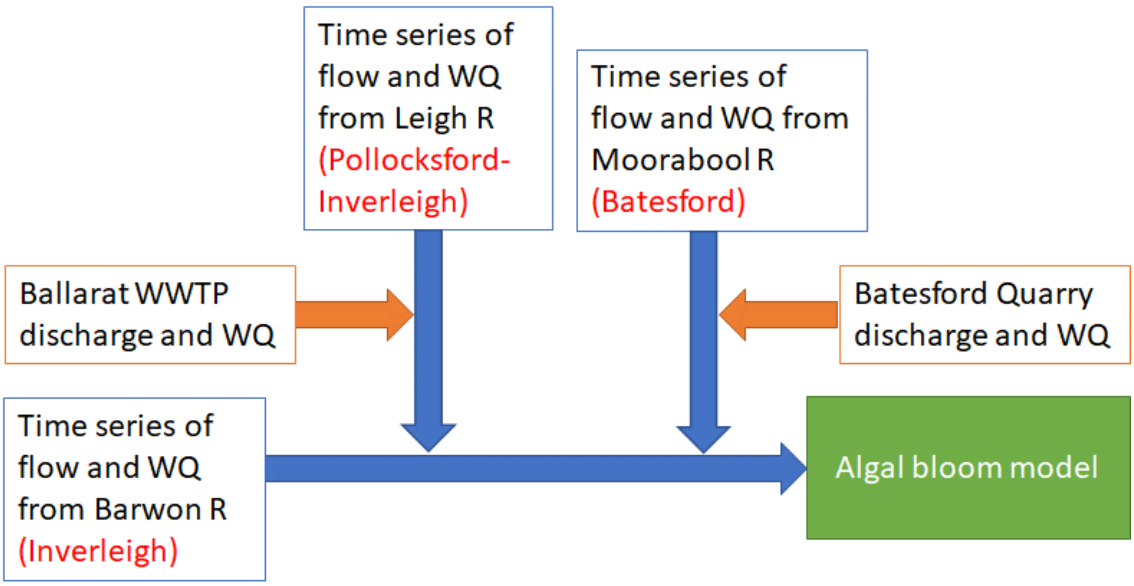

Figure 5-1 Diagram of the conceptual model of flow and water quality generated from the catchment

As discussed in the Scoping Report, an analysis was performed, using available water quality monitoring data, of the concentrations of the above constituents at monitoring sites through the catchment. The location of water quality monitoring sites is shown in Figure 5-2. Concentrations of nutrients discharged from WWTP were considerably higher than nutrient concentrations at all of the other monitoring sites through the catchment. Conversely, TSS and EC discharged from the WWTP are, in general, lower than concentrations recorded at the other monitoring sites. As with the nutrient concentrations, the suspended sediment concentrations and EC recorded at the Leigh River at Mount Mercer site generally sat between the Ballarat South WWTP and those recorded at other sites, due to mixing of the WWTP discharge with runoff from the Leigh River catchment.

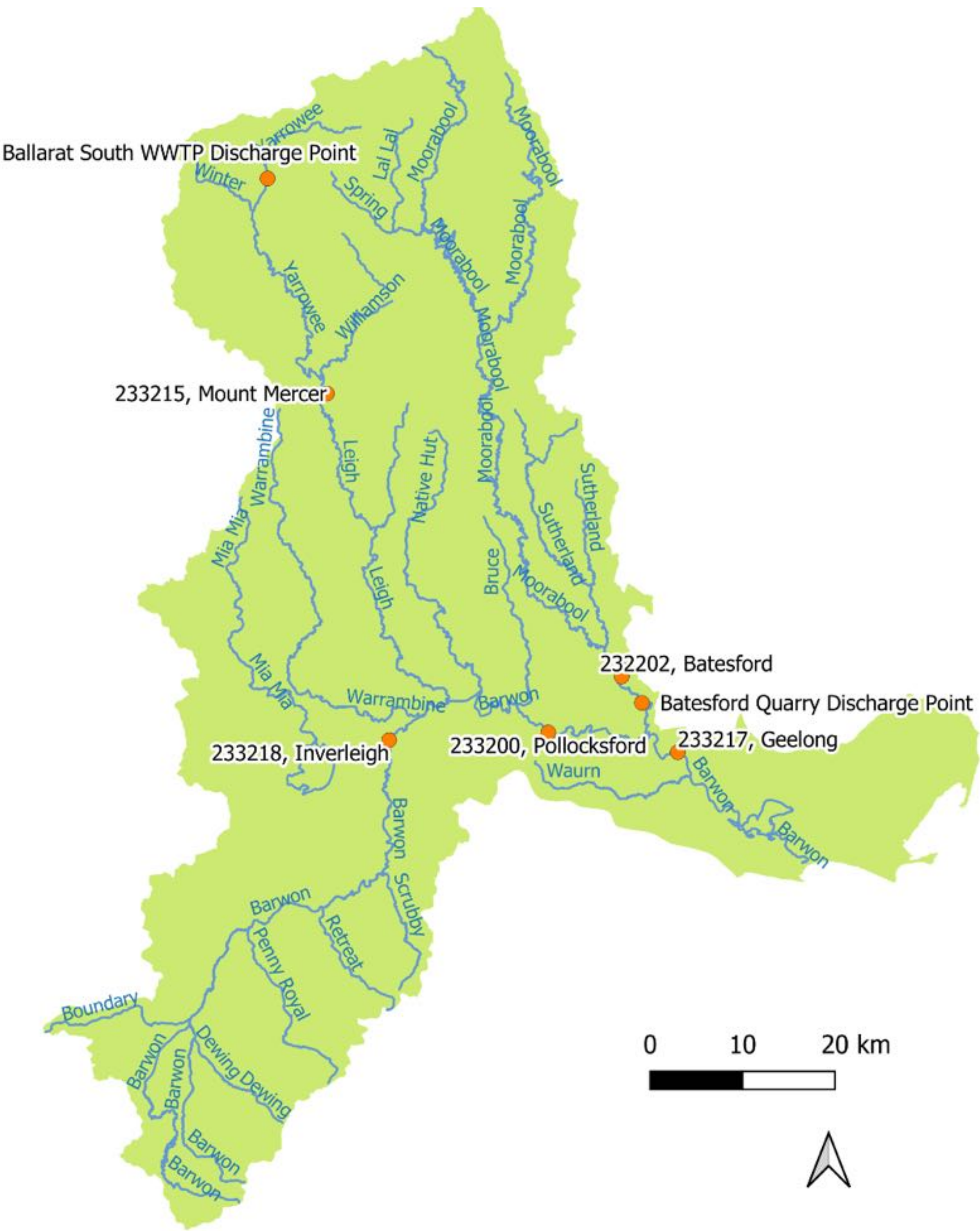

Figure 5-2: Location of water quality monitoring sites

5.2 Modelling approach

Daily flow and water quality inputs to the algal bloom model were created by:

- Disaggregating weekly modelled flows at key locations to daily
- Using daily flow versus water quality relationships to derive loads at these sites
- Combing loads and dividing by total flow to get water quality concentrations at Geelong.

The Barwon-Moorabool REALM model outputs weekly modelled data, which required disaggregation to be utilised in the daily algal bloom model. A different disaggregation approach was used for the regulated and unregulated flow components at each site. For the regulated component of the flow, it was assumed that the weekly flow is disaggregated uniformly to daily. For the unregulated component, a representative pattern was assumed. The two components were added back together to represent the daily flow at that site.

The first step of disaggregation was to separate out the regulated and unregulated share of flow at that location. This was undertaken by extracting the regulated share based on releases in the model and then assuming the remainder is unregulated flow. However, for the Moorabool River at Batesford, the converse was undertaken, where the unregulated portion of the flow was extracted from the model and the regulated share assumed to be the remainder.

To disaggregate the unregulated flow at the Barwon River at Inverleigh the sum of daily flows in the Barwon system from the Geelong Source model was utilised, excluding flows from the West Barwon River at West Barwon Dam.

The flow at the Leigh River includes the regulated discharge from the Ballarat South WWTP, which was disaggregated uniformly. The unregulated component in the Leigh River was assumed to be the total flow with WWTP removed. The weekly unregulated flow at Leigh River was disaggregated to daily by utilising the gauged pattern in the Leigh River at Mount Mercer (233215), which has data available from 1956. However, gauged flow at Mount Mercer has WWTP discharge embedded in the data. To remove this regulated flow from the gauged flow to use the unregulated component as a pattern for daily disaggregation, a combination of baseflow separation and historic WWTP discharge data was utilised. Historic WWTP discharge was adopted from 2002 to 2017. Prior to this, baseflow separation analysis was undertaken with the parameters adjusted until the magnitude of the baseflow removed was representative of the historic WWTP discharge from 2002 to 2017. The gauged flow at Mount Mercer with WWTP discharged removed (historic data from 2002 to 2017 and baseflow separation from 1956 to 2002) was used to disaggregate the Leigh River modelled flow from 1956 to 2017. As there was no data available, a method of fragments was used to disaggregate the data from 1927 to 1956.

To disaggregate unregulated flows in the Moorabool River at Batesford, the daily pattern at Leigh River was utilised as, when summed to weekly, it was most representative of weekly unregulated flow in the Moorabool River (INFLOW UPSTREAM 204 + 204 TO SHE OAKS INF + INF SHE-BATES). The weekly flows at Geelong were disaggregated using the sum of the daily patterns from the inflows upstream.

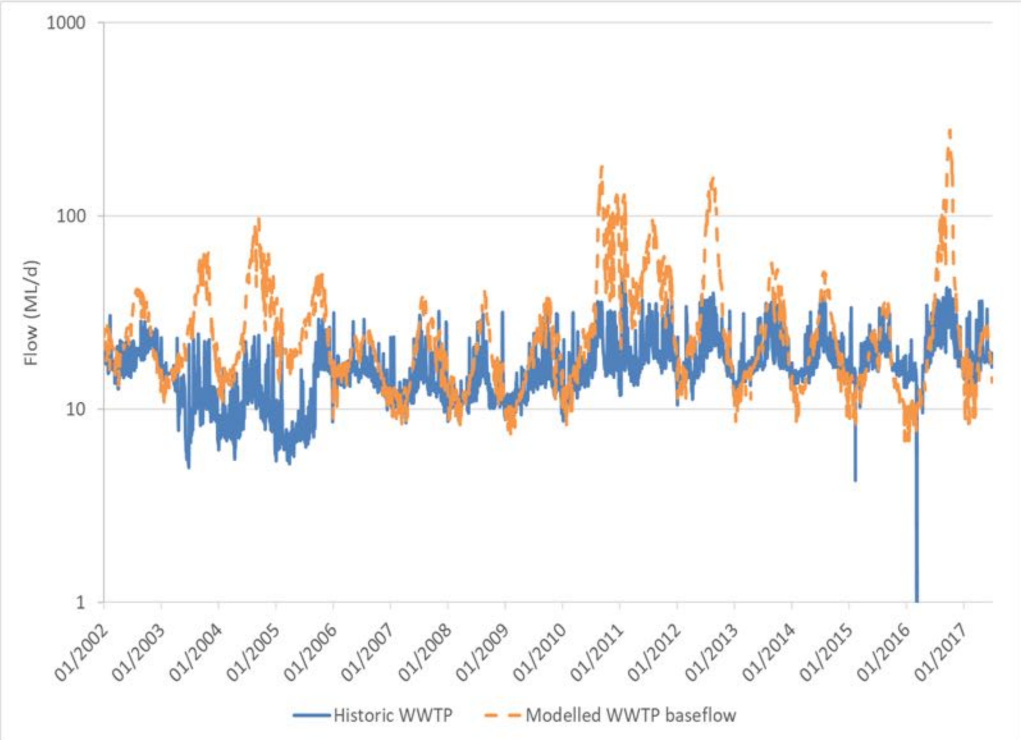

Figure 5-3 Modelled baseflow removal against historic Ballarat WWTP discharge

As discussed in the Scoping Report, analyses of the water quality monitoring data were conducted to derive relationships between flow and water quality concentration at each site. These relationships allowed for concentrations of each water quality parameter to be interpolated to a daily basis at each of the four monitoring sites: Barwon at Inverleigh, Leigh at Mount Mercer, Barwon at Pollocksford and Moorabool at Batesford. As discussed in the Scoping Report, daily water quality concentrations were estimated for discharges from the Ballarat South WWTP.

These fitted relationships were used to derive daily time series of concentrations for each constituent, at each site, for the full period from 1927-2017. The relationships were applied to derive daily concentrations for the base case and each of the scenarios.

For each scenario and for each constituent on each day of the model run period (1927-2017), concentrations in the Lower Barwon River at Geelong, c_G, were computed from:

$$c_G = \frac{c_{L+BSWWTP}Q_{L+BSWWTP} + c_{UB}Q_{UB} + c_{toG}Q_{toG} + c_{MB}Q_{MB} + c_{BQ}Q_{BQ}}{Q_{L+BSWWTP} + Q_{UB} + Q_{toP} + Q_{MB} + Q_{BQ}}$$

Where *c* was the daily concentration of a water quality constituent

Q was the daily flow

And the inputs were represented by:

- *L+BSWWTP* was the combined input from the Ballarat South WWTP and the Leigh River catchment

- *UB* was the upper Barwon River catchment to Inverleigh
- *toG* was the Barwon River catchment between Inverleigh/Leigh River confluence and Geelong
- *MB* was the Moorabool River to Batesford
- *BQ* was Batesford Quarry

For each scenario and for each constituent of the model run period (1927-2017), daily loads in the Lower Barwon River at Geelong were then calculated by multiplying the daily concentration estimates, computed using the above equation, by the daily flows computed from the REALM model.

5.3 Applying flow versus water quality relationships to calculate total load

Daily flow versus water quality relationships, previously derived from historic data and discussed in the Scoping Paper, were used to derive concentrations and loads, for each scenario, and for each of the input locations: the Leigh River, Barwon River at Inverleigh, Moorabool River at Batesford and for the quarry and WWTP discharges. These were combined to derive a time series of concentrations applicable for Geelong and used with modelled Geelong flows disaggregated to daily to form inputs to the algal bloom model.

For the base case, the daily time series of concentrations from the Ballarat South WWTP and the Leigh River catchment was computed by analysing flow versus water quality relationships from the monitoring site on the Leigh River at Mount Mercer. For those scenarios that modified volumes discharged from the WWTP, an adjustment was made to this load component. The relative contributions from WWTP and the Leigh River catchment to the mean annual load of each constituent were computed for the base case. The contributions to mean annual load from the Leigh River catchment were assumed to remain unchanged but the contributions to load from the WWTP were factored in accordance with the change in mean annual discharge, for each of the scenarios. This was then used to calculate an adjustment factor for the concentration of each constituent, due to the change in the discharge from WWTP for each scenario. This adjustment factor, which was assumed to be constant for all days (but varied by constituent and scenario), was used to factor the daily concentrations for the Leigh + WWTP time series in each scenario.

As discussed in the Scoping Report, there was limited data to assess the water quality discharged from the Batesford Quarry. However, the monitoring data that was available showed that Batesford Quarry generally had relatively high EC but low concentrations of nutrient and sediment. Based upon the analysis of the monitoring data from within the quarry, discharges from Batesford Quarry were therefore assumed to be at constant concentrations of:

- 0.02 mg/L of NOx,
- 0.08 mg/L of NH4+,
- 0.2 mg/L of TN,
- 0.05 mg/L of TP,

- 2 mg/L of TSS and
- EC of 5950 uS/cm.

5.4 Assumptions and limitations

The model for estimating water quality generated from the catchment was based upon analysis of monitoring data from several long-term sites across the catchment. This analysis was able to pick up temporal variations in water quality and represent, to some degree, the relationship between flow and water quality loads. This approach was appropriate for a preliminary assessment of the influence on water quality of options that were focussed on changing flows. However, water quality is also likely to be dependent upon on other drivers, such as land use change, changes in agricultural practices and management and restoration of riparian zones. Simulating these influences is outside of the scope of the current project. If these influences were to be considered, a more spatially explicit model, such as a Source Catchments model of the catchment would be required.

The modelling approach effectively considered that loads contributed from Ballarat South WWTP reach the monitoring site on the Leigh River at Mount Mercer, without attenuation. It is possible that some of the load contributed by WWTP would be assimilated along the stream between the discharge point from the treatment plant and the monitoring site. Similarly, water quality loads were treated as being conserved between each of the upstream monitoring sites (at Mount Mercer, Inverleigh and Batesford) and Geelong. Again, it is possible that some attenuation of loads could occur along the rivers and streams between these upstream sites and the Lower Barwon River. Under some conditions, it is also possible that some re-mobilisation of sediments and nutrients could occur from bed materials. These aspects could be incorporated in a more spatially explicit model, such as a Source Catchments model.

Treatment processes were last upgraded at the WWTP in around 2000/01. The model assumed that the water quality discharged from WWTP in future will continue to be similar to that discharged since about 2001. It is possible that investments could be made at WWTP to further reduce the concentrations of nutrients discharged from the treatment plant.

As discussed in Section 3.1.2, there are losses from surface water flows, presumably to groundwater, in the lower reaches of the Barwon and Moorabool Rivers. Water that is lost from the river system would carry with it the dissolved components of the water quality loads. The conceptual model for estimating water quality generated from the upstream catchment assumed that the concentrations of each water quality constituent at Geelong were the same as the flow-weighted concentrations from the upstream catchment. This assumption effectively assumes that any water lost from the lower reaches from the model carry out constituents at the same concentration as the water generated from upstream. Whilst this approach is likely to be reasonable for dissolved constituents, such as EC and most of the Nitrogen, it possibly results in slightly lower loads at Geelong for those constituents that are at least partially transmitted in particulate form, TSS and TP. As with the above two limitations, this could also be addressed by a Source Catchments model that allows for more process representation of loss of sediment and nutrients from the river system.

6. Algal bloom modelling

The purpose of this component of the project is to simulate algal blooms in the Barwon River at Geelong using a simple predictive algal bloom model and test the effects of future flow scenarios.

6.1 Key model assumptions

See Section 3.5 of project's Scoping Paper for a full discussion of the algal bloom modelling approach.

Primary drivers of blue-green algal blooms in the Barwon River at Geelong are flow and total phosphorus concentrations. Flow-related thresholds for blue-green algal growth were identified by studying the blue green algal data relationship with flow over some recent algal bloom events in the Barwon River at Geelong. The following flow-thresholds were incorporated into the predictive model:

- < 20 ML/d is favourable for algal growth
- 20-50 ML/d inhibits growth but does not disperse the bloom
- 50-150 ML/d reduces (by factor of 2 per day) but does not eliminate blooms
- 150-400 ML/d significantly reduces (by factor of 4 per day) the algal counts
- >400 ML/d eliminates all blooms from the river

Phosphorus concentrations for the Barwon River at Geelong were developed from a flow vs water quality relationship for the catchment loads (see Section 3). A phosphorus decay rate of 0.05 d^{-1} was applied when flows in the river were less than 50 ML/d, to account for assimilation through biomass growth.

An algal bloom was defined as >50,000 cells/ml of total blue-green algal cells.

6.2 Updated model calibration

The algal bloom model was calibrated using daily flow and monthly averages from 1999 to 2010 and infilled historic flow and water quality data from 2011 – date. Simulated algal counts correlated well with the observed weekly total cyanobacterial counts at key monitoring sites within the Barwon River at Geelong river reach (Figure 6-1). The model predicted the presence/absence of algal blooms at the correct times. It predicted the years that did not have algal blooms (i.e. 2002, 2005 and 2011).

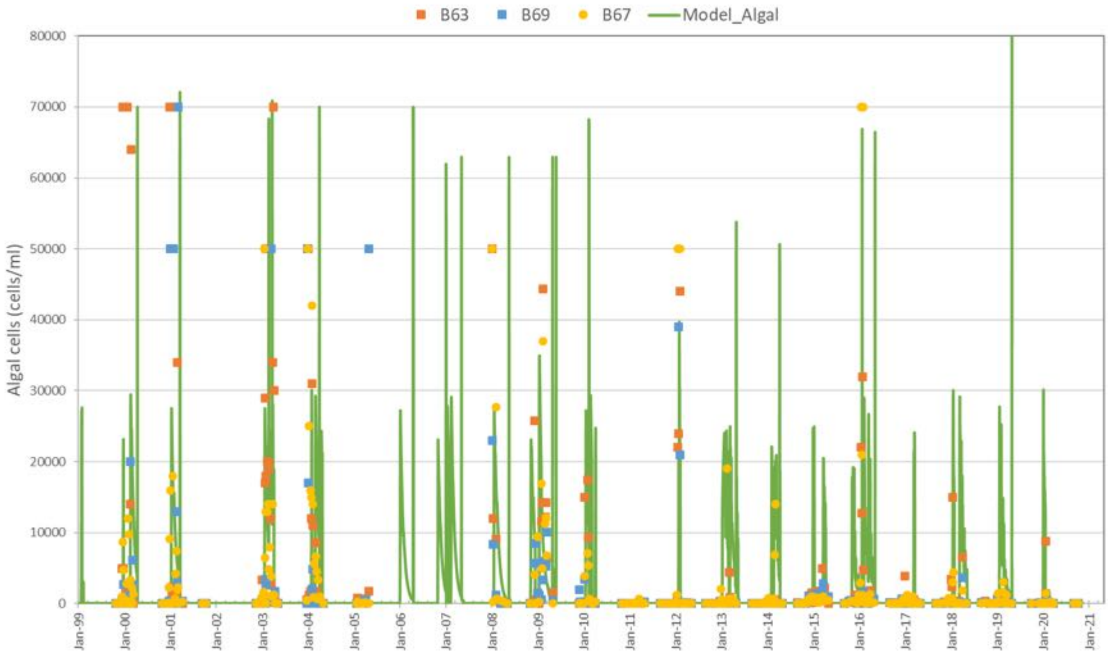

Figure 6-1 Calibration of algal bloom model outputs (green line) for Barwon River at Geelong with observed total cyanobacterial counts (weekly) at monitoring sites at B67 (Fyans Park), B63 (MacIntyre Bridge) and B69 (Breakwater Road)

6.3 Base case modelling results

Daily algal bloom cell count in the Barwon River was simulated from 1927 to 2017 using flow and water quality inputs from the previous tasks for the Base Case. The results have been presented as the number of days per year when algal blooms (>50,000 cells/ml) are predicted to be present in the river.

6.3.1 Current climate

Under current climate, base case conditions, an average of 27 days/year with algal blooms was predicted over the 90-year modelled period (Figure 6-2).

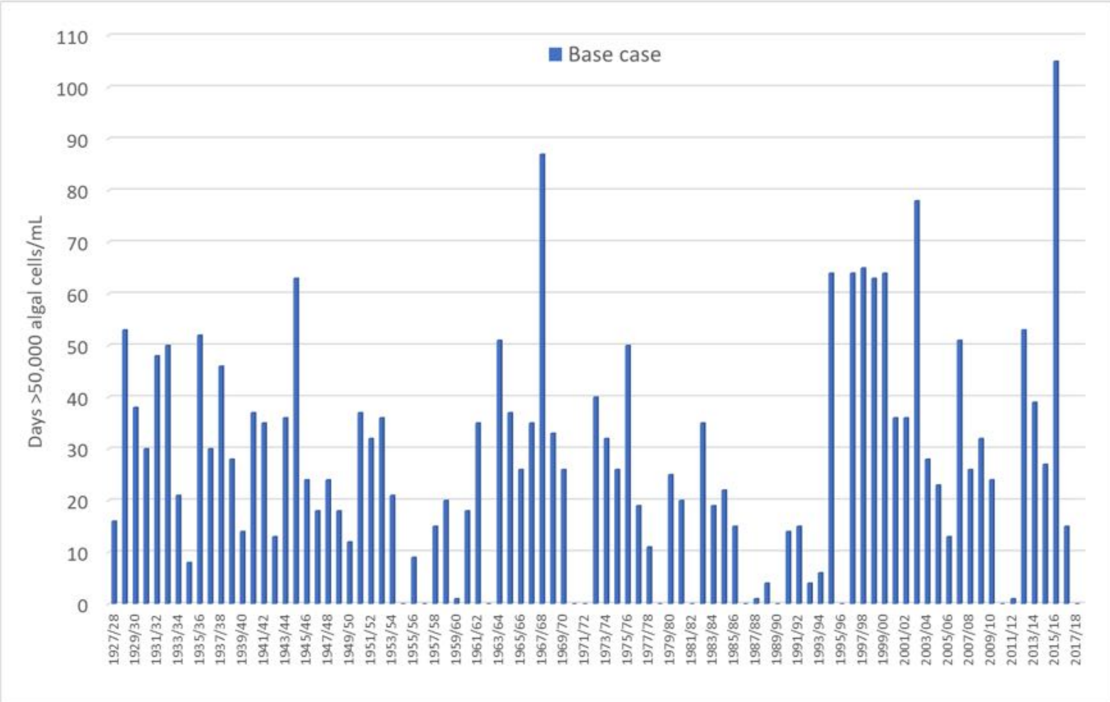

Figure 6-2 Base case: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.3.2 Future climate

Both the base case post-1997 adjustment for climate change scenario and base case 2065 high climate change scenario reduces the algal blooms over the 90-year modelled period to 18 days/year compared to current climate average of 27 days/year (Figure 6-3). This is due to a drop in nutrient-laden catchment inflows, which offsets the effect of the flow reduction on algal blooms.

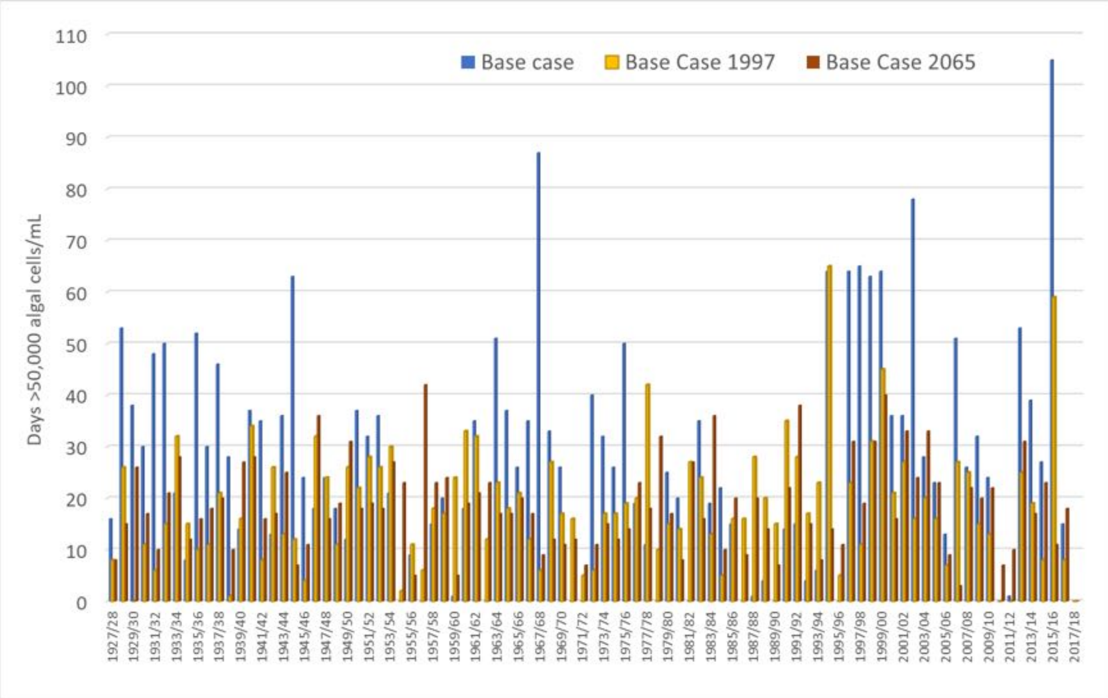

Figure 6-3 Base case (current climate) and future climate adjusted base cases for 1997 and 2065 climate scenarios: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.4 Scenario modelling results

6.4.1 Scenario 1: Changes to Ballarat South WWTP discharges

As per section 2.3.1, Ballarat South WWTP discharges around 7.8 GL annually to the Upper Leigh River, which is included in the base case. The WWTP discharges contain elevated concentrations of nitrogen and phosphorus that adds to the catchment loads.

Scenario 1a involves reducing the flows to 2 GL (with a corresponding reduction in the nutrient loads). While reducing flows may increase the likelihood of creating conditions conducive to algal blooms, reducing nutrient loads will reduce the magnitude of algal blooms. The model simulation for Scenario 1a shows that the reduction in nutrient loads is more significant than flow and leads to a decrease in the duration of algal blooms compared to the base case (Figure 6-4). The average days per year with algal blooms reduces from 27 days/year for the base case to 6 days/year for Scenario 1a. In making this assessment, it should be noted that nutrient decay along the run of river downstream of the WWTP outfall was not factored into water quality predictions at Geelong.

Scenario 1b is run with WWTP discharges switched off, to show the contribution that the WWTP discharges make to flows and nutrient loads at Geelong (Figure 6-5). The average days per year with algal blooms reduces from 27 days/year for the base case to 3 days/year for Scenario 1b.

Scenario 1c involves storing some of the WWTP discharge so greater volumes can be discharged at times when Geelong flows are low (Figure 6-6). The average days per year with algal blooms reduces from 27 days/year for the base case to 7 days/year for Scenario 1c.

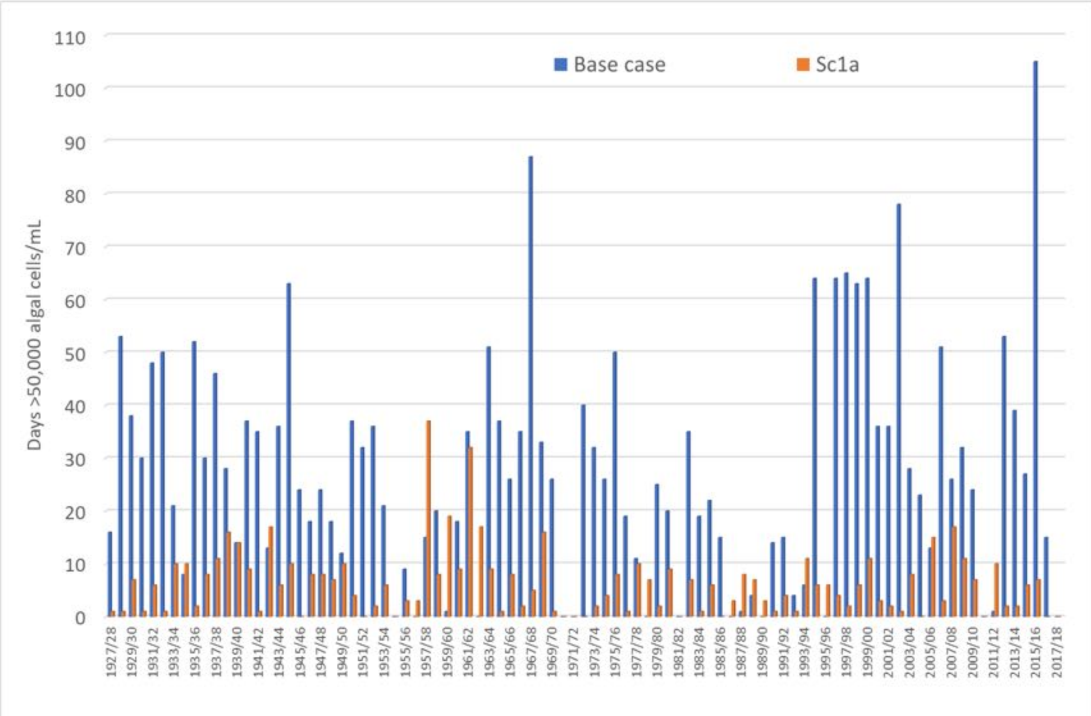

Figure 6-4 Base case and Sc1a: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

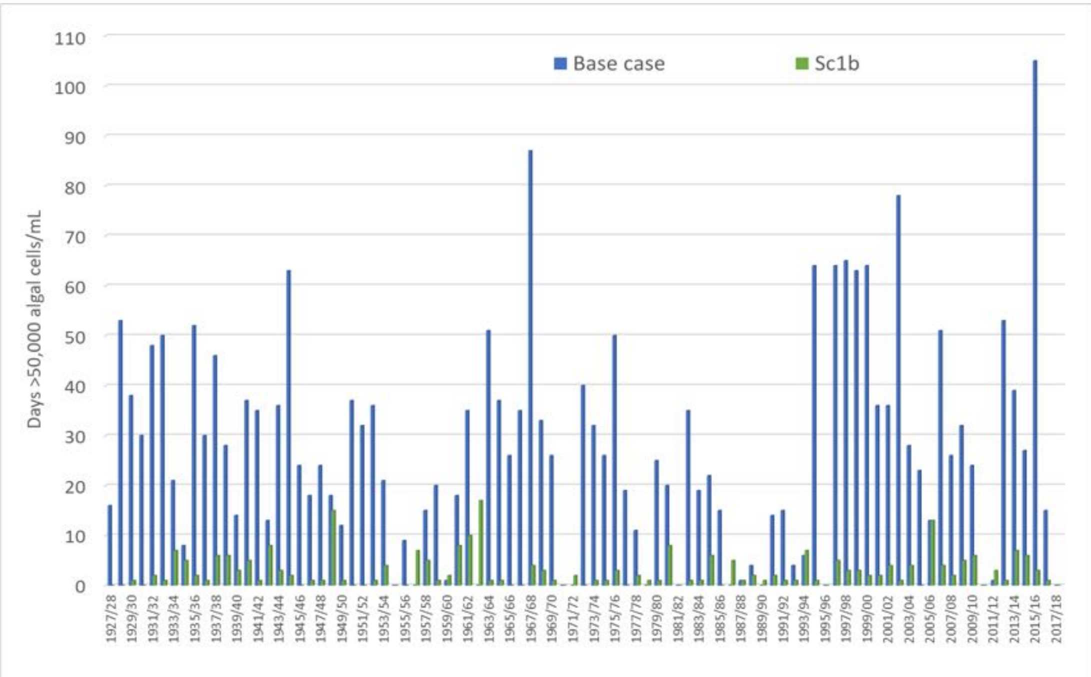

Figure 6-5 Base case and Sc1b: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

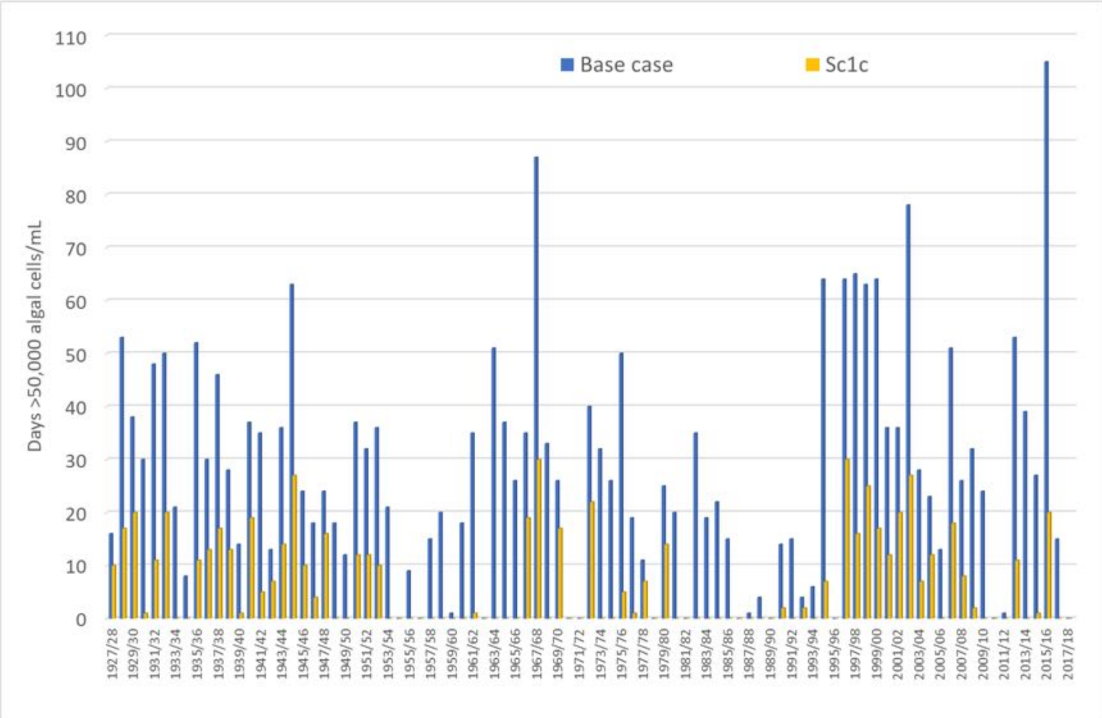

Figure 6-6 Base case and Sc1c: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.4.2 Scenario 2: Changes to Batesford Quarry discharges

As per section 2.3.2, Batesford Quarry currently discharges around 3.5 GL annually to the Moorabool River below Batesford. Scenario 2a involves reducing that by 50%, while Scenario 2b is run with quarry discharges switched off, to show the contribution that they make to flows at Geelong.

For Scenario 2a, the average days per year with algal blooms increases from 27 days/year for the base case to 33 days/year (Figure 6-7). This is due to the reduction in low nutrient flows in the Barwon River at Geelong.

For Scenario 2b, the average days per year with algal blooms increases from 27 days/year for the base case to 38 days/year (Figure 6-8). This is due to the reduction in low-nutrient flows in the Barwon River at Geelong without the quarry discharges.

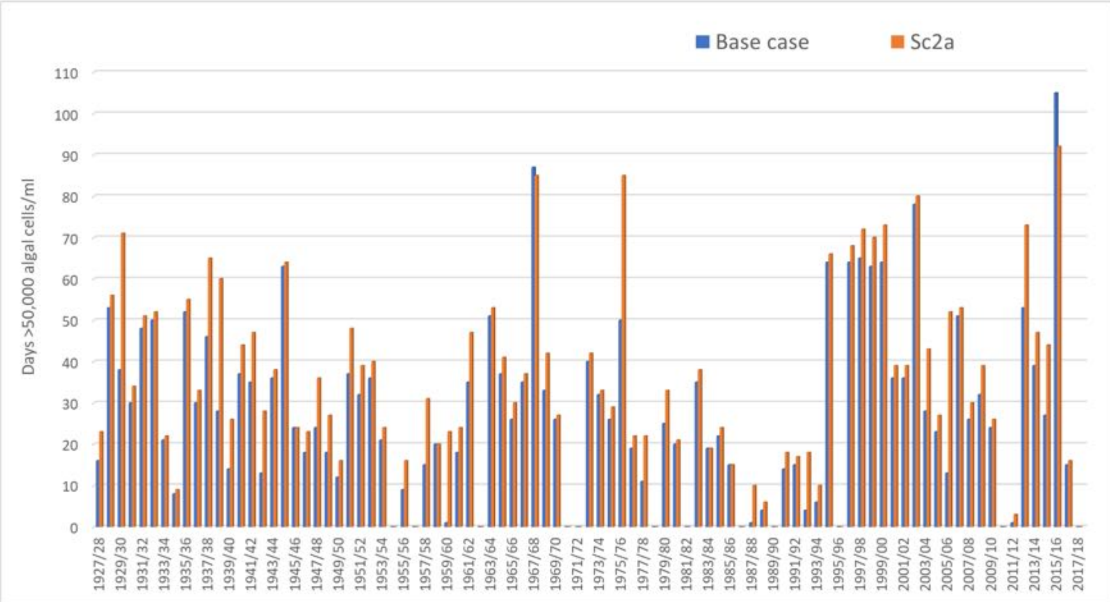

Figure 6-7 Base case and Sc2a: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

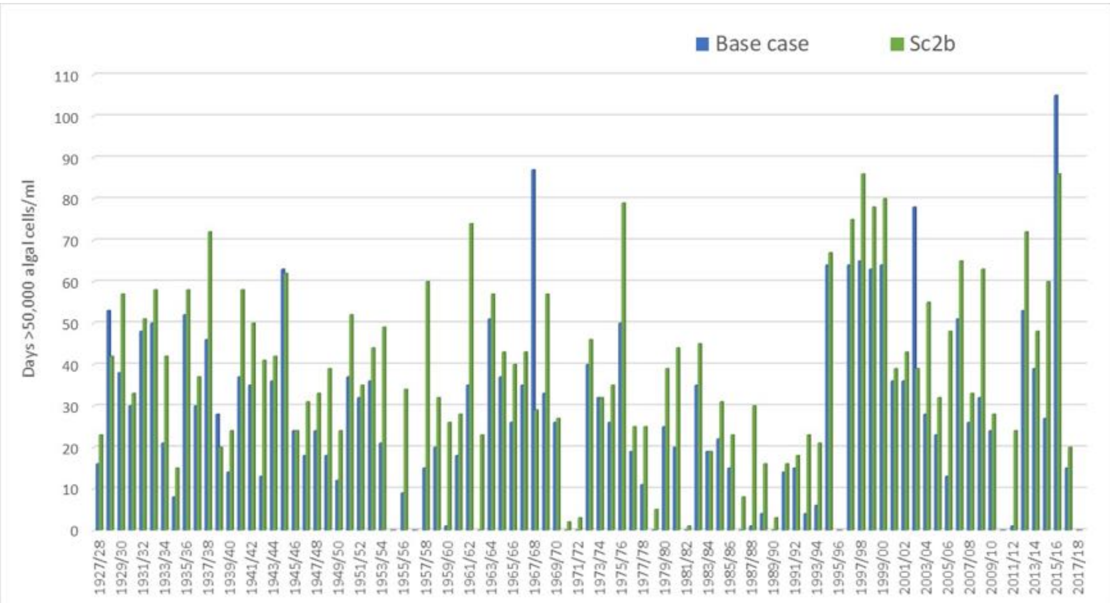

Figure 6-8 Base case and Sc2b: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.4.3 Scenario 3: Meeting water recovery targets

Scenario 3a involves increasing the environmental share in Lal Lal and West Barwon reservoirs to meet the minimum environmental flow requirements in reaches downstream of the storages. Scenario 3b involves higher environmental flow requirements downstream of Lal Lal and West Barwon reservoirs. This flow delivery pattern reduces the average number of days per year with algal blooms from 27 days/year for the base case to 12 days/year for Scenario 3a and Scenario 3b (Figure 6-9).

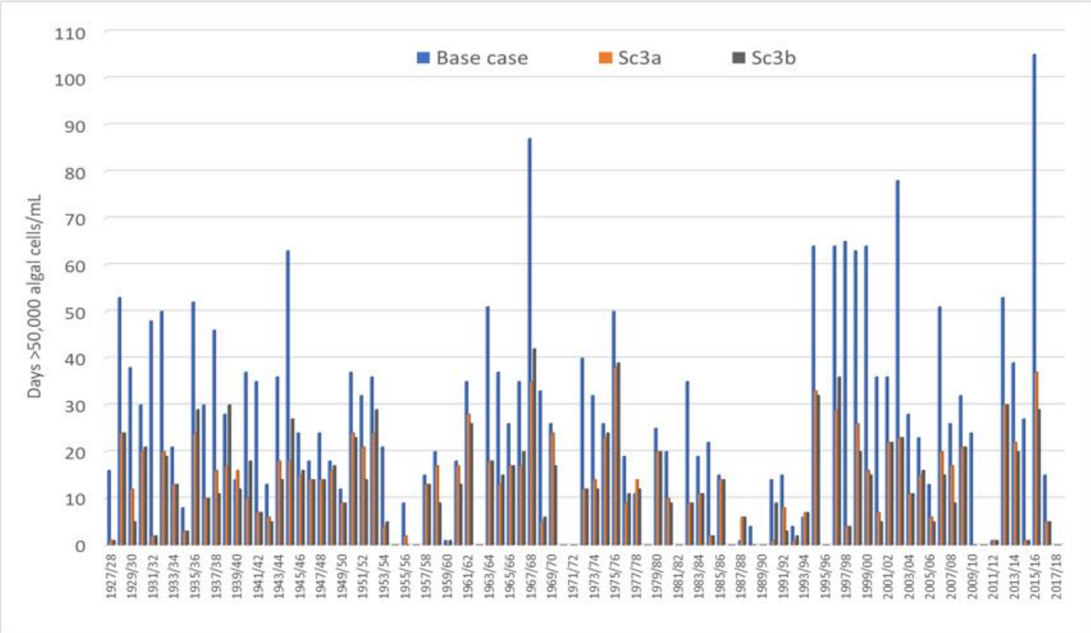

Figure 6-9 Base case and Sc3a and b: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

Scenario 3c delivers dry and wet season low flows to reaches further downstream, and result in a marked reduction in the frequency and severity of algal blooms. This is achieved through increasing the environmental share of water storages and prioritising the delivery of low flow environmental flow recommendations in reaches closer to Geelong (Figure 6-10).

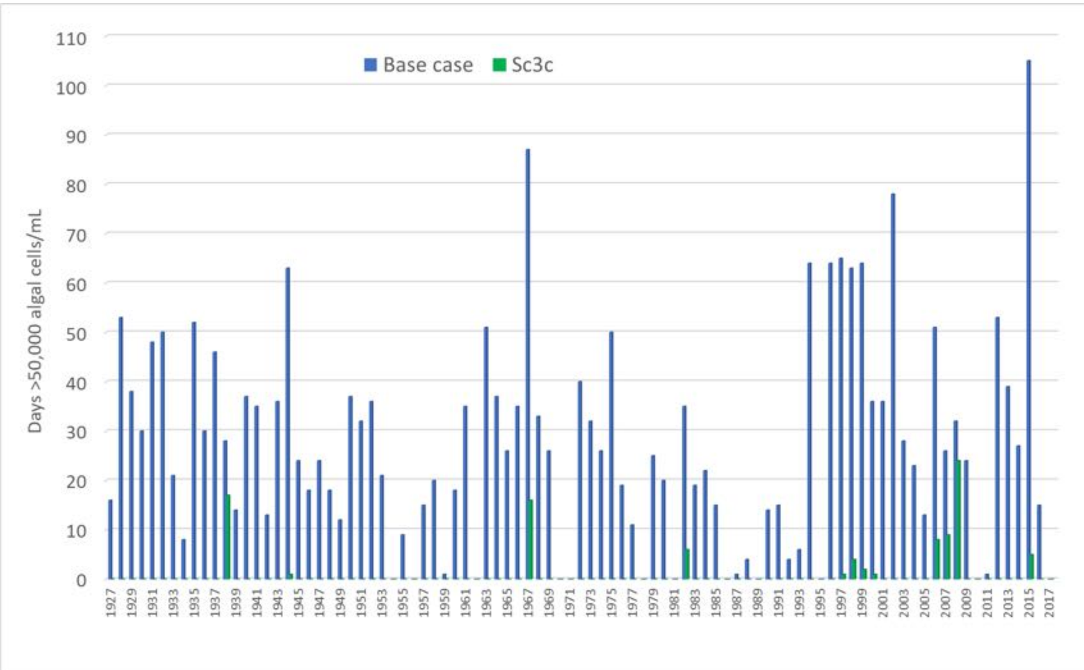

Figure 6-10 Base case and Sc3c: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.4.4 Scenario 4: Water recovery with optimised WWTP discharge

Scenario 4 is the same as Scenario 3b in terms of meeting higher environmental flow requirements from Lal Lal and West Barwon reservoirs. However, in Scenario 4, the BSWWTP discharges were optimised for environmental flows by utilising off-stream storage. This flow delivery pattern reduces the average number of days per year with algal blooms from 27 days/year for the base case to 6 days/year for Scenario 4 (Figure 6-11).

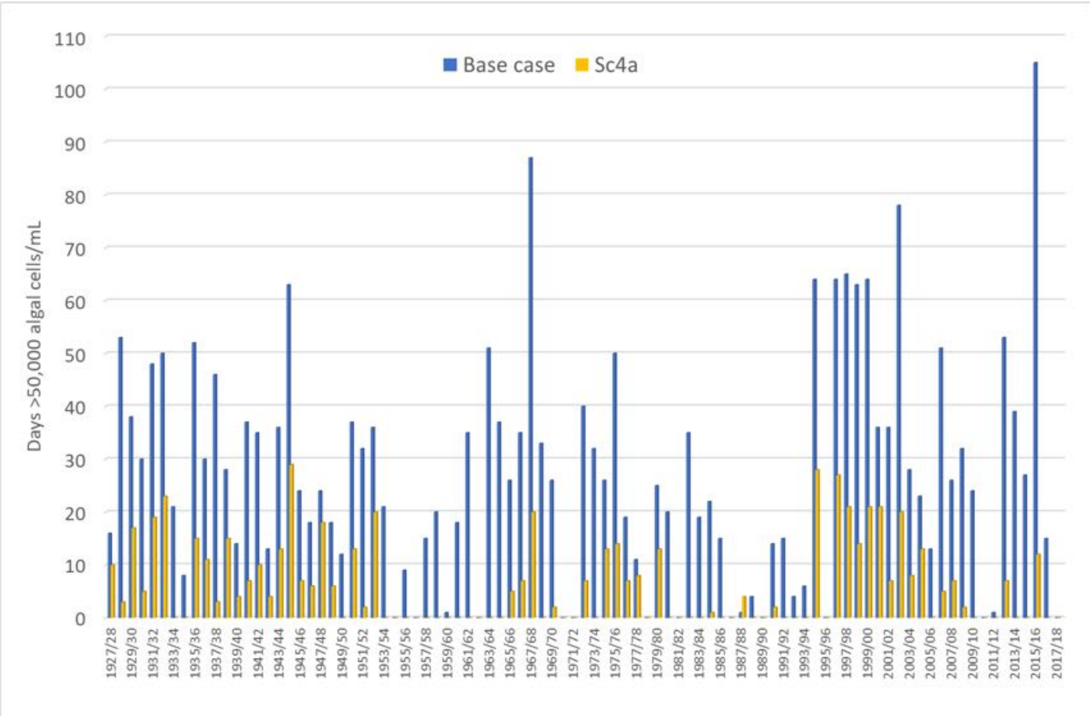

Figure 6-11 Base case and Sc4: predicted number of days per year with algal blooms (>50,000 cells/mL) in the Barwon River

6.5 Summary of results

According to the algal bloom model simulations, reducing the Ballarat South WWTP discharges reduces the algal bloom frequency/duration compared to the base case due to the reduction in nutrient loads (Scenario 1). *However, the decay/assimilation of the effluent-derived nutrients along the river prior to Geelong needs greater attention to verify this result.* Reducing or eliminating the discharges from Batesford Quarry causes algal bloom frequency/duration to increase (Scenario 2). Delivering low flow environmental flow recommendations to the lower reaches of the system significantly reduces the frequency/duration of algal blooms (Scenario 3c).

Table 6-1 Comparison of no. days per year with algal blooms in Barwon River at Geelong per Scenario. [green shading = better than base case; orange shading = worse than base case]

Stats	Base Case	Base 1997	Base 2065	Sc1a	Sc1b	Sc1c	Sc2a	Sc2b	Sc3a	Sc3b	Sc3c	Sc4
Median	25	17	18	6	2	1	30	35	13	11	0	3
Ave	27	18	18	6	3	7	33	38	12	12	1	6
Max	105	65	42	37	17	30	92	86	38	42	24	29

Modelled time series were then analysed to check the periods of each year when this reach of river is used for rowing and other on river events and recreational use. As above, the key events considered were:

- Barwon Regatta (Australia day weekend in January)
- Head of the School Girls Regatta (second weekend of March).

The impact of the climate change and water recovery scenarios is evident on these key rowing events as seen in Table 6-2 below.

Table 6-2 Number of years BGA cell counts exceed 50,000 cells per ml at the time of key rowing events.

Scenario*	Barwon Regatta (Australia Day)		Head of School Girls Regatta (March)	
	No of years above 50,000 cells per ml***	% years from 1927 to 2017	No of years above 50,000 cells per ml***	% years from 1927 to 2017
Base case post 75 climate	28	30%	19	21%
Base case post-97 climate	13	14%	20	22%
Base case 2065 High climate change	11	12%	10	11%
Scn 1a: Ballarat South WWTP discharge reduced to 2 GL	5	5%	11	12%
Scn 1b: Ballarat South WWTP discharge turned off (Scn 1 worst case)	0	0%	7	8%
Scn 1c: Ballarat South WWTP discharge pattern manipulated (Scn 1 best case)	7	8%	10	11%
Scn 2a: Batesford quarry discharge reduced by 50% (Test impact of no winter discharge)	36	39%	23	26%
Scn 2b: Batesford quarry discharge turned off (Scn 2 worst case)	38	41%	28	31%
Scn 3a: Min enviro water recovery target	12	13%	10	11%
Scn 3b: Higher enviro water recovery target	12	13%	12	13%
Scn 3c: environmental water recovery for lower reaches	0	0%	3	3%
Scn 4: Ballarat South WWTP discharge pattern manipulated and Higher water recovery target	8	9%	6	7%

Notes
* The event date used is 26/01 in any given year
** The event dates used are Friday to Sunday (inclusive) of the third weekend in March in any given year
*** A year is counted if BGA levels are higher than 50,000 cells per ml on any one of the days counted for the event dates.

6.6 Assumptions and limitations

The following aspects are limitations of the model:

- The model is developed and calibrated based on incomplete and sporadic monitoring data, which limits the accuracy of the outputs.
- The model outputs are based on a simple stoichiometric relationship couple to a derived flow-algal bloom site-specific relationship. This does not attempt to capture all the complex biological processes the contribute to or are affected by algal blooms.
- The model does not account for stratification patterns or wind-driven mixing that may limit the algal biomass growth.
- The model does not account for the mobilisation of nutrients stored in the sediments of the Lower Barwon River that may fuel algal blooms.
- There was no useful flow gauging or monitoring data on stormwater discharges from the Geelong urban area into the lower Barwon River or estuary. Gauging and monitoring of stormwater discharges would assist to quantify the stormwater contribution to flows and loads.
- The model does not differentiate between blue-green algae and other algal species.
- Fluctuations of water quality are accounted for by developing factors for seasonal and flow-based qualities from monthly water quality monitoring data.
- Decay of nutrient-laden point-source discharges from the Ballarat South WWTP has not been accounted for in the catchment water quality modelling. This assumption is discussed further, in Section 6.6.1 below.

6.6.1 Effect of not accounting for decay

Not accounting for the decay/assimilation of nutrients from the Ballarat South WWTP point source effluent discharge biases the outcome of the algal bloom scenario modelling in favour of Scenario 1. Scenario 1 is shown to significantly reduce the magnitude of algal blooms at Geelong by eliminating, reducing, or optimising the WWTP discharges to the Leigh River but the modelled impact of reducing the BSWWTP discharge is likely to be over-estimated compared with real-world outcome. Treated WWTP effluent has highly bioavailable forms of nutrients that are assimilated quickly in ambient riverine environments. The WWTP outfall is 80 km upstream of the lower Barwon River study area, so any residual effects of the WWTP discharge on nutrient loads are likely to be over-estimated at Geelong. Monitoring data at Geelong shows severe depletion of inorganic nitrogen over the summer period which supports this hypothesis. These nitrogen limiting conditions explains why cyanobacterial blooms of Microcystis and Dolichospermum have a competitive advantage over other algal species in the Barwon River (see Section 6.4 of the Scoping Paper).

Continuous WWTP discharges constitute a significant fraction of the flow and nutrient loads during dry periods and prolonged low flow conditions which are the focus of this study. While WWTP discharges are only a small fraction of the annual nutrient loads (which get overwhelmed by catchment loads during large flow events), there is a significant effect on in-stream concentrations during low flows (Figure 6-12). By not incorporating nutrient decay into the modelling (at the request of CCMA), the nutrient concentrations of the inflows to the Barwon River at Geelong for the **base case** are an order of magnitude above measured data [TP (summer av.) = 0.07 mg/L; NOx (summer av.) = 0.11 mg/L (Figure 6-12).

Scenario 1B switches off the WWTP discharges. Comparing the base case with Scenario 1B shows only a minor reduction in flow at Geelong during low flow periods, but the TP and NOx concentrations are significantly lower, particularly during low flow periods (Figure 6-12). Modelled nutrient concentrations for Scenario 1B are more closely aligned with measured data, which supports the hypothesis that the residual WWTP nutrient loads are insignificant at Geelong. By not accounting for decay, the algal bloom modelling results (which are based on a flow and water quality conditions) are biased towards scenarios that reduce, eliminate, or optimise the WWTP discharges.

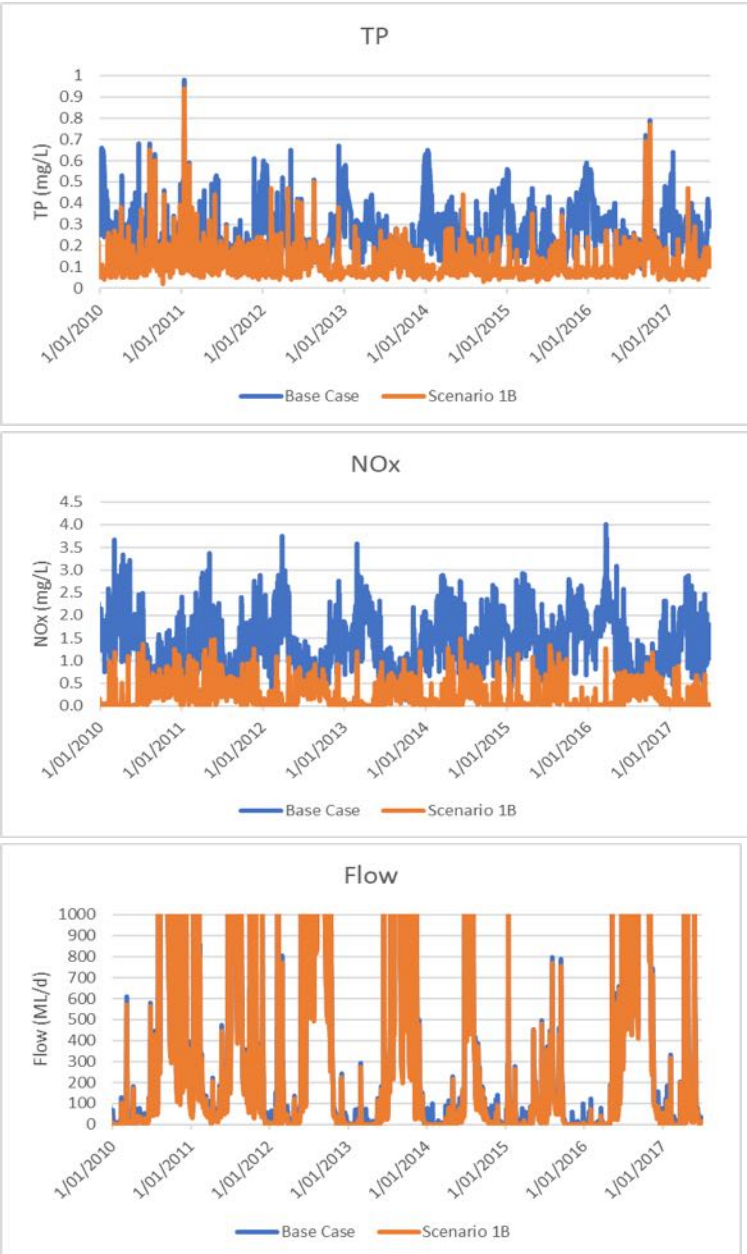

Figure 6-12 Modelled TP and Nox concentrations in the Barwon River and corresponding flow for Base Case (with WWTP discharges) and Scenario 1b (without WWTP discharges)

6.6.2 Effect of not accounting for sediment nutrient fluxes

Sediment nutrient fluxes in the Barwon River at Geelong were studied by Longmore & Nicholson (2010). They found sufficient levels of stored phosphorus and flux from the sediments to supply the magnitude of blooms experienced in the Barwon River. Most of the phosphorus was reversibly bound by iron compounds that could be released by prolonged anoxic conditions. These conditions may occur during prolonged low flow conditions, particularly in summer and autumn, when the water column can undergo thermal and/or saline stratification. They concluded that the sediment stores of phosphorus were sufficient to supply blue green algal blooms for at least one decade and that reductions in blue green algal blooms were unlikely in the short to medium term, even if catchment nutrient sources were reduced.

Sediment nutrient fluxes have not been quantitatively included in the algal bloom modelling for this study but were assumed to be constant across all scenarios. The difficulty in reducing/eliminating nutrient sources from ongoing sediment nutrient fluxes, in addition to catchment nutrient sources, shows the importance of providing flows for mitigating blue green algal blooms, at least in the short to medium term.

7. Summary of results

Examination of water quality data shows there is a risk of algal blooms when flows drop below 20 ML/d. **Base case** modelling over a long climatic sequence showed that flows drop below 140 ML/wk for an average of 12 weeks per year. When run thorough the algal bloom model, this results in algal blooms for an average of 27 days per year.

Scenario 1: Changes to Ballarat South WWTP discharges explored the contribution the Ballarat South WWTP makes to flows and nutrient loads, and the impact that changed discharges have on the results. Reducing discharges to 2 GL, which is the volume to be maintained for environmental purposes as specified in the current Central Region SWS (Scenario 1a) increases the number of weeks of low flows per year, but decreases the average number of days of algal blooms per year due to a reduced nutrient load during summer.

Turning discharges off (Scenario 1b) results in a significantly reduced average number of days per year of algal blooms due to reduced nutrient loads. Manipulating the pattern of discharge so that the incidence of low flow times are reduced (Scenario 1c) increased the variability, but also reduced the number of days per year of algal blooms compared to the base case. This suggests that the nutrient load impact can be offset by maintaining higher flows.

It is noted the decay/assimilation of the effluent-derived nutrients along the river prior to Geelong needs greater attention to verify this result.

In terms of the ability to maintain the critical river depths required for rowing, this reduces significantly compared to the base case if WWTP discharges are reduced (Scenarios 1a and 1b), but can be significantly improved by the manipulation of the WWTP discharge pattern (Scenario 1c).

Scenario 2: Changes to Batesford Quarry discharges showed that while changing discharges from the quarry makes only a small difference to the number of weeks per year that Geelong flows are below 140 ML/wk, these discharges have an important dilution effect in summer, as the average number of days of algal bloom increases substantially when they are decreased or turned off. Decreasing or turning of this discharge also has a small impact on the ability to maintain the critical river depths required for rowing.

Scenario 3: Meeting environmental water recovery targets. Scenarios 3a and 3b focussed on delivering environmental flows to the reaches immediately downstream of each storage. These scenarios slightly reduce the number of weeks of low flow at Geelong, provide a more significant reduction in the average number of days of algal blooms, and improve the ability to maintain the critical river depth required for rowing.

Scenario 3c focusses on delivering wet and dry season low flows to reaches immediately upstream of Geelong. This scenario significantly decreases the number of weeks of low flow at Geelong and hence the frequency of algal blooms. It provides the best results in terms of the ability to maintain critical rowing depth.

Scenario 4: Environmental water recovery with optimised WWTP discharges also successfully reduces the average number of days of algal blooms, and significantly improves the ability to maintain the critical river depth required for rowing.

Climate change modelling showed that the number of weeks with flow below 140 ML/wk increases compared to the current (baseline) climate case, but that algal blooms actually decrease due to the overall drop in nutrient load from the whole catchment. In terms of river levels at Geelong for key events, climate change has a significant impact on how often required depths can be achieved for key events.

Table 7-1: Summary of modelling results

Scenario	Avg no wks per yr < 140 ML/wk	Avg no days per yr algal blooms	% of years above critical depth for rowing	
			Head of schoolgirls Regatta	Barwon Regatta
Base case (current)	12	27	29%	37%
Base case (future 1997 climate)	17	18	21%	30%
Base case (future 2065 climate)	23	18	9%	16%
Scn 1a: WWTP discharge reduced to 2 GL	17	6	15%	20%
Scn 1b: WWTP discharge zero	18	3	11%	16%
Scn 1c: WWTP discharge pattern changed	8	7 (note median of 1)	67%	81%
Scn 2a: Quarry discharge halved	12	33	27%	34%
Scn 2b: Quarry discharge zero	15	38	26%	27%
Scn 3a: Min water recovery target	11	12	34%	45%
Scn 3b: Higher water recovery target	11	12	35%	45%
Scn 3c: environmental water recovery for lower reaches	3	1	90%	88%
Scn 4: Water recovery optimised	8	6	64%	79%

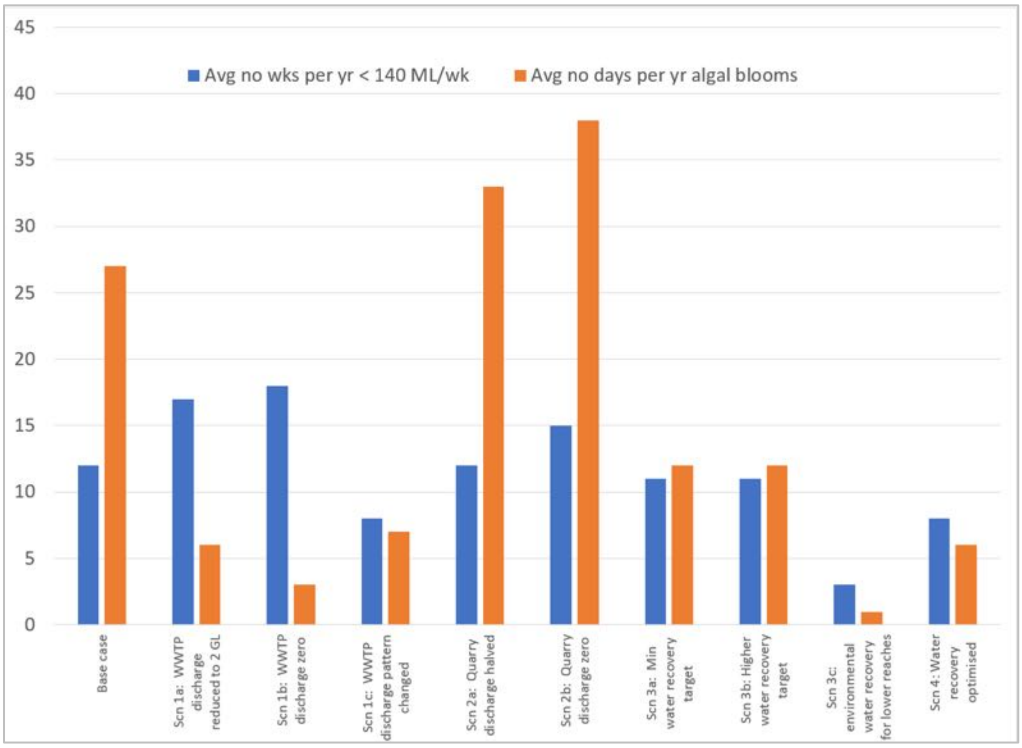

Figure 7-1: Summary of results – scenarios

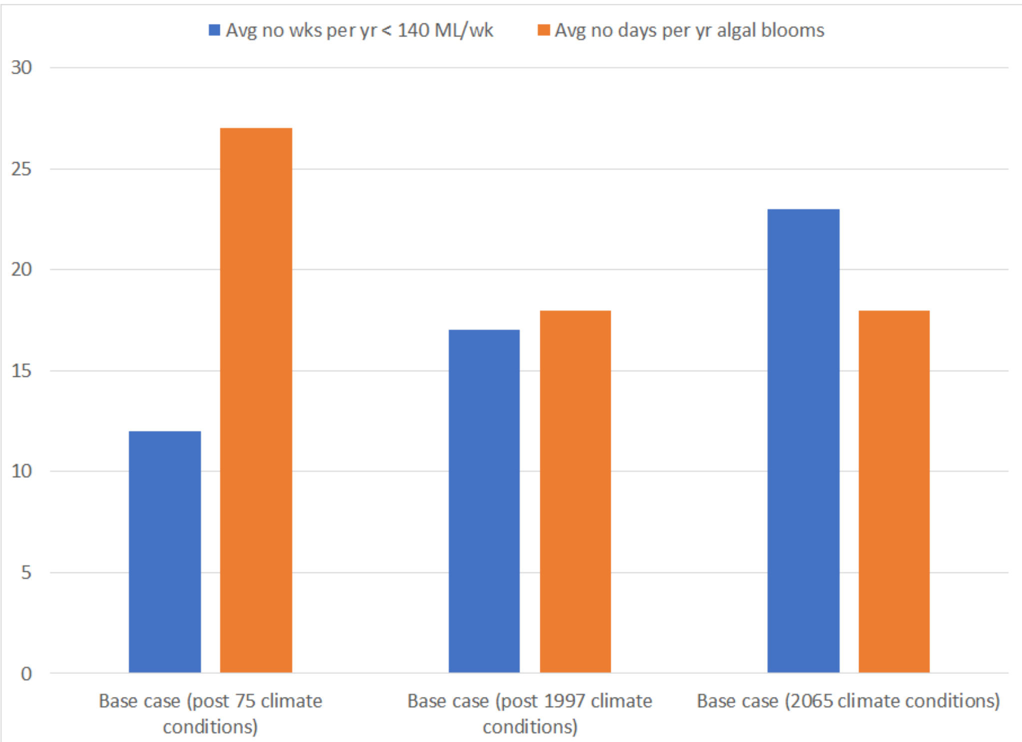

Figure 7-2: Summary of results – climate change

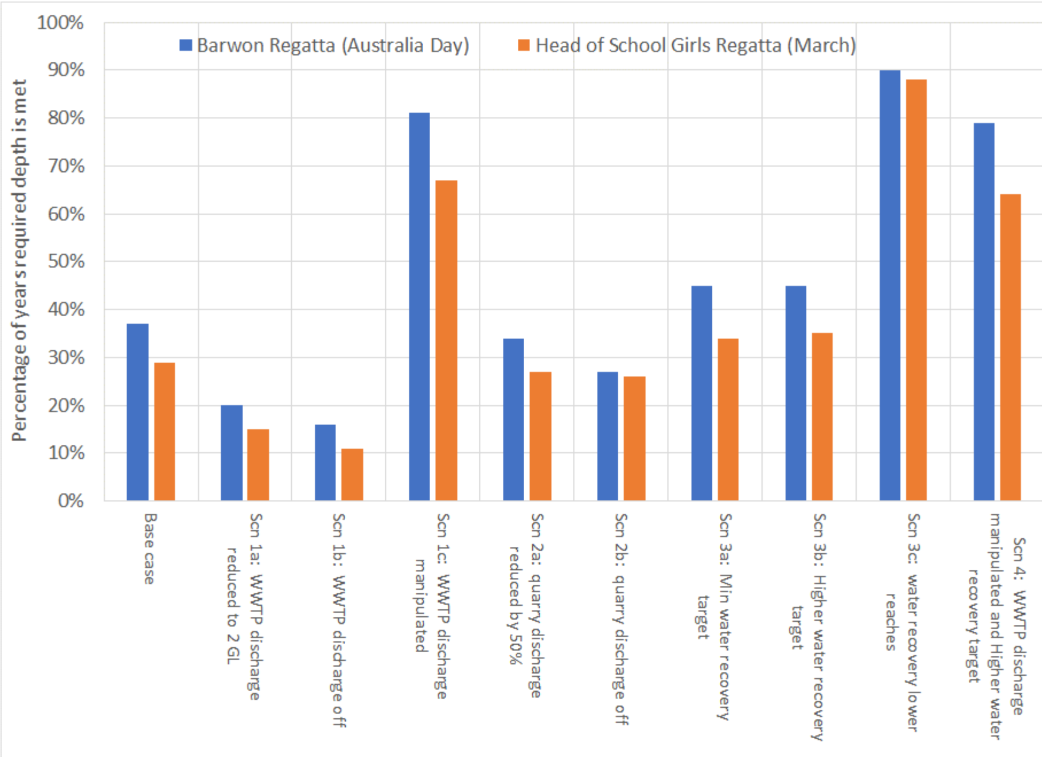

Figure 7-3: Percentage of years required rowing depth can be met for key events

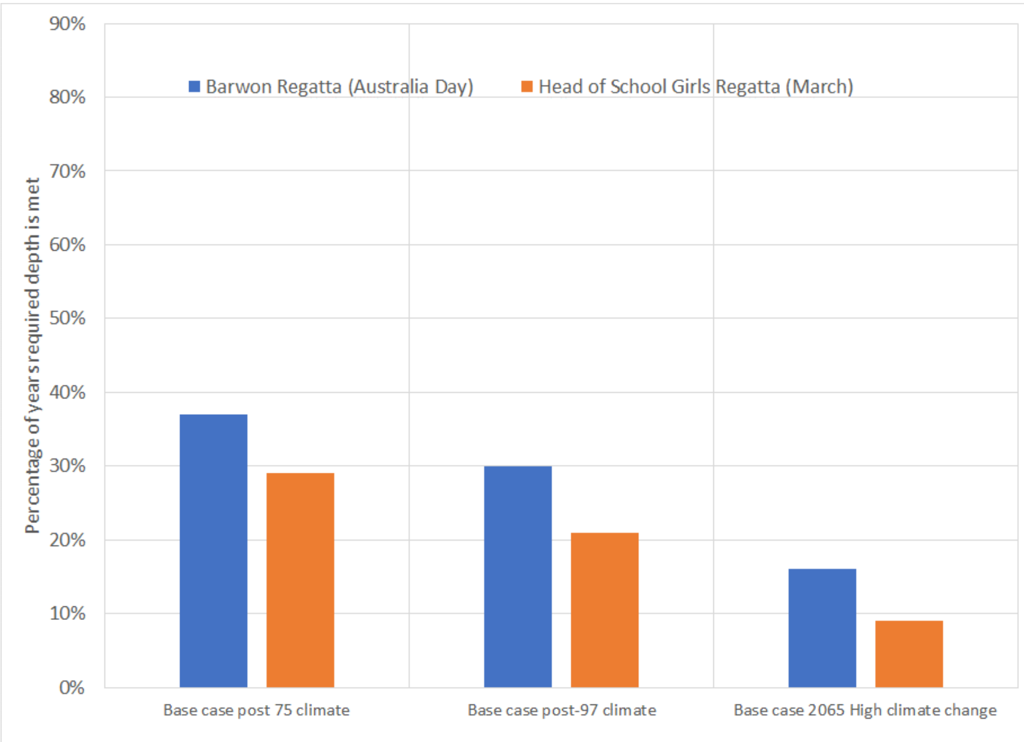

Figure 7-4: Impact of climate change on percentage of years required rowing depth can be met for key events

8. Discussion and recommendations

Flow and algal bloom modelling showed that under current climate and levels of development algal blooms occur in Geelong for an average of 27 days per year, and critical rowing depths for regattas will not be met in around one third of years*. These conditions worsen under demand growth and climate change.

The Ballarat South WWTP was shown to deliver a significant volume of water that helps maintain river depths in Geelong, but also a significant nutrient load that can drive algal blooms. The frequency with which this nutrient load creates algal blooms can largely be negated by manipulating the pattern of WWTP discharge to maintain flows above 20 ML/d in Geelong.

Batesford quarry discharge only contributes a small volume of flow to the river but was shown to have an important dilution effect, reducing nutrient load and hence algal blooms.

Providing all required environmental flow components for the reaches immediately downstream of West Barwon Dam and Lal Lal Reservoir provides good local environmental benefit but, due to losses along the river, has limited impact on reducing algal blooms or maintaining critical flow depth in Geelong. Targeting environmental flow provision to low flow requirements in the lower reaches of the Barwon and Moorabool rivers instead provided the largest reduction in the incidence of algal blooms and the best maintenance of critical river depth in Geelong compared to the base case. Modelling also showed combined environmental flow provision and manipulation of WWTP discharge is also successful.

On the basis of these results, it is recommended that quarry discharges be maintained into the future, and that options to deliver low flows and manipulate WWTP discharge patterns be explored further. The manipulation of WWTP discharge patterns and the provision of low flow requirements both result in substantial reduction in algal blooms and times when critical rowing depths are not met. The manipulation of WWTP discharge patterns does not require extra water but does require development of additional storage. The provision of low flow requirements requires extra water but provides a wide range of additional environmental and recreational benefits throughout the system. There would be benefit in exploring all these options further, including the combined manipulation of WWTP discharge patterns and the provision of low flow requirements to maximise benefits and minimise costs.

As noted throughout this report, the water quality modelling undertaken is simplified and does not represent the decay of WWTP nutrient loads as they pass downstream or any sediment fluxes. It is recommended that more detailed water modelling be undertaken to take into account these effects. It was also noted that there was no useful data on stormwater discharges from the Geelong urban area into the lower Barwon River or estuary. Gauging and monitoring of stormwater discharges would assist to quantify the stormwater contribution to flows and loads now and in future.

**Note these results assume no dredging or other intervention works are undertaken to improve river depths.*

Water resource modelling was carried out on a weekly timestep and a daily pattern applied for the purposes of algal bloom modelling. DELWP is currently undertaking a project to create a daily timestep Source model of the Barwon-Moorabool system. Creation of this model will include a rederivation of reach inflows, lags and losses and the representation and prioritisation of environmental flow requirements by individual flow component. This will allow for the modelling of a more accurate daily time series at Geelong and hence more accurate algal bloom modelling. It will also allow for the targeting and reporting of the compliance of individual flow components in each reach. It is recommended that scenarios be re-run in the daily Source model once it is available.

9. References

Alluvium (2019). Upper Barwon, Yarrowee and Leigh rivers FLOWS study update. Report prepared by Alluvium Consulting Australia for Corangamite Catchment Management Authority, Colac.

Barwon Water (2017). Barwon Water 2017 Urban Water Strategy, Barwon Water, Geelong, Victoria.

Central Highlands Water (2017). Urban Water Strategy 2017: A 50-year water outlook for our communities in the Central Highlands Region, Central Highlands Water, Wendouree, Victoria

DELWP (2016): Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria

DELWP (2016). Long-Term Water Resource Assessment for Southern Victoria, Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

DSE (2006). Central Region Sustainable Water Strategy, Department of Sustainability and Environment, East Melbourne, Victoria.

GHD (2013). Barwon River Rowing Mile Dredging Project – Technical Specification.

Jacobs (2015). Moorabool River FLOWS Study Update, Report prepared by Jacobs for Corangamite Catchment Management Authority, Colac.

Longmore AR & Nicholson GJ (2010). Quantifying sediment nutrient drivers for blue-green algal blooms in the Barwon River. Marine and Freshwater Systems Internal Report No. 71. Department of Primary Industries, Queenscliff.

RMCG (2020): Analysis of the social and economic values dependent on a flowing Barwon River through Geelong and lower Moorabool River - Scoping Report

WaterRes (2020). Barwon - Moorabool REALM model development. File note to DELWP

Appendix 3: Stakeholder interview guide

INTRODUCTION

RMCG has been engaged by Corangamite CMA to investigate the economic and social benefits derived from a flowing Barwon River through Geelong and lower Moorabool River, as well as the risks posed by climate change to river flows and social and economic benefits.

The results of the study will be used to support decision making on river flows and the best way to maintain the economic and social values of the rivers identified in the study.

As part of the study, we are interviewing user groups to understand how people use and enjoy the river and how use changes under different river conditions.

[Include a map so that use can be mapped]

THE ACTIVITY

- Description of use

- Is the use organised through a group (e.g. through a club) or independent?

- Where along the river is the use (show on map)?

USERS

- How many users per weekday/weekend day during each month of the year (Jan, Feb, Mar, Apr etc)?

- What age/gender of people use the river?

- Where do the users live? (% nearby the river, % other parts of Geelong, % outside of Geelong). Follow up question - if outside Geelong (% Melbourne, % further afield, % closer than Melbourne)

- How long (hours) do people do [activity] for?

- Do any of the users stay overnight? (what percentage or number) – follow up question - where do they typically stay?

THE BARWON RIVER

- Why do people use the Barwon River for [activity]?

- What do users like about the river?

- Are there improvements that would encourage more people to undertake [activity] on the river? (prompts: facilities, river conditions, other support)

THE ACTIVITY IN THE FUTURE

- How is [activity] changing (increasingly popular, less popular, shorter, longer)

- How will [activity] change in the future on the Barwon? (population growth, changing behaviour)

RIVER CONDITIONS AND ALTERNATIVE ACTIVITIES

- Do you do [activity] somewhere else?

- What conditions do you need to undertake [activity] on the Barwon River (prompts: no blue-green algae, river levels, odour, river flow, fish populations, duck populations)?

- What have you done during poor conditions in the past, as per question above (prompts: use a different part of the river, use another water body, do another activity, stay home)

- Is it possible that [activity] would cease altogether on the river if certain conditions prevailed for a long enough period of time, say a number of years in a row? What would you do in this scenario?

Appendix 4: Summary of economic methods

Further details on the economic methods used in this study are detailed below:

BENEFIT TRANSFER METHOD

The benefit transfer method is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location or other context. For example, values for recreational fishing in a particular area may be estimated by applying measures of recreational fishing values from a study conducted in another location.

The goal of benefit transfer is to estimate benefits for one context by adapting an estimate of the benefits from another context. Benefit transfer is often used when it is too expensive and/or there is too little time available to conduct an original valuation study, yet some measures of the expected benefits are needed. It is important to note that benefit transfers are only as accurate as the initial study.

In this study we used information from three studies (outlined in section 5 of the report) using three economic evaluation approaches, the travel cost method, DALY method and hedonic pricing method. A further description of these methods is given below:

1. Travel cost

This method can be used to estimate the economic benefit or costs resulting from

- Changes in access costs for a recreational site
- Elimination of an existing site
- Addition of a new recreational site
- Changes in environmental quality at a recreational site.

The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the “price” of access to the site. Therefore, peoples’ willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating peoples’ willingness to pay for a marketed good based on the quantity demanded at different prices.

In this study we used the zonal approach to the travel cost (benefit transfer) method. There are six steps that are used to estimate economic values, that include:

- Define the area that will be looked at in the study (zoning)
- Collect information from visitors about their use within these zones
- Calculate the visitation rates in each zone
- Calculate the average distance (round trip) or time spent at each zone for each set of user
- Calculate the demand for the site in relation to the population within the surrounding area
- Estimate the final economic benefit based on total site visitors and consumer surplus.

2. Disability Adjusted Life Year (DALY)

This method is used where the impact of recreation is considered to improve the quality and length of life and is reported in monetary terms per unit (in this case per km of cycling, running and walking).[53]

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[53] The method outlined in this report is taken directly from https://www.atap.gov.au/mode-specific-guidance/active-travel/5-estimation-of-benefits

Available data on the health characteristics of Australians was derived from the 2003 Burden of Disease study (Begg et al, 2007, AIHW Cat No PHE 82), the 2007-2008 National Health Survey (ABS Cat. No. 4364 2009) and the 2011-13 Australian Health Survey (ABS Cat. No. 4364.0.55.004 2013). The Burden of Disease study quantifies the extent to which a healthy life is lost to disease manifested as prolonged illness, disability, and/or premature death. The disability adjusted life year (DALY) is the measure used to quantify the effects of individual diseases and injuries. One DALY is one year of healthy life lost due to disease or injury (AIHW, Australia's Health 2010, Cat. No. AUS 122 2010). Since inactive adults have most to gain by participating in physical activity, full benefits are allocated to those who were previously inactive, with only marginal benefits allocated to existing active adults (Genter, 2008, p.40).

The Value of a Statistical Life (VSL) is a monetary value of a human life based on the willingness to pay concept. It is updated using the Consumer Price Index. The value of statistical life is an estimate of the economic value society places on reducing the average number of deaths by one. The Australian estimate of the value of statistical life is $3.5 m and the value of statistical life year is $151,000.

Morbidity and mortality costs of inactivity are valued using DALYs associated with inactivity. The steps used in the calculation include:

- Estimate DALYs for years of life lost to both morbidity and mortality. The Population Attributable Risk Fraction (PAF) for inactivity identified by Begg et al (2008, p.38) in the Burden of Disease and Injury in Australia 2003 study (Begg et al, 2007, AIHW Cat. No. PHE 82) is 6.6% of total DALYs.
- Determine the annual ratio of DALY per inactive adult by dividing the DALYs due to inactivity by the estimated adult inactive population in 2010, derived from Australian Health Survey 2007-8 and 2011-12 results (ABS 2012, 43640DO001_20112012 Australian Health Survey: First Results, 2011–12 – Australia.)
- Multiply this ratio by the undiscounted 2013 value of DALY to produce the per capita annual benefit of physical activity.

Three physical activity weightings associated with walking and cycling used in developing the per km benefits of walking and cycling, which were applied in this study were:

- Weighting 1 - Inactive – shifting the inactive group into some moderate physical activity has most benefits in terms of reduced morbidity and mortality. This group can receive full annual benefits by walking at 5 km per hour for 30 minutes, five days per week. This is an annual walking distance of 625 km.
- Weighting 0.85 – insufficiently active – the insufficiently active group can receive most of the health benefits of increased activity, even though they already engage in some moderate activity. An additional 20 minutes' physical activity per day for five days per week requires an annual distance of 450 km.
- Weighting 0.15 – sufficiently active – the sufficiently active group may receive ongoing health benefits and encouragement to maintain physical activity. An additional 14 minutes' physical activity per day for five days per week requires an annual distance of 312 km.

Accordingly, the 2013 monetary value of the health benefits of walking is $2.77 per km and the monetary value of the health benefits of cycling is $1.40 per km for Australian adults aged 18 years and older. These are the values used in this study.

3. Hedonic pricing method:

This method used to determine a price by internal characteristics and external factors affecting a good. In this case we obtained values that considered the increased value of houses located within close proximity to a river, where residents are willing to pay for a premium for access to natural areas, recreation and aesthetics.

There are two parts to performing hedonic regression analysis.[54]

- The initial step is determining the relationship between an asset's value or price (which would be the dependable variable in the analysis) and the independent explanatory variables (which are the characteristics, including the property's features, the location features, and the environmental features). The price variation, which occurs due to changes in any of the property or asset's characteristics, is called the hedonic price. The hedonic price of an asset can be called the asset's additional cost, based on the additional benefit derived from the property's features.
- The second part of hedonic regression is the analysis of the households' willingness to pay, with consideration of their income and preferences. The willingness to pay is derived from the size of the property, the income of a household, and preferences based on individual characteristics, which include age, family size, race, and social background, etc.

In this research a conservative estimate of 5.8% was used to calculate the hedonic price of houses within 500m of the Barwon River.

54 The method outlined here is taken from https://corporatefinanceinstitute.com/resources/knowledge/valuation/hedonic-pricing/

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Document review and authorisation

Project Number: #1029

Doc Version	Final/Draft	Date	Author	Project Director review	BST QA review	Release approved by	Issued to
1.0	Draft	02/09/21	T. Wardley T. Wallis K. Austin (HARC) W. Henderson	S. Annett	M. Sandford M. McIntosh	S. Annett	A. Harrison/ J. Woolley, Corangamite CMA
1.1	Draft	15/09/21	T. Wallis T. Wardley				A. Harrison, Corangamite CMA
2.0	Final	18/10/21	T. Wallis T. Wardley K. Austin	S. Annett		S. Annett	A. Harrison/ J. Woolley, Corangamite CMA
2.1	Final (updated)	15/11/21	T. Wallis T. Wardley K. Austin	S. Annett		S. Annett	A. Harrison/ J. Woolley, Corangamite CMA
2.2	Final (minor updates)	18/11/21	T. Wallis K. Austin				Corangamite CMA