Australian Government

MURRAY–DARLING BASIN AUTHORITY

Goulburn River reach report

Constraints Management Strategy

Published by the Murray–Darling Basin Authority

Postal Address: GPO Box 1801, Canberra ACT 2601
Telephone: (02) 6279 0100 international + 61 2 6279 0100
Facsimile: (02) 6248 8053 international + 61 2 6248 8053
Email: engagement@mdba.gov.au
Internet: http://www.mdba.gov.au

ISBN (online): 978-1-925221-03-9

Cover image: Floodplain vegetation in the lower Goulburn near Stewarts Bridge Road, 2013. *Photo: Janet Pritchard, MDBA.*

Edited by Biotext, Canberra.

Disclaimer
To the extent permitted by law, the Murray–Darling Basin Authority and the Commonwealth excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this report (in part or in whole) and any information or material contained within it.

Accessibility
Australian Government departments and agencies are required by the *Disability Discrimination Act* 1992 (Cwth) to ensure that information and services can be accessed by people with disabilities. If you encounter accessibility difficulties or the information you require is in a format that you cannot access, please contact us.

Acknowledgement of the Traditional Owners of the Goulburn waterways
MDBA acknowledges and pays its respects to the Taungurung and Yorta Yorta people as the Traditional Owners of the land surrounding and the catchment of the Goulburn River downstream of Eildon Dam. MDBA recognises and acknowledges that the Traditional Owners and their Nations have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

Contents

Summary 1
What is the Constraints Management Strategy? 8
Why is the Strategy important? 17
What is happening in the Goulburn River? 23
What flows are being considered for the Goulburn River? 32
What might be the effect of the proposed flows in the Goulburn River? 41
What does the community think? 45
What happens next? 52
What is happening in the subreaches? 58
- Eildon Dam to Killingworth 63
- Killingworth to Mitchellstown 92
- Mitchellstown to Kialla 106
- Kialla to Loch Garry 116
- Loch Garry to the River Murray 127

Appendix 1 Constraints of the Goulburn River 136
Appendix 2 Environmental water management in Victoria 144
Appendix 3 Constraints-related studies relevant for the Goulburn River 151
Appendix 4 Changes to the Shepparton ratings table 155
Appendix 5 Examples of flow events along the Goulburn River 157
Appendix 6 Easements 160
Appendix 7 Flow interactions between tributaries and the main stem 164
References 167

Structure of this report

This Goulburn reach report has two main parts.

The first part describes what is happening in the Goulburn River, what the Constraints Management Strategy is designed to achieve and what effects it could have. It includes:

- What is the Constraints Management Strategy?
- Why is the Strategy important?
- What is happening in the Goulburn River?
- What flow footprints are being considered for the Goulburn River?
- What might be the effect of the proposed flow footprints in the Goulburn River?
- What does the community think?

In the second part, 'What is happening in the subreaches?', each chapter focuses on one subreach and has been designed as stand-alone documents to allow people to easily find information on the area of the Goulburn River they are particularly interested in.

Summary

For the past century, the Murray–Darling Basin (the Basin) has been developed with a focus on delivering water for productive use. Large dams have been built to capture and store as much water as possible to be used later for consumption and irrigation. There have also been many rules put in place across the Basin around how the rivers and dams are managed.

These structures and practices are of great benefit to our industries and have greatly supported the building of our nation, our Basin communities and our economy. However, the changes we have made have affected how, when and where the Basin's rivers flow and how healthy they are. Water that once flowed downstream is now often stored, and delivered in regular patterns at times that suits production, not necessarily in a more natural variable way that most benefits and supports the environment.

For many floodplain areas of the Basin, the time between drinks is now too long for floodplain plants and animals. Overbank flows that connect the river to its floodplain are vital to the environment. These overbank flows improve water and soil quality, recharge groundwater, and support native plant and animal species. Before rivers were regulated, these flows were far more common. The lack of these flows is affecting long-term river and floodplain health, and ultimately Basin communities and businesses who rely on healthy waterways.

Environmental watering has been successfully done for many years in some parts of the Basin, and is one way we can deliver water to benefit the environment. However, there would be many environmental benefits if we could deliver slightly higher flows in the future to reach the floodplains (up to flows in the minor flood level range). So, state and federal governments requested that the Basin Plan include a Constraints Management Strategy (the Strategy) to explore how this might be done.

The Constraints Management Strategy

The Strategy is about ensuring that water can flow onto the floodplain, while mitigating any effects this water may have on property and people. For the purpose of the Strategy, constraints are river rules, practices and structures that restrict or limit the volume and/or timing of regulated water delivery through the river system. The Strategy seeks to find smarter ways to operate our highly regulated rivers to increase how often overbank flows below and in the minor flood range occur to sustain and improve floodplain health.

Given consumption and irrigation needs, it is not possible, nor is it the goal, to return regulated rivers to their ‘natural’ or ‘without-development’ flows. The Strategy is also not trying to create or change how often damaging moderate and major floods occur. The idea is to make modest regulated releases from storages, generally when higher flows downstream would have occurred if dams were not there. That is, the overbank flows being proposed will be created by releasing water from storage in response to natural cues to ‘top up’ unregulated tributary inflows, to increase either the flow peak and/or duration of the event.

The Constraints Management Strategy has a number of overarching principles to help guide work over the next 10 years. These include that:

- affected communities should be involved from the beginning to identify potential impacts and solutions
- any solutions need to recognise and respect the property rights of landholders and water entitlement holders
- any solutions will not create new risks to the reliability of entitlements
- any solutions will work within the boundaries defined by the *Water Act 2007* (Cwlth), the Murray–Darling Basin Plan and relevant state water access and planning systems
- any investment should focus on avoiding and addressing any impacts to third parties and focus on lasting solutions to provide certainty and protection to stakeholders over time.

In 2014, we completed the first phase of work — the prefeasibility phase — which involved looking at seven areas of the Basin in more detail. The Murray–Darling Basin Authority (MDBA) collected information about how overbank flows up to the minor flood range affect the environment and people who live and work along the Goulburn River. We also collected information about how such flows can be managed, and what sorts of protective measures are needed first.

Victorian and Australian Government investment in water recovery for the environment has enabled the delivery of significant volumes of water to improve the health of our waterways. Although this can provide greater environmental benefit, it can also increase the risk to communities and property.

In Victoria, water corporations and catchment management authorities are liable to pay compensation if they intentionally release water from their works and this water causes injury, loss or damage, or if, through a negligent act, they cause flows that result in loss, injury or damage. These laws are intended to protect landowners who, through no fault of their own, are flooded by flows from works of water corporations or catchment management authorities.

Currently, river operators cannot deliver water orders that would result in water flowing onto private land unless they have landholder approval to do so. To ease constraints in the Goulburn, the Victorian government would need to formalise and pay for land-based agreements with landholders, such as easements, to allow water to flow onto private land (for flows to reach an environmental asset or allow sufficient water to flow down a channel). Landholders can still use their land freely, but are paid up front for potential impacts.

This report, about investigating potential changes to environmental water management for the Goulburn River, was released for public comment in September 2014. Since then, we have continued discussing constraints with the communities that might be affected by any changes to river management. This final version contains some new information that communities thought should be included to tell a more complete story of the region.

The Goulburn River

The Goulburn River is one of seven areas of the Basin that the MDBA is studying for the Strategy.

The Goulburn River is 570 km long and around 215,000 people call the Goulburn region home. The river and its associated floodplain and wetland habitats support a diversity of habitats and species. Over time, the Goulburn River has been modified and become highly managed.

Eildon Dam and Goulburn Weir store and deliver water for irrigation and consumption, and also significantly alter the flow of the river. On average, 91% of water released from Eildon Dam is diverted for irrigation in the Goulburn, Loddon and Campaspe valleys, and the lake supplies about 60% of water used in the Goulburn–Murray Irrigation District. With such a large storage capacity, operation of Eildon dam fully captures flows from the upstream catchments in all but the wettest years.

Changing the seasonal flow pattern disrupts the natural cycles of feeding, growing and breeding for many plants and animals. Because of this, many native species have significantly declined in the Goulburn region. A series of studies have consistently reported that the frequency of overbank flows is less than what is needed to maintain the health of the lower Goulburn floodplain (see 'What the science says').

To allow the Goulburn River to connect with its floodplain more often, and to deliver flows to the River Murray downstream, we are looking at possible new ways to release regulated water from storage to add to unregulated tributary flows to make them large enough to reach the floodplain. The overbank flows being looked at are between 25–40,000 megalitres/day (ML/d), or 9.4–10.3 m at Shepparton (gauging station number 405204).

This range of flow footprints wets the majority of wetlands and flood-dependent vegetation on the lower Goulburn floodplain (mainly native vegetation and the Lower Goulburn National Park). This range of flows also avoids the risks and liabilities of flooding valuable agricultural land outside of the levee network, and avoids triggering the opening of the Loch Garry regulator. Flow footprints in this range at the Shepparton gauge would get water to between 45% and 89% of the water-dependent vegetation on the floodplain, while staying within the leveed floodway.

These flows would occur between June and November, when rainfall and natural tributary flow events typically happen and when the Goulburn floodplain needs the water most. This timing also minimises competition for channel space by avoiding peak irrigation demands in late spring and summer. Based on initial overbank flow recommendations for the lower Goulburn in 2011, the flows would occur at least once every three years. Given that these flows sometimes happen naturally, this means an extra one to two managed overbank flows every ten years on average to achieve lower Goulburn environmental outcomes (not managed overbank flows every year).

From our consultations, it is clear that duration of flow is a key concern for many Goulburn landholders, because duration is perhaps the biggest factor driving the severity of impacts.

Extended releases from Lake Eildon have never been proposed (e.g. months as can occur during pre-releases during flood operations). The lower Goulburn overbank flow events that are being investigated are relatively short, in the order of lasting days to weeks. Feedback from most riverbank landholders that we have talked with so far is that short duration events that rise and fall quickly in a week or less might be acceptable, subject to the time of year and how often they occur.

Development and testing of real-time catchment and river models would provide water managers, river operators and community with the confidence to water within the target flow range. This would take the floodplain closer to an environmentally sustainable watering regime. Further analysis of how governments might manage the river in the future may provide different opportunities to achieve these flows, however any increase in managed overbanks flows will only occur when effects on public and private assets are able to be managed.

Potential effects on businesses and communities in the Goulburn mainly centre on the inundation of river flats on private land and closure of some local roads and bridges. Mitigation measures would need to be put into place to protect communities and businesses from any risks associated with an increase in regulated flows.

Flows of between 25,000 and 40,000 ML/d at Shepparton could be created by topping up unregulated tributary flows with some regulated releases from Eildon Dam and/or Goulburn Weir. This should be examined in more detail in the next phase of the Strategy.

The community

This report reflects MDBA's current knowledge base after preliminary technical work and after talking with a range of people along the Goulburn River. In 2013, MDBA formed three advisory groups of local residents and businesses. Many of the group members have decades of first-hand experience of Goulburn River conditions and this has been an incredibly valuable source of knowledge. Meetings were also held with a range of other residents to collect additional information on how people are affected by different river flows. Community input is included throughout this report.

In addition, before publication on the MDBA website, an early draft of the reach report was shared with the three advisory groups in August 2014 so that their feedback could be included in the draft. The report was published on the MDBA website in September 2014, and was also emailed and/or posted to stakeholders that had been involved in previous conversations with MDBA about constraints throughout 2013–14.

After publication, further community engagement to May 2015 included: 7 public meetings; community advisory group meetings, 12 landholder meetings (individuals and groups), and three local council and regional authority briefings. Email feedback was also received from several landholders in the mid-Goulburn region.

The revisions in this final report reflect the comments made by stakeholders over September 2014 to March 2015. Changes were made to include more information on the tributaries of the Goulburn River and to better describe the impacts and risks of higher flows in the mid-Goulburn region. In particular a landholder case study was developed to detail potential impacts after visiting a number of Molesworth farms and businesses in April and May 2015.

Naturally, there has been a diversity of reactions towards exploring managed overbank flows in the Goulburn. Some people are proponents, others are cautious — reserving judgement until more information is available — and others are very concerned.

Increases in water levels don't have to be large to start affecting landholders downstream of Eildon Dam. There is a lot of community concern about the impacts and risks of the higher flow footprints being looked at, especially around Molesworth.
Residents and farmers in the mid-Goulburn

Overall, there were concerns about flows potentially happening too often (more than a few extra times a decade), lasting too long (longer than a week) or happening too late in spring (October–November). However, there was general recognition that water on river flats can be good for farming, the environment and the productivity of the land.

Some long-time residents believe that the river flats are not as good as they used to be when overbank flows used to happen more often.

A lot has been taken out and nothing has been put back in.
Long-time farmer from the mid-Goulburn

People saw less impact for the smaller overbank flows being investigated, namely:

- Eildon – Killingworth, flow footprint up to 12,000 ML/d for the Molesworth region, and 15,000 ML/d elsewhere in the subreach
- Seymour – Goulburn Weir, flow footprint of 15–20,000 ML/d
- Goulburn Weir – River Murray, flow footprint of 25–30,000 ML/d.

The general feeling of residents was that impacts on businesses and communities for these flows **may** be tolerable if appropriate mitigation measures are put in place first.

This is balanced by strong community reaction to the scale of potential impacts and risk of things going wrong around the following flows:

- Eildon – Killingworth, flow footprint above 12,000 ML/d at Molesworth and 15,000 ML/d elsewhere in the subreach
- Goulburn Weir – River Murray, flow footprint of 40,000 ML/d.

People are very concerned about the size of the larger proposed flows, in particular, the potential for unintended adverse consequences. At the upper range of the flows being investigated, the Goulburn community would need to be comfortable with the risk and the level of issues created, and confident that the risk and issues can be managed well. We do not yet know if this is the case.

People in the Goulburn community are willing to continue to work with MDBA, especially around exploratory feasibility and technical work.

Some of the key points that Goulburn residents have raised include:

- It is important that managers know enough to ensure that the system can be controlled and risk managed at the flows being proposed.
- The Strategy is an opportunity to fix long-standing minor flooding issues for people.

- There are community members who identify themselves as being direct beneficiaries of floodplain watering in the lower Goulburn — flexibility to fill up creeks and wetlands when the waterways need it, not just putting water down the main Goulburn River channel.
- The wetness of the catchment (or recent previous flow events) has a big influence on how far the river rises or spreads. This needs to be taken into account.
- Detailed planning is needed around how specific flow footprints could be created and managed under a range of catchment conditions and tributary flow scenarios, including worst case (e.g. unexpected rainfall event after a release from storage has been made).
- People want the Strategy to plan for residual risk. What if the flow footprint is larger than expected? How will people be protected? Where does the financial liability lie? Financial risk and liability should not be shifted onto the affected individual or business.
- A flow of 40,000 ML/d (10.3 m) at Shepparton is too close to triggering the Loch Garry flood protection scheme (10.36 m). Opening the Loch Garry regulator is very damaging to landholders in the Bunbartha region.
- Improvements to the stream gauging network will be needed to deliver more accuracy, confidence and forecasting power for safely making regulated releases from storage in combination with unregulated tributary flows.

Next steps

This is the start of a 10-year process. Basin governments are only at the early stages of finding out what the issues and opportunities are, to support future decision-making.

This reach report:

- provides a context and background to MDBA work on constraints, which seeks increased flexibility to connect rivers with their floodplains, as part of the implementation of the Basin Plan
- outlines the types of changes needed to achieve the river flows being investigated
- reports on community feedback and reaction to possible changes to managed river flows.

The MDBA released the reach reports for all seven regions on our website through September–December 2014. Discussions with community on these reports have continued to add to the knowledge base and refine our understanding of what changes to flows might mean for businesses and communities throughout the southern Basin.

Information from the seven priority areas of the Basin was included in the constraints annual report, which made recommendations to Basin governments about options for further investigations. The report was made available on the MDBA website in late 2014.

In late 2014, state and federal governments decided to continue investigations in all of the seven priority areas. The 2014 decision was about whether to proceed with collecting more information including technical and community studies to better understand the feasibility of overbank flows and the mitigation measures needed for delivering the proposed flows. The 2014 decision was not a green light to build, do or change anything about how the river is managed.

Further to this, state and federal governments refined the flow limits that should be considered in future investigations. In the Goulburn region, it was decided that 40,000 ML/d at Shepparton should be the upper limit for future investigations. It was agreed that the work for the feasibility phase would be led by the Victorian Government and that a constraints business case for the Goulburn River would be prepared.

The second decision by state and federal governments, due in mid-2016, is about whether to start detailed planning and preparation towards putting mitigation measures in place, based on recommended flow options put forward in constraints business cases. Actions would take place between 2016 and 2024 to ensure mitigation measures are in place — such as formal arrangements with landholders to allow water onto private land, rule or management practice changes, asset protection, gauging system and infrastructure upgrades — before any managed overbank flows are delivered.

What is the Constraints Management Strategy?

At a glance

The Constraints Management Strategy looks at ways to allow rivers to connect to their floodplains more often to improve and maintain the environment, while avoiding, managing or mitigating effects on local communities and industries.

In a river, 'constraints' are the things that stop water from reaching some areas.

The constraints can be:

- physical structures, such as bridges, roads or outlet works and
- river management practices.

In the case of the Goulburn River, Goulburn-Murray water currently constrains releases from Eildon Dam to 9,500ML/d (outside of flood operations) because of the risks of inundating private land around Molesworth

The Constraints Management Strategy (the Strategy) is about ensuring that our rivers — and the environments and communities they support — stay healthy and sustainable.

In particular, it is about investigating how to connect rivers with their floodplains more often, while avoiding, managing or mitigating effects to local communities and industries.

By carefully managing constraints, we can ensure that water continues to sustain our vital river environments and communities, both now and in the future.

What areas are being looked at

The Strategy is looking at seven areas of the Murray–Darling Basin (Figure 1). These areas were chosen because we are likely to get the best environmental benefits by changing constraints to increase regulated flows in these areas. The areas are:

- Hume to Yarrawonga
- Yarrawonga to Wakool Junction
- Goulburn
- Murrumbidgee
- Lower Darling
- Lower Murray in South Australia
- Gwydir region.

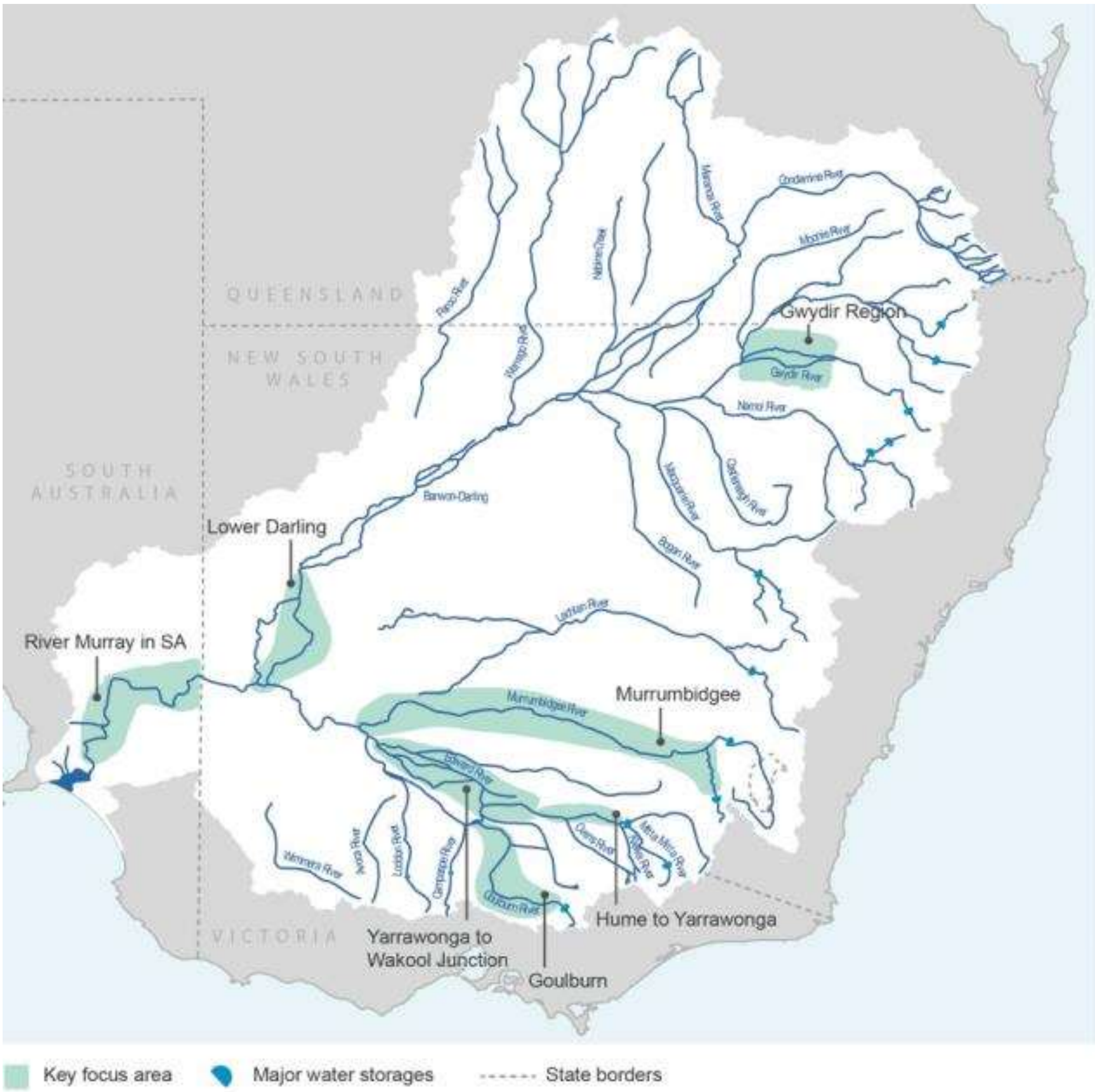


Figure 1 Areas in the Murray–Darling Basin being looked at for the Constraints Management Strategy

What could change

Current situation:

- The current regulated operation of the river system provides flows within a range that is largely governed by irrigation requirements and minimum flow provisions.
- Irrigation requirements generally follow crop demand patterns and do not vary significantly during the summer irrigation season.
- Rivers are operated to maximise water availability to consumptive use and to limit evaporation losses on floodplains.
- Releases from storages resulting in overbank flows are a consequence of managing storages when they are close to full or spilling over, rather than to meet environmental objectives.

Over time, such operations have led to a substantial decline in floodplain health. The Strategy is about identifying and enabling smarter ways to manage rivers so that water availability is still maximised and damage from large floods is limited, but also so that some of the smaller overbank flows that are essential for floodplain health are reinstated.

The environment is a relatively new customer for regulated water delivery and has different water requirements — including timing and amounts — compared to crops. This is why constraints work is trying to determine if there are ways to increase flexibility in the range of regulated flows that can be delivered to meet the needs of this ‘new customer’.

Possible future situation:

- Flows from unregulated tributaries may be topped up with regulated releases from storages. Together, these sources of water would combine to become a flow of sufficient size to result in overbank flow footprints downstream.
- Overbank flow footprints are designed to reach particular parts of the floodplain to achieve specific ecological outcomes.

The ability to do this relies on river managers having hydrological information that is accurate enough to enable them to plan with confidence, when and when not to make regulated releases. It also relies on governments being able to understand and mitigate any impacts on private land and community assets along the entire flow path.

Mitigation measures must be in place before regulated overbank flows can be delivered. These include formal arrangements with landholders, rule or management practice changes, asset protection, and infrastructure upgrades. The Strategy is focusing on these types of activities during the next decade.

It is important to note that the Strategy should not increase how often damaging moderate and major floods occur. The Strategy is about delivering overbank flows, which are less than half the size of the damaging floods that Goulburn residents vividly remember (e.g. 2010, 1993, 1974) (see ‘Overbank flows’).

Overbank flows

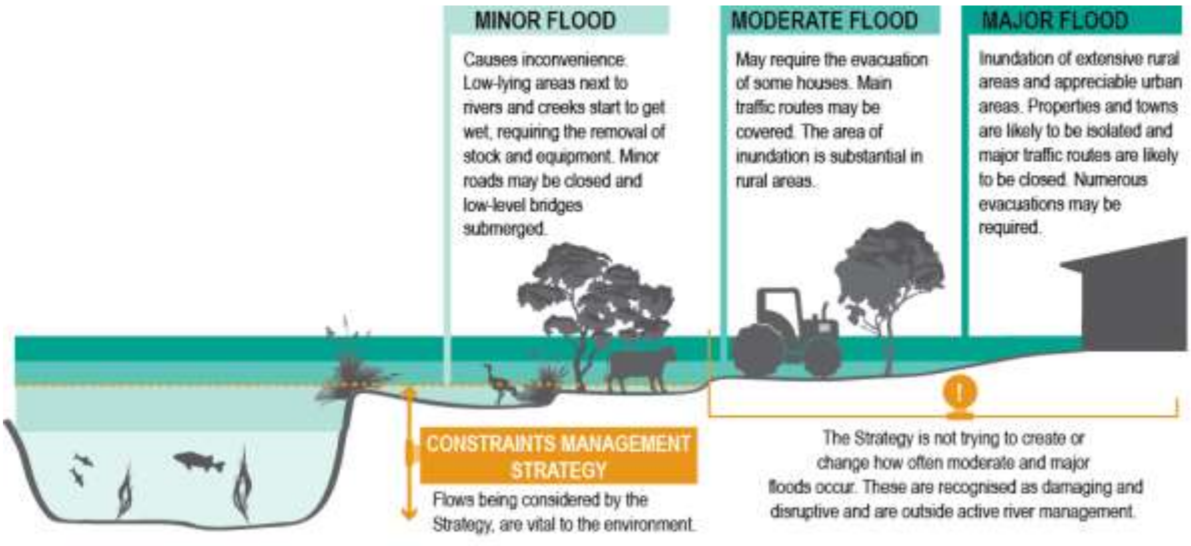
In unregulated river systems, overbank flows occur frequently, wetting the floodplain areas around the river.

The changes being investigated in the Constraints Management Strategy aim to increase the frequency and duration of some of the overbank flows in regulated rivers, allowing water to reach particular parts of the landscape that haven't been getting water as often as they need, such as creeks, billabongs and floodplain vegetation.

The flow footprints being investigated are generally below or in the range of flows defined as a 'minor flood' by the Bureau of Meteorology. Bureau of Meteorology flood warnings fall into three categories — minor, moderate and major. The official definition of a minor flood is a flow that causes inconvenience. Low-lying areas next to rivers and creeks start to get wet, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.

It is also important to recognise that flow ranges for flood warnings are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge. This can mean that flood warning categories may not be timely or relevant, especially for rural areas with large amounts of ungauged catchment, flow from unregulated tributaries and long distances between river gauges (i.e. some areas can be in flood when the nearest upstream gauge is not in flood and no flood warning is issued).

This Strategy is about delivering overbank flows, which are below flood levels that are majorly damaging (Figure 2).



Note: The descriptions of minor, moderate and major floods are the official definitions from the Bureau of Meteorology[1].

Figure 2 The impacts of minor floods compared with moderate and major floods

1 www.bom.gov.au/water/floods/floodWarningServices.shtml

The overbank flows would be created by 'topping up' unregulated tributary flows with releases from storage to increase the peak or duration of a flow event, and so reinstate some of the flows that have been intercepted and stored by dams.

The Murray–Darling Basin Authority understands that some of the flow footprints under investigation by the Constraints Management Strategy will affect businesses and the community and that these effects need to be mitigated.

Background to the Strategy

The Strategy was developed in 2013 through technical assessments and many conversations with local communities and industries. It incorporated community views and suggestions from a public comment period in October 2013 (see 'What does the community think?' and the Constraints Management Strategy public feedback report[2]).

The Strategy is about giving effect to the Murray–Darling Basin Plan to make the best use of the water that has been recovered for the environment.

The Australian Government has committed $200 million to carry out approved mitigation works that are identified as priorities by the Basin states between 2016 and 2024.

Goulburn River at Killingworth Road. Many plant species are supported by the river environment. *Photo: Janet Pritchard, MDBA.*

2 www.mdba.gov.au/sites/default/files/CMS-Public-Feedback-Report.pdf

Impacts, benefits and risks of the Strategy

The ability to deliver overbank flows relies on governments being able to understand and mitigate impacts on private land and public infrastructure along the entire flow path. The entire flow path includes the potential for impacts on tributary landholders through backing up of flows, or reduced ability of tributary flows to drain freely. Community consultation has identified a number of impacts, options to mitigate impacts, benefits and risks of implementing the Strategy, which are described below.

It is important to remember that overbank flows can affect different areas in different ways. This list is compiled from peoples' experiences of a range of overbank flows, including large floods beyond the overbank flow footprints being considered by the Constraints Management Strategy. Therefore, not all of the potential impacts and risks are applicable to the flows being examined by the Strategy.

Potential impacts

General

- Bank erosion and tree fall during high flows
- Extended inundation causing damage to riverbank vegetation
- Carp breeding and vermin control
- Spread of weeds
- Interruption to recreational activities
- Increased water table affecting hydrological connection of on-farm wetlands

Private property

- Infrastructure and access
  - inundation restricting access to certain parts of properties
  - damage to crossings or access roads
  - damage to pumps and interruption to pumping
  - damage to fences
  - time required to move assets to higher ground or protect them in place (e.g. machinery)
  - drainage problems (managing where water spreads, drains and remains on the property)
  - damage to levee banks and subsequent increased maintenance needs
- Pasture and cropping impacts
  - pasture renovation
  - lost hay and silage production
  - damage to pastures from extended inundation (if greater than one week)
  - weed spread and subsequent impact on pasture growth and quality
  - increase in costs and effort of controlling weeds and native saplings
  - soil compaction from extended inundation, nutrient leaching on fertilised paddocks
  - interference with opportunistic cropping
- Clean-up
  - increased time and costs spent on general clean-up after flood (e.g. logs, fences, troughs, non-compostable rubbish and debris)

- Stock issues
  - loss of production due to stock exclusion from inundated areas, including time after the area has drained
  - increased time and resources spent moving stock
  - risk of stock loss at certain times of year (lambs, calves)
  - cost of additional feed, livestock transportation or agistment
  - fragmentation of paddocks and effects on stock rates, stock movement and management
  - increased stocking rates on higher ground and therefore depleted pastures elsewhere on property

Public infrastructure

- Inundation of low-lying roads and bridges and subsequent increased maintenance needs
- Damage to crossings or access roads
- Damage to levee banks and subsequent increased maintenance needs
- Storm water drainage backing up
- Potable water supply where change to river water quality may require changes to the water treatment protocol
- Access to river beaches, camping, wood-gathering areas, walking and bicycle paths and boat ramps may be impeded

Ways to mitigate impacts

General

- Upgrades to tributary and main-stem gauging network
- Information system to provide flow advice and advance warning to give people more time to prepare and protect assets
- River health program that controls riverbank erosion

Private property

- Payment for easements, or other landholder agreements, to pay in advance for future impacts of managed water on private land
- Upgrades to on-farm roads, bridges, crossings and drainage
- Upgrades to other on-farm infrastructure (e.g. pump house location)
- Levee upgrades or construction

Public infrastructure

- Road and bridge upgrades
- Levee upgrades
- Levee outlet infrastructure upgrades

Potential benefits

General

- Increased riverine productivity (See ‘Why is the Strategy important?’)
- Improved soil and water quality
- Increased resilience in riverine systems — the capacity for the landscape to recover after droughts or floods

- Improved recreational, aesthetic and amenity benefits
- Benefits to businesses that directly depend on healthy rivers and floodplains
- Reduction in blackwater events due to regular 'cleaning up' of organic matter
- Increased fish breeding for whole-of-river recreational fishing benefits
- Improved efficiency of environmental water use
- Downstream ecological benefits in the River Murray system

Private property

- Pasture benefits from short durations of flooding (less than one week), although this is dependent on the type of pasture
- Soil improvements due to deposition of silt
- Regeneration of vegetation used as food and shelter by stock
- Improved capacity to deal with already occurring overbank flows due to infrastructure upgrades (stock crossings, on-farm access roads, improvements to drainage)
- Improvements to strengthen rural levees and bring them up to a minimum standard of protection
- Filling up creeks and wetlands on private property for amenity and production values

Public infrastructure

- Improved capacity to deal with overbank flows by investing in infrastructure upgrades (e.g. roads, bridges, stormwater)
- Addressing flood 'problem areas' and fixing long-standing infrastructure issues (e.g. areas with frequent road or bridge closures, uncontrolled nuisance flooding)
- Improvements to the stream gauging network
- Improvements to strengthen rural levees and bring them up to a minimum standard of protection
- Upgrades to regulatory structures to control when and where water spreads
- Stormwater and drainage improvements

Residual risks

Residual risks are those risks that may remain after investing in mitigation.

General

- Flood risk — potential for managed flow to be larger than intended due to unexpected additional rainfall or higher tributary flow contributions (especially given week-long travel times for managed releases from Lake Eildon and the amount of ungauged tributary catchment: up to 50% in some cases)
- Potential for modelled flow footprint maps (our understanding of spread of water and level of impact) to not be accurate enough to match real flow events under a range of catchment and rainfall conditions
- Workplace health and safety risks (working in flooded or fast flowing areas, moving machinery and stock, operating drainage control systems, etc)

Private property

- Potential stock bogging, stranding and loss
- A change in how often parts of properties get wet could affect farm planning, land use, and in extreme cases farm viability
- Reduced property value due to potential for reduced stocking capacity and interrupted access, or simply by having an easement registered on title

Public infrastructure

- Ability to maintain public assets under a changed flow regime where they get wet more often (e.g. ongoing maintenance and repair needs)
- In some reaches, high volume flows could trigger flood protection schemes allowing water into areas that would be damaging to landholders (e.g. Loch Garry regulator)
- Indirect effects such as road closures can cause a change to traffic management and associated risks (e.g. traffic hazards increase such as increased traffic volumes, kangaroos, pedestrians or cyclists or changes to emergency management routes or response times)

River red gum forest at Shepparton. River red gums are dependent on regular floods to stay healthy and germinate seeds. *Photo: Janet Pritchard, MDBA.*

Why is the Strategy important?

At a glance

Connecting rivers to their floodplains sustains the local environment and provides benefits to communities, such as improved soil and water quality. River development and regulation have reduced the overbank flows that provide this connection. The Constraints Management Strategy aims to put back some water to the environment to boost riverine productivity, and increase health and resilience.

In the Goulburn River, assessments have rated the current health of the environment as ‘poor’.

Rivers before and after river regulation

In unregulated river systems, there are no constraints to overbank flows caused by high rainfall and catchment run-off, which regularly spread out across the floodplain and reach floodplain creeks, wetlands and billabongs.

In regulated river systems, dams and weirs harvest and control high rainfall events, significantly reducing the flow footprint downstream (Figure 3).

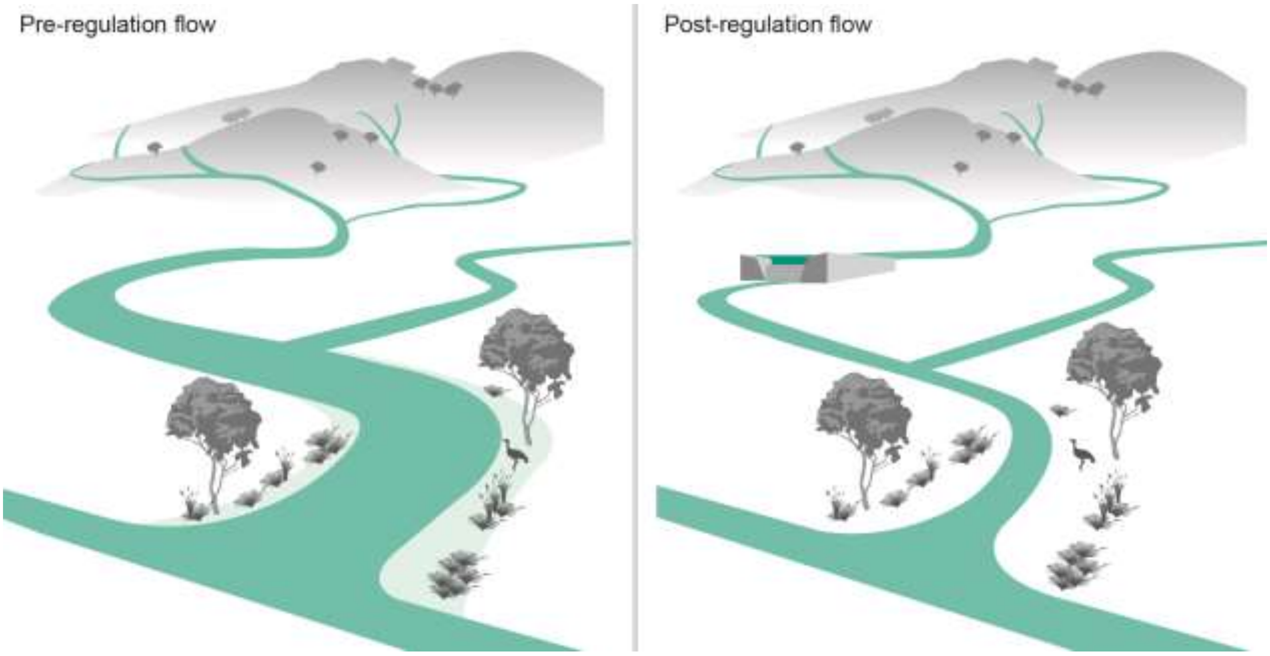


Figure 3 Rivers with pre-regulation and post-regulation flow footprints

This affects the behaviour of the river downstream. It reduces the height and duration of overbank flows, and increases the time between overbank flows (Figure 4).

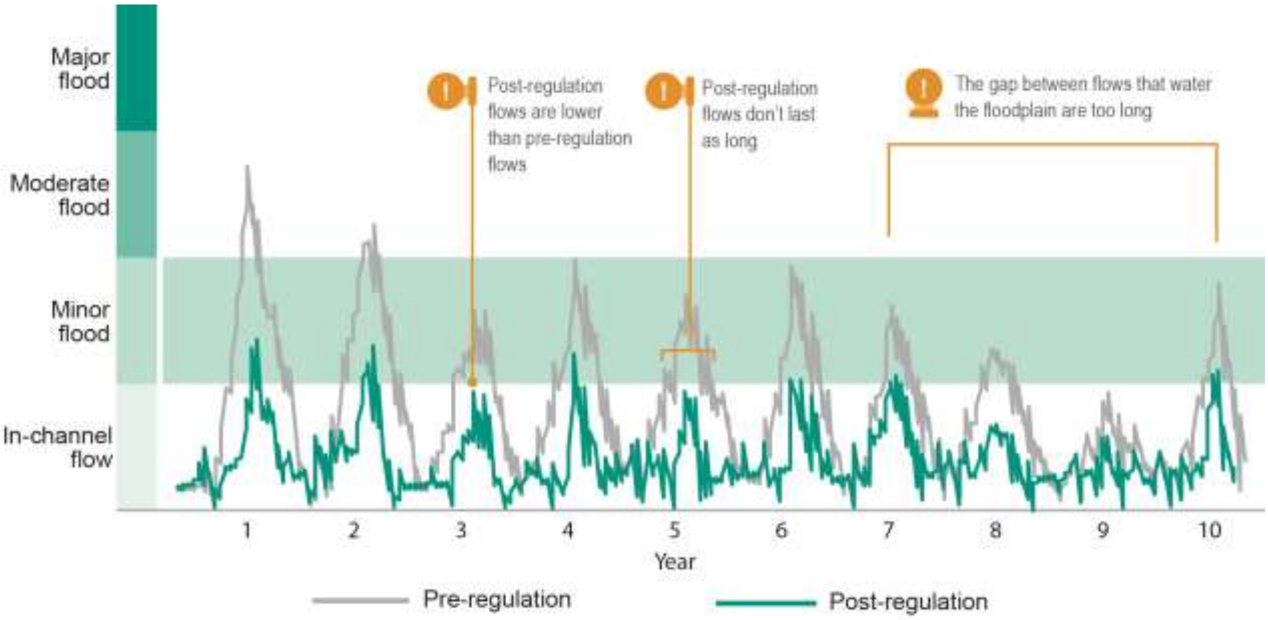


Figure 4 Changes to a river's hydrology after river regulation

Regulated releases from storage are mostly restricted to in-channel flow footprints (Figure 5). This reduces the water that reaches particular parts of the landscape — most notably the floodplain and its creek network, wetlands and billabongs. River water stimulates the ecology of many plant and animal species, and without flows to trigger a range of ecological processes (feeding, breeding, moving) both the diversity of species and their individual numbers have declined.

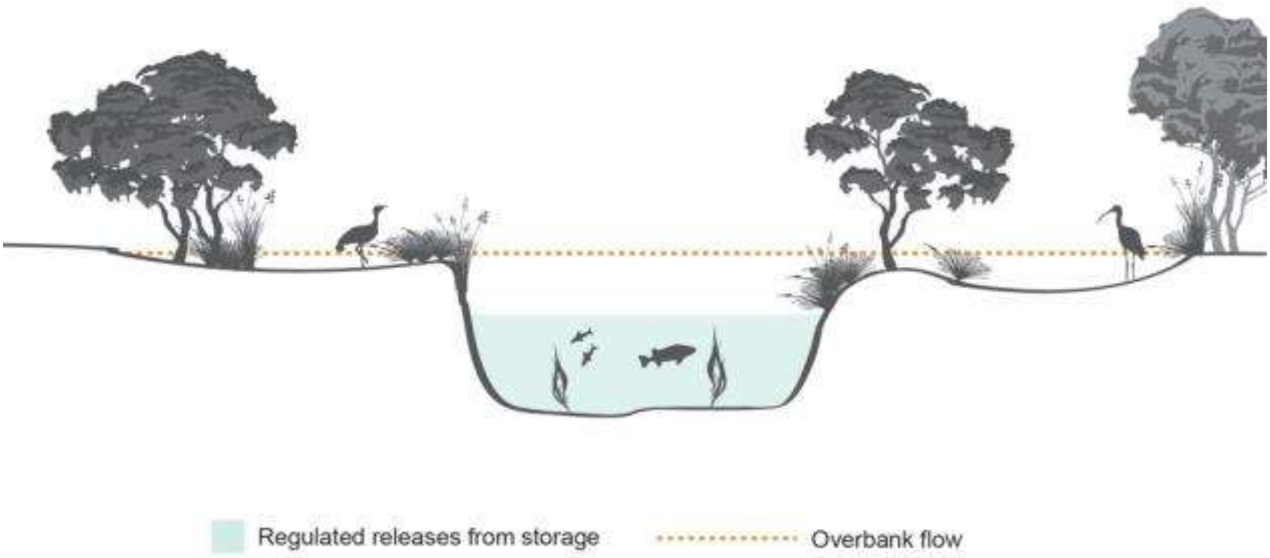


Figure 5 Regulated releases from storage are mostly restricted to in-channel flow footprints

In the Murray–Darling Basin

The Murray–Darling Basin (the Basin) has become highly regulated. In 1891, the construction of Goulburn Weir near Nagambie, Victoria, marked the beginning of almost a century of construction of major assets to support irrigation in the Basin.

By the time Dartmouth Dam was completed in 1979, enough dams had been built across the Basin to store more than one year's average inflow. The large dams in the southern Basin — Burrinjuck, Blowering, Hume, Dartmouth and Eildon — were all sited at locations where they could capture and store as much inflow as possible.

These dams typically fill through winter and spring, and are subsequently drawn down through summer and autumn to support large-scale irrigation.

In the southern Basin, where 80% of the Basin irrigation occurs, the combination of dam construction and irrigation changed the rivers from winter–spring flowing to summer–autumn flowing and, in the process, eliminated most small flood events.

With Australia's highly variable rainfall and heavy irrigation use, it became quite common from winter–spring rain events to be almost fully captured in storages. Significant overbank flows only happen when the major storages have filled and, subsequently, spill. Thus, only the wettest 15% of years now result in significant overbank flows in the middle to lower Murray. Before development, such flows would have occurred in almost 50% of years.

The impact on floodplain species has been dramatic, with large areas of floodplain forests and woodlands dead or highly stressed.

Connecting rivers to their floodplains

Overbank flow footprints up to the minor flood level range, which are being considered by the Constraints Management Strategy (the Strategy), are vital to the environment. Before river regulation, overbank flows were common events and they deliver a range of benefits (Figure 6).

Overbank flows:

- **improve water quality and supplies**, by
  - flushing out the salt along river banks and floodplains
  - helping recharge groundwater supplies
- **improve soil quality and reduce erosion**, by
  - moving carbon and nutrients between rivers and floodplains
  - stabilising riverbanks through better plant growth, thus reducing erosion into the river
- **support native species**, by
  - triggering plants to seed or germinate — for example, river red gums need flooding for their seeds to germinate
  - supporting habitat and breeding of aquatic bugs and insects (the primary source of the river food chain)
  - stimulating animals like native fish to feed and breed — for example, golden perch need high river flows to spawn, and floodplains make great nursery habitats to rear young fish
  - allowing plants and animals to move throughout river systems and colonise new areas.

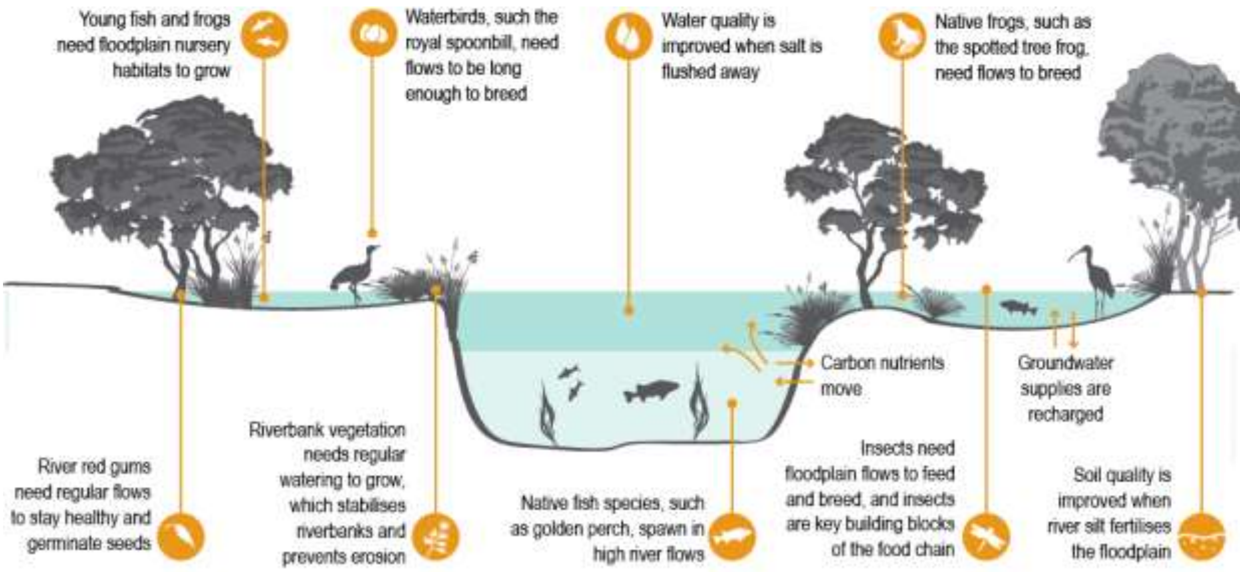


Figure 6 The environmental effects of overbank flows

Constraints to delivering overbank flows are damaging the river environment. It is important to recognise that this threatens not only the natural environment, but the communities that depend on it. For example, good water and soil quality is vital to local farming communities along the river.

The proposed overbank flows will usually 'top up' existing flows, increasing either their peak (river height) or duration (Figure 7).

Flows are important for many environmental processes, such as breeding and migration, and many species use weather conditions as triggers in anticipation of a large flow. Coordinating regulated water releases with rainfall events and catchment run-off makes use of natural ecological cues to improve environmental outcomes.

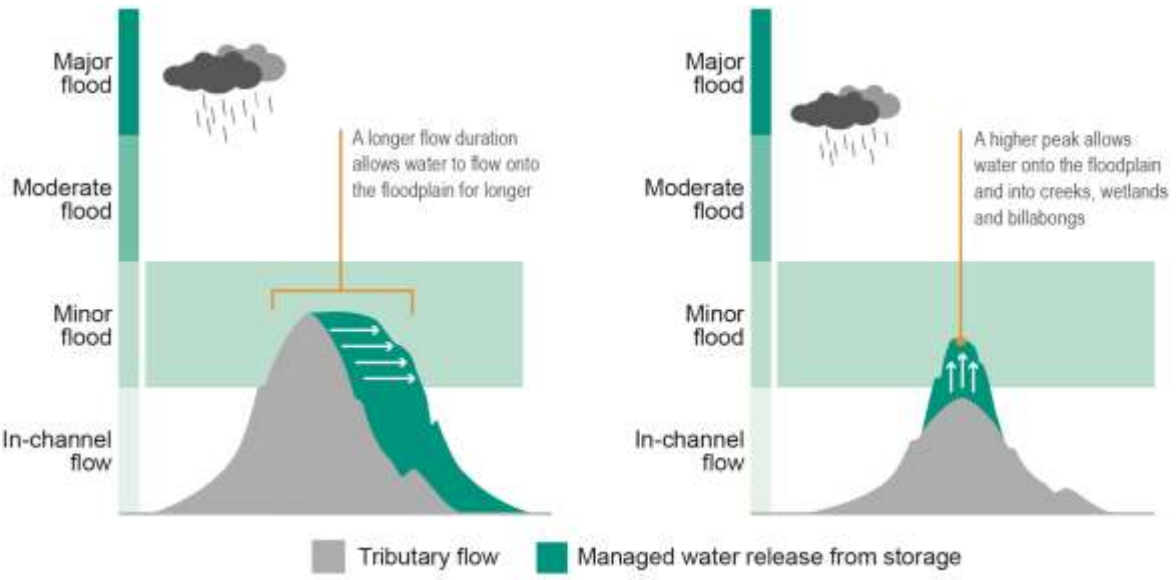


Figure 7 'Topping up' unregulated tributary flows with regulated releases to create overbank flows

Why the Strategy is important in the Goulburn River

Over time, the Goulburn River has been modified and become highly managed. Eildon Dam and Goulburn Weir store and deliver water for irrigation and consumption, and also significantly alter the flow of the river. The operation of dams and river regulation to secure water resources for communities reverses the natural seasonal flow pattern. Under unregulated conditions, the river flows are highly variable, and have high flows in winter and low flows in summer. Under regulated conditions, the river flows are much less variable, and have lower flows in winter and higher flows in summer.

Changing the seasonal flow pattern disrupts the natural cycles of feeding, growing and breeding for many plants and animals. Because of this, many native species have significantly declined in the Goulburn region.

> *Moira grass has pretty much disappeared from the lower Goulburn around Yambuna forest. There used to be plenty around and it was good feed for the cattle. In fact, cattle used to wade into the water right up to their backs to graze on the Moira grass — they looked just like water buffalo.*
> *You used to be able to boat around and even when the water was over 7 feet deep, you still had a mass of Moira grass floating on top and flowering. It was amazing stuff. Moira grass probably disappeared from the lower Goulburn, as there is no longer enough water deep enough or long enough in the forest to meet its growing requirements.*
> *Comments made to the Murray–Darling Basin Authority (MDBA) by two long-time lower Goulburn floodplain residents*

There have been two recent comprehensive assessments of river ecosystem health (Sustainable Rivers Audit 2008 and 2012), relating to 2004 to 2010. Both audits concluded that the health for the northern Victorian rivers — including the Goulburn, Broken, Campaspe, and Loddon Basin zones — was ‘very poor’. The exception was the Ovens Basin zone, which was rated as ‘poor’.

Under the Strategy, overbank flows aim to address these impacts as well as to improve flows further downstream, such as to the River Murray.

Case study — native fish

An analysis of historical newspaper reports, old photographs, oral histories and early explorer accounts clearly show that native fish used to be far more abundant and widespread in the Goulburn River (Trueman 2012).

For example, silver perch used to occur in such numbers at Shepparton that they were considered a pest. Murray cod were so abundant that they supported a commercial fishery at Goulburn Weir. Catfish were common in the river and lagoons near Murchison, plentiful near Toolamba and abundant near Shepparton, and even occurred as far upstream as Yea.

Mirroring the trajectory of many other native fish in the region, catfish abundance underwent a serious decline in the 1930s, becoming uncommon by the end of the 1940s and rare by the 1980s. Catfish have now all but disappeared from the lower Goulburn River, with the exception of a small remnant population being harboured in Tahbilk wetlands and the occasional capture of a catfish downstream of Goulburn Weir.

Of course, there are many reasons why native fish have declined in the Goulburn catchment, but a key factor among them is the change in river flows and seasonal signals that have accompanied river regulation.

Native fish need overbank flows to trigger them to move and breed, and to provide suitable nursery and juvenile habitat. This is a key objective of the Constraints Management Strategy.

Goulburn River at Shepparton. Dams and weirs reduce flow heights and duration. *Photo: Janet Pritchard, MDBA.*

What is happening in the Goulburn River?

At a glance

The Goulburn River is highly modified and managed. A series of studies have consistently said that the frequency of overbank flows is less than what is needed to maintain the health of the lower Goulburn floodplain. Based on initial overbank flow recommendations for the lower Goulburn in 2011, the managed flows would occur at least once every three years. Given that these flows sometimes happen naturally, this means an extra one to two managed overbank flows every ten years on average to achieve lower Goulburn environmental outcomes. Future development and testing of real-time catchment and river models would provide water managers, river operators and community with the confidence to water within the target flow range. This would take the floodplain closer to an environmentally sustainable watering regime.

Hydraulic models developed for the Goulburn River show how high the river gets for any given flow at that point along the river, and what gets wet at that height. These models and flow footprints are being used to help develop the recommendations for the Constraints Management Strategy, which will form the next phase of more detailed investigations.

Catchment characteristics

The highly regulated Goulburn River and much less-regulated Broken River form the Goulburn–Broken catchment in North Central Victoria, with five subreaches (Figure 8). The Goulburn–Broken catchment covers an area of 2.4 million km^2, which is around 2% of the Murray–Darling Basin (the Basin), or about 10.5% of Victoria.

The Goulburn River is 570 km long, flowing from the Great Dividing Range upstream of Woods Point to the River Murray east of Echuca. The Broken River, the second main river in the region, is 550 km long and forms about 25 km east of Mansfield. It flows to the north through Benalla and then west to enter the Goulburn River near Shepparton. Broken Creek is a distributor of the Broken River, leaving the Broken River downstream of Benalla and joining the River Murray just upstream of Barmah.

The average annual rainfall varies across the catchment, from 1,600 mm in the southern high country to 400 mm in the north-west plains. Inflows to the rivers in the catchment are 3,559,000 megalitres (ML) per year, or about 11% of the total annual inflows to the Basin.

The Goulburn Valley has a relatively narrow floodplain from Goulburn Weir to south of Toolamba before widening from Shepparton towards Loch Garry, with significant wetland and floodplain areas adjacent to the river. Levee banks confine the floodplain downstream of Loch Garry and the capacity of the leveed floodplain decreases from approximately 85,000 ML per day (ML/d) at Shepparton to 37,000 ML/d at Yambuna.

From Yambuna to the River Murray, the floodplain widens again to the north to Deep Creek and the River Murray, whereas levees contain flows on the south side of the river. The major wetlands and floodplain forests of the lower Goulburn River are located in this northern area — downstream of Yambuna to the Murray confluence.

Historically, the river has discharged a large portion of flood flows overland and along distributary creeks. Diminishing downstream flow channel capacity, eroding flood paths and distributary creeks potentially encourage the development of alternative courses capable of diverting the river by avulsion or breakaway. This risk is increased if the ground surface is exposed by vegetation clearance or if flood flows are concentrated as a result of drainage or flood mitigation works.

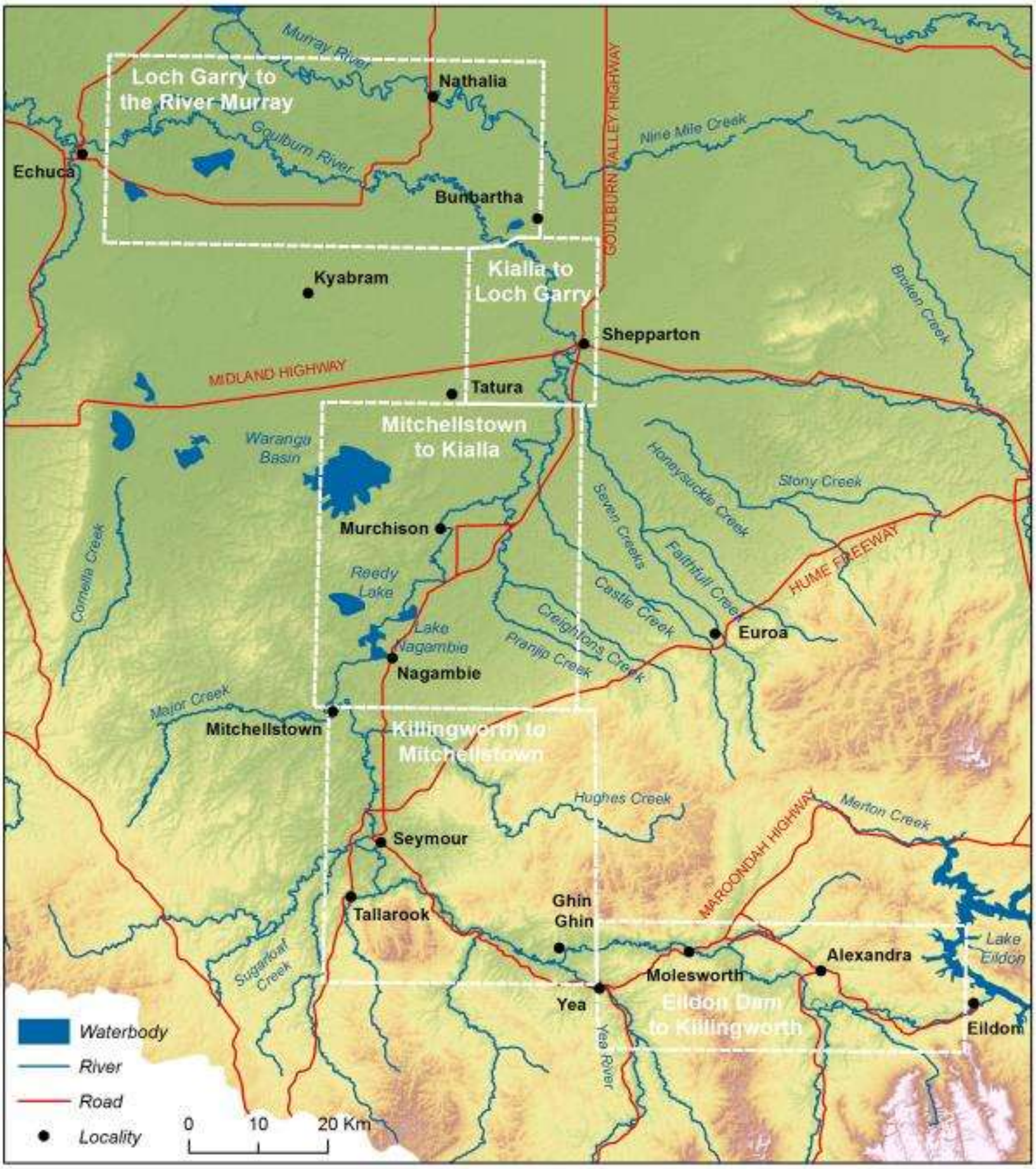


Figure 8 Goulburn catchment subreaches

People and economy

Around 215,000 people call the Goulburn region home. Major population centres include Shepparton, Seymour, Nagambie and Benalla. The majority of land in the catchment is privately owned, with 1.4 million hectares used for dryland agriculture and 270,000 hectares for irrigated agriculture. There are 800,000 hectares of public land, including extensive areas for conservation (GB CMA 2013).

Natural resource-based industries underpin the catchment's economy. Livestock, dairy, fruit, vegetable, grape, aquaculture and other food production and processing contribute to the $15.9 billion gross regional output (2009 figures). The gross value of agriculture production in the catchment in 2009–10 was $1.16 billion (GB CMA 2013a). The irrigated areas of the Shepparton region (Northern Riverine Plain) comprise nearly 70% of Victoria's irrigated agriculture (GB CMA 2013).

Environment

The Goulburn River has been recognised for its significant environmental values. It includes a nationally important wetland area (covering 13,000 hectares) and the Lower Goulburn National Park (approximately 9,310 hectares), which protects the red gum floodplain forests on either side of the lower Goulburn River from Shepparton to its junction with the River Murray near Echuca.

The river and its associated floodplain and wetland habitats support a diversity of habitats and species. There is intact river red gum forest and numerous threatened species, such as Murray cod, trout cod, silver perch, squirrel glider and eastern great egret. There are a large number of colonial nesting waterbirds and a diverse native fish population. The lower Goulburn floodplain has flood-tolerant vegetation communities, such as black box, grey box, yellow box, white box and flood-dependent river red gum communities (GB CMA 2012).

The river, floodplains and wetlands also contain many important cultural heritage sites, provide water for agriculture and urban centres, and support a variety of recreational activities, such as fishing and boating.

How the Goulburn River has changed

Waterways in the Goulburn have been substantially modified to convey water for irrigation and consumptive purposes, drain excess water and protect properties from flooding.

The CSIRO Sustainable Yields Project reported that flooding in the lower Goulburn River has been significantly reduced, which is largely due to water resource development in the Goulburn River (CSIRO 2008). Before development, flows that inundated the lower Goulburn River floodplain were relatively common, occurring every two and a half years on average, and there was never more than about a decade between events (CSIRO 2008).

Two major features have principally modified river flow along the Goulburn River — Eildon Dam in the upper catchment and the Goulburn Weir in the mid-catchment. These two features regulate river flow, and supply water for irrigation, urban and environmental purposes:

- **Eildon Dam:** The dam fully captures flows from the upstream catchments in all but the wettest of years. Flow conditions in the mid-Goulburn (downstream of Eildon Dam to Goulburn Weir) have been reversed. Lower flows now occur in winter and spring due to

harvesting of tributary flows into storage at Eildon Dam, and higher flows now occur in summer and autumn due to water releases from Eildon Dam for irrigation and consumptive demands.
- **Goulburn Weir:** The weir and its operation to harvest water for irrigation use have reduced the average annual downstream flow in the Goulburn to less than half of the estimated pre-regulated flow (CSIRO 2008). Large flow diversions by Eildon Dam and Goulburn Weir have reduced the size, frequency and duration of ecologically important flows. Although flows are greatly diminished in size, frequency and duration, the Goulburn River below Goulburn Weir still retains much of the natural seasonal flow pattern. This is partly due to the influence of natural flow patterns from the mostly unregulated Broken River and the Seven Creeks tributaries, which join the Goulburn River below Goulburn Weir.

Floodplain development and levees along the lower Goulburn have also altered the flow characteristics of the floodplain. For example, along the riverine plain downstream of Shepparton, artificial levees and other structures obstruct flood flows and have significantly changed where water spreads across the landscape.

> *The lower Goulburn has been extensively modified. The floodplains have been cleared for agriculture and grazing right up to the levees. The south side includes established irrigation and drainage infrastructure with its network of roads. Dryland agriculture and grazing occupy the floodplain to the north with a small proportion of irrigation.*
> *Following several flooding episodes, a committee was set up on the 'eastern side'. A petition to government was prepared requesting assistance to construct a levee scheme. When landholders on the 'western side' awoke to the fact that levees were being considered, they had the government veto the scheme.*
> *Several years followed, where a local dispute over a levee in Yambuna occurred. Mr George Stickels saw this to be an opportunity to call for a conference of the interested shires of 'Deakin, Rodney, Shepparton and Numurkah'. Within a few days of a deputation asking that the unemployed be set to work to construct levees, 'men with barrows and tools' were at work constructing levees.*
> *According to the 1936 Nathalia Herald news article, the engineers were instructed to save all the land they could. The engineers Messrs Muntz and Bage set out the levee scheme whereby no levees were to be nearer than seven chains (approximately 140 m) from the river and in no case were the river bends to be followed. The levees constructed, as they exist today clearly do not conform to the engineers' criteria.*
> *Excerpt from SMEC (1998).*

See Appendix 1 for further details of the constraints on the Goulburn River.

How the Goulburn River is managed

Goulburn–Murray Water (GMW) manages the storage and regulated release of water for irrigation, environmental and urban purposes in northern Victorian catchments.

The Goulburn River is actively managed. The highly variable tributary inputs downstream of Eildon Dam require adjustments and balancing manipulations at Eildon Dam and Goulburn Weir every day to ensure reliable delivery of water to customers. GMW has a wide range of customers that require different amounts of water at different times, one of which is the environment.

Day-to-day river operations by GMW have to take into account a wide range of factors, including:

- current river conditions
- channel capacity
- weather forecasts
- tributary inflows
- order variability
- diverter behaviour
- electricity generation requirements (hydropower at Eildon Dam)
- gauge accuracy
- loss assumptions.

An overview of how environmental water is planned and managed in Victoria is included in Appendix 2.

Current management patterns

Current regulated operation of the river system is based on the provision of flows within a range governed largely by irrigation requirements and minimum flow provisions. GMW manages the day-to-day river operations of Eildon Dam to limit flows to 2.5 metres at the river gauge, equivalent to flows of 9,500 ML/d (outside of flood operations).

Irrigation requirements generally follow crop demand patterns and do not vary significantly during the summer irrigation season. Generally, regulated flows do not exceed irrigation demands, although limited provision for additional releases exist in the Goulburn Bulk Entitlements (a bulk entitlement is a right to use and supply water, which may be granted to a water corporation, the Victorian Environmental Water Holder and other specified bodies). Outside of flood operating conditions, GMW will not release water orders from Eildon Dam or Goulburn Weir if there is a risk of flooding.

What the science says

To develop the Strategy, the Murray–Darling Basin Authority (MDBA) is examining and constructing a scientific understanding of river processes and their effects.

Goulburn River studies

A series of technical studies and policy recommendations have been made about the Goulburn River (Table 1). These have consistently reported that the frequency of overbank flows is less than what is needed to maintain the health of the environment, and that regulated flows are constrained by possible effects on private land.

Based on initial overbank flow recommendations for the lower Goulburn in 2011, the managed flows would occur at least once every three years. Given that these flows sometimes happen naturally, this means an extra one to two managed overbank flows every ten years on average to achieve lower Goulburn environmental outcomes. Future development and testing of real-time catchment and river models would provide water managers, river operators and community with the confidence to water within the target flow range. This would take the floodplain closer to an environmentally sustainable watering regime.

Table 1 Goulburn River studies and current Victorian policies

Year	Study	Findings
2003	**Environmental flow recommendations for the Goulburn River below Eildon Dam,** Cooperative Research Centre (CRC) Freshwater Ecology and CRC Catchment Hydrology[1]	In all reaches of the Goulburn River, the frequency of environmental flows is less than natural and less than recommended. An environmental flow regime of between 15,000 and 60,000 ML/d is recommended to meet the needs of floodplain wetlands. The highest priority recommendation of this study is the delivery of an overbank environmental flow event below Eildon Dam, of varying size, every year.
2006	**Goulburn Campaspe Loddon environmental flow delivery constraints study** Sinclair Knight Merz on behalf of Goulburn Broken Catchment Management Authority (CMA)[2]	The delivery of overbank environmental flows is constrained by potential flood effects on private land. In particular, flows in excess of around 14,500 ML/d cause nuisance flooding around Molesworth and the township of Thornton.
2007	**Evaluation of summer inter-valley water transfers from the Goulburn River** Cooperative Research Centre Freshwater Ecology and CRC Catchment Hydrology[3]	(This is a follow-on to the 2003 environmental flow recommendation study.) An annual floodplain inundation event is recommended for the lower Goulburn downstream of Goulburn Weir, ranging from 15,000 to 65,000 ML/d to connect the river and its floodplain.
2009	**Northern Region Sustainable Water Strategy** Victorian Department of Sustainability and Environment[4]	Water recovery targets were set for northern Victorian catchments to address a range of water resource threats into the future, including climate change. One of the environmental management objectives for the Goulburn River should include overbank environmental flows at least once in every three years.
2010	**Goulburn River environmental flows hydraulics study** Water Technology and URS Australia on behalf of Goulburn Broken CMA[5]	In the lower Goulburn, environmental flows of up to 40,000 ML/d may provide the majority of the environmental benefits with the least economic cost. Inundation of private land occurs at flows of less than 20,000 ML/d between Lake Eildon and Molesworth, meaning that 40,000 ML/d releases solely from Lake Eildon are unlikely to be feasible. Therefore, to achieve overbank environmental flows in the lower Goulburn (downstream of Goulburn Weir), this means relying on a combination of unregulated tributary flows and some releases from Eildon Dam.

Year	Study	Findings
		As the river varies in flow capacity along its length, a lower environmental flow range may be appropriate in the upstream reaches, and a higher environmental flow range in the downstream reaches.
2011	**Overbank flow recommendations for the lower Goulburn floodplain** Victorian Department of Sustainability and Environment and Goulburn Broken CMA	Environmental flow rates at Shepparton of between 25,000 ML/d (with a median duration of ≥5 days and a maximum period between events of 3 years) and 40,000 ML/d (with a median duration of ≥4 days and a maximum period between events of 5 years) are recommended. The lower bound of 25,000 ML/d inundates the majority of wetlands in the lower Goulburn floodplain. The upper bound of 40,000 ML/d gets almost all the water-dependent terrestrial plants wet, while largely avoiding the major risks and liabilities associated with flows above this rate (e.g. flooding of private land).
2013	**Victorian Waterway Management Strategy** Victorian Department of Environment and Primary Industries[6]	Victorian and Australian Government investment in water recovery for the environment has enabled the delivery of significant volumes of water to improve the health of our waterways. Although this provides the opportunity for greater environmental benefit, it can also mean increased risk to communities and property from high flows in waterways, and minor flows on public or private property. This recognition resulted in Policy 8.12, which states that 'deliberate inundation of private property will not be undertaken without the landholder's consent (e.g. easement arrangement)'.
2014	**Water Bill: exposure draft — an explanatory guide and fact sheets** Office of Living Victoria[7]	In Victoria, water corporations and catchment management authorities are liable to pay compensation if they intentionally release water from their works and this water causes injury, loss or damage, or if, through a negligent act, they cause flows that result in loss, injury or damage. These laws are intended to protect landowners who, through no fault of their own, are flooded by flows from works of water corporations or catchment management authorities. The bill ensures that the 'water infrastructure' functions of a water corporation include the operation of storages and delivery of water from those storages, including for environmental purposes. This makes it clear that liability for intentional or negligent releases of water for environmental purposes would be determined under clause 722. This removes confusion under the *Water Act 1989* (Vic), where different liability schemes operate in relation to the same conduct (i.e. releases of water from storages) depending on whether a water corporation has been appointed a storage manager or whether the storages from which releases are made are jointly owned.

ML/d = megalitres per day

1 www.water.vic.gov.au/__data/assets/pdf_file/0006/28284/Goulburn-River.pdf

2 www.gbcma.vic.gov.au/downloads/EnvironmentalFlows/2006-11-23_Goulb_Camp_Lodd_Env_Flow_Delivery_Constraints_Study-SKMReport.pdf

3 www.gbcma.vic.gov.au/downloads/EnvironmentalFlows/2007-06-30_Evaluation_of_Summer_Inter-Valley_Water_Transfers_from_the_Goulb_River.pdf

4 www.depi.vic.gov.au/water/governing-water-resources/sustainable-water-strategies/northern-region-sustainable-water-strategy

5 www.gbcma.vic.gov.au/downloads/goulburnriverhydraulicstudy/goulburn_hydraulics_executive_summary_eflows_final.pdf
6 www.depi.vic.gov.au/water/rivers-estuaries-and-wetlands/strategy-and-planning
7 www.livingvictoria.vic.gov.au/content/economic/economic-legislative-reform-water-bill

For constraints-related studies relevant for the Goulburn region, see Appendix 3.

Flow footprint maps

Flow footprint maps let you look at what areas of land are likely to get wet for different-sized flow rates. They are based on simulation hydraulic models that approximate how water moves down the river and across the landscape, which are then checked against photos or satellite images from real events. The advantage of using a hydraulic model compared with aerial or satellite images is that it produces in-depth information about how a 'typical' flow might spread across the landscape.

The hydraulic modelling approach to creating flow footprints is designed to answer two questions:

- How high does the river get for any given flow at that point along the river?
- What gets wet at that height?

Goulburn modelling

For the Goulburn River, a set of eight hydraulic models have been tested and calibrated to make sure that they approximate real events.

In the 2010–11 Water Technology study, flow footprints were developed for 20,000, 30,000, 40,000, 50,000 and 60,000 ML/d from Eildon Dam downstream to the River Murray. Recently, MDBA has built on this work by modelling three new flow rates: 12,000, 15,000 and 25,000 ML/d. This is because landholders considered the previously modelled flows of 20–60,000 ML/d to be too high for the Goulburn River between Eildon and Molesworth, and the overbank flow recommendation of 25,000 ML/d downstream of Goulburn Weir had not been modelled previously.

In some areas, limited data reduce the accuracy of the hydraulic models (especially in the mid-Goulburn just downstream of Eildon Dam and in the lower Goulburn downstream of Loch Garry), but the models are a useful first approximation and show what happens to the landscape as it gets covered by different-sized flows.

Although work is still in progress, the flow footprint mapping work is proving to be valuable as a first estimate of how different-sized flows move across the landscape.

See 'What is happening in the subreaches?' for flow footprints for each of the subreaches.

How MDBA is using the flow footprint maps

MDBA uses the flow footprint maps to determine how flows could affect native vegetation and wetlands on the floodplain, as well as agricultural land use, and roads, bridges and other structures.

The flow footprint maps have already resulted in three strategic decisions for environmental water managers in Victoria:

- There is not much additional environmental benefit in getting flows above 40,000 ML/d for the floodplain downstream of Shepparton (gauging station 405204). For the lower Goulburn floodplain, a flow of 40,000 ML/d wets most of the wetlands and watercourses, and most of the water-dependent floodplain vegetation while staying inside the protective levee network.
- A flow rate of 40,000 ML/d below Shepparton is about a one in three-year flood, but further up the catchment that size of flow is much more significant — closer to a one in 40-year flood at the Eildon gauge. The recognition of the scale of impact below Eildon Dam clarified that the focus for future overbank flows needs to be some level of release from Eildon Dam on the back of tributary inputs downstream of the dam. Large releases from Eildon Dam on their own, while possible, are not being considered, other than as part of normal flood operations.
- The modelling showed that the 40,000 ML/day event at Shepparton (gauging station 405204) is not a dry-weather event (i.e. managers could not artificially create this event in a dry year). This is a wet-weather event, only likely to occur in years when the catchment is wet and tributaries are flowing strongly.

Flow footprint maps can help us calculate the environmental benefits. In addition, by identifying what might be affected at different flow levels, we can also estimate what costs might be associated with mitigation to reduce effects. Mitigation can include:

- Paying for easements or other arrangements to allow flows on private land
- undertaking infrastructure works — for example, upgrades to roads and bridges.

Initial cost estimates were prepared and presented for all seven key focus areas in the Constraints Management Strategy annual report.

What flows are being considered for the Goulburn River?

At a glance

The flows being considered are aligned with the overbank flow recommendations for the lower Goulburn (DSE 2011).

The flows at Shepparton are being considered at three levels: 'small-scale' change — 25,000 megalitres per day (ML/d, or 9.4 m); 'moderate' change — 30,000 ML/d (9.8 m); and 'large' change — 40,000 ML/d (10.3 m). The flows would be delivered between June and November at least every three years. The proposed change, based on current frequencies, is seeking an extra one or two 'topped-up' or managed events every ten years on average to maintain in-valley environmental outcomes..

We are looking at possible new ways to manage the Goulburn River to ensure its long-term health, while avoiding or minimising the effects on people who also depend on the river. The environmental objective for the lower Goulburn is to allow the river to connect with its floodplain more often.

This means investigating a range of overbank flows (9.4–10.3 m, which is 25–40,000 megalitres per day [ML/d]) at Shepparton. The timing of these managed overbank flows would be between June and November when the floodplain needs water most, and they would occur at least once every three years.

We are collecting information on river and tributary flow patterns and behaviours, environmental effects, and community knowledge and views to understand what is and isn't possible. We also need more work on understanding the Goulburn's relative contribution to meeting the downstream water needs of the River Murray. Further detailed analyses are required to determine what size of a Goulburn flow, and when and how often flows would be needed to contribute to successful floodplain outcomes in the Murray.

How these flows have been chosen

The Victorian Government's Northern Region Sustainable Water Strategy (DSE 2009) first established the environmental watering objective of allowing the Goulburn River to more regularly connect with its floodplain. Specific flow recommendations for the lower Goulburn floodplain were then derived from an understanding of the water requirements of the different vegetation communities on the floodplain (DSE 2011). The Murray–Darling Basin Authority (MDBA) adopted these flow recommendations during development of the Basin Plan in 2012, which are:

- a 25,000 ML/d flow rate at Shepparton (9.4 m); this flow rate gets the majority of floodplain wetlands and watercourses in the lower Goulburn wet
- a 40,000 ML/d flow rate at Shepparton (10.3 m); in addition to the above, this flow rate gets the majority of flood-dependent vegetation on the lower Goulburn floodplain wet, while largely avoiding the risks and liabilities of flooding outside of the levee network.

Flows in the range of 25–40,000 ML/d occur much less often than they used to. The Victorian Department of Sustainability and Environment work in 2011 showed that flow events from Murchison to Shepparton of between 25,500 and 55,000 ML/d:

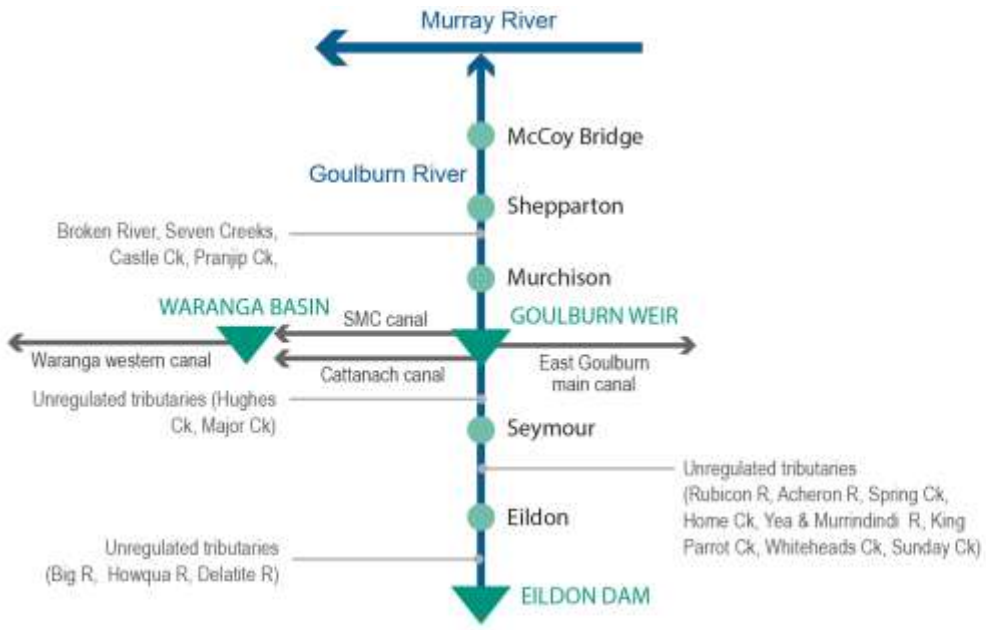
- are a lot less common than they used to be (occur at 20% to 30% of their unregulated frequency)
- don't last as long (last 50% to 70% of their unregulated duration)
- have a longer gap between events (have a maximum period between events that is 2.5 to 3.5 times longer than in the unregulated condition).

However, during MDBA consultation in 2013, we were informed that there has been a recent change to the rating table at Shepparton. This now means that the 40,000 ML/d flow at Shepparton is close to triggering the rules for opening the Loch Garry flood protection scheme (see further detail in Appendix 4). Recognising the potential risk of the 40,000 ML/d flow rate, MDBA has introduced a third flow rate of 30,000 ML/d, which is between 25,000 and 40,000 ML/d. An intermediate flow rate would get the floodplain trees and other vegetation wet as well as the wetlands and watercourses within the leveed floodway, while staying well below the river level at Shepparton that triggers the pulling of bars at the Loch Garry regulator.

Thus, constraints work is investigating three possible scales of change to flow rates at Shepparton:

- 'small-scale' change — 25,000 ML/d (9.4 m)
- 'moderate' change — 30,000 ML/d (9.8 m)
- 'large' change — 40,000 ML/d (10.3 m).

Figures 9 and 10 show the position of flood gauges along the river, and the river levels constraints work is investigating for these gauges. These flows would involve releases from Eildon Dam and/or Goulburn Weir when downstream tributaries are also flowing.



Cr = creek; R = river

Note: There is also a flood gauge at Trawool used for Bureau of Meteorology flood forecasting purposes, but this has not been included as it is very close to Seymour, with a very similar hydrology.

Figure 9 Schematic of the Goulburn River showing the flood gauges (circles) used for Bureau of Meteorology flood forecasting purposes along the main stem of the river

m = metre; MDBA = Murray–Darling Basin Authority

Note: Minor, moderate and major flood levels, as used by the Bureau of Meteorology, are included for comparison noting that the warnings are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 10 The river levels that constraints work is investigating for the different gauges along the main stem of the Goulburn River

Examples of historical flow events are provided in Appendix 5.

When and how often these flows would happen

The timing for overbank flows is winter and spring (June to November), not the summer irrigation season. This matches the time of year when rain and unregulated tributary flows typically occur in the Goulburn River, and when floodplain plants and animals need the water most. The duration for the peak of an overbank flow is expected to be less than a week.

Flow rates of this size already occur in the Goulburn, but what is missing is how often they occur. In preregulation conditions, flows at Shepparton of 25,000 ML/d (9.4 m) occurred nine times a decade on average; they now occur six times a decade. Flows at Shepparton of 40,000 ML/d (10.3 m) occurred seven times a decade on average, and now occur four times a decade.

The proposed change, based on current frequencies, is seeking an extra one to two overbank events every ten years on average to maintain in-valley environmental outcomes.

Typically, such releases will occur at times when inflows to Eildon are exceeding the rate of release. The pattern of release will aim to ensure that flows at Shepparton remain below the upper flow threshold set for Shepparton — further analysis will be needed before this is possible.

The recommended flows and rates are shown in Table 2. The maximum gap between events is recommended to be three years for 25,000 ML/d flows and five years for 40,000 ML/d flows (based on DSE 2011 recommendations).

Table 2 Recommended flows and rates

Flow rate at Shepparton	Season	Duration	Current number of events in 10 years	Recommended number of events in 10 years	Maximum time between events
25,000 ML/d	June–November	~5 days	**<6**	lower 7 **optimal 8** upper 10	3 years
40,000 ML/d	June–November	~4 days	**<4**	lower 4 **optimal 5** upper 6	5 years

ML/d = megalitres per day
Source: DSE (2011)

Gauge at Ghin Ghin Bridge. For the Constraints Management Strategy to be successfully implemented, it will be important to understand the effect of flows at different points along the river. *Photo: Janet Pritchard, MDBA.*

What is not being considered

We are not trying to create or change how often moderate and major floods occur (floods such as those occurring in 2010, 1993, 1981 and 1974). These are recognised as being damaging and disruptive to communities, and are outside the bounds of active river management. Such floods would occur with or without the Strategy.

We do not want to trigger the opening of the Loch Garry regulator (which would reduce flows to the floodplain forest in the leveed floodway downstream and inundate productive farmland). We are also not suggesting major changes to Eildon Dam, Goulburn Weir or Waranga Basin, or any changes that affect the reliability of water for other users.

Large water releases from Eildon Dam are not being considered (outside of flood operations).

The intent is not to change the flow regime of tributaries (unregulated creeks and rivers downstream of Eildon Dam). The only exception is backing-up effects in tributaries where creeks and rivers meet the Goulburn River (see Appendix 8). High in-channel Goulburn River flows can prevent tributary flows from draining freely, and cause backing-up effects that affect the lower reaches of tributaries. Further work is needed to determine the scope and likely significance of this issue for landholders along tributaries, particularly in relation to better understanding the likely duration of regulated water releases from Eildon Dam.

Options for creating an overbank flow in the Goulburn River

Once any effects on private landholders and community assets have been mitigated, there are several possible ways to create and manage overbank flows downstream of Shepparton.

Option 1 — Release all required flow from Eildon Dam

Although this is the most obvious option, it is not being considered. Using large releases from Eildon Dam to achieve an overbank flow downstream of Shepparton is impractical and undesirable due to the scale of impact it would have on communities downstream of Eildon. Although flows of 40,000 ML/d below Shepparton are in the minor flood level range of flows, further up the catchment the channel capacity of the river is much smaller and this flow would nearly result in a major flood.

The recognition of the potential effect of Option 1 showed that the focus for future overbank flows needs to be some level of release from Eildon on the back of tributary inputs downstream of Eildon.

Option 2 — Add some Eildon Dam releases to unregulated tributary flows downstream

Topping up unregulated inflows with releases to generate a higher peak flow and/or longer event duration has proved successful and this is a common tool for environmental water managers (see ‘What is the Constraints Management Strategy?’).

Taking into account operational decision factors (such as catchment and rainfall conditions), water could be released from Eildon Dam at the same time as a flow is observed on the Acheron and Rubicon rivers (but not large flows), and it will reach Trawool at approximately the same time as the tributary flows, increasing the flow peak. Releasing water from Eildon Dam will not ‘catch up' to those tributary flows entering downstream of Trawool, but releases from Eildon may help extend the duration of the flow event rather than the peak height of the flow event.

From MDBA consultation in 2013, there is some concern that we do not yet have sufficient accuracy in the stream gauge network to confidently predict how tributaries will behave under different weather scenarios. Further technical work is needed to determine the start and stop triggers for releasing water from Eildon Dam to add to downstream tributary flows safely. This should include explicit consideration of when environmental water releases should not be made and under what conditions they should be stopped.

There is also community concern that prolonged Eildon Dam releases could be similar in behaviour to pre-releases during flood operations. In essence, high Goulburn River flows that last for longer than a week could affect the ability of tributaries to drain freely. This could cause backing up, inundation and drainage effects for tributary landholders adjoining the Goulburn River.

Option 3 — Provide translucent flows at Goulburn Weir

'Translucent' flows aim to mimic an unregulated flow of water by releasing water when it rains in the mid-catchment. Translucent flows at Goulburn Weir temporarily allow catchment run-off water from rainfall events to continue to pass downstream rather than diverting it to Waranga Basin.

Translucent flows are a potential way to supplement flows at Shepparton and downstream without necessarily relying on additional water releases at Eildon Dam. Any water deliberately not diverted into Waranga Basin will be debited as an environmental water use. This is important because it means that environmental entitlements are debited for water used without affecting the reliability of supply for other entitlement holders.

The translucent flow option, although of limited size and availability (up to 7,500 ML/d), it is potentially a useful tool for achieving higher overbank flows at Shepparton. As the position in the catchment is much closer to Shepparton than Eildon Dam, this would allow river operators more confidence in predicting river flow conditions (especially flows coming from the mid-Goulburn tributaries, and Broken River and the Seven Creeks).

The translucent flows option also has an 'off switch' — if there is a rain event or higher tributary flows than expected, then diversions to Waranga Basin can quickly and simply be resumed to reduce risk.

Translucent flows released from Goulburn Weir could be timed to coincide with natural flow peaks from the Broken River or Seven Creeks, thereby providing increased flows in the Goulburn downstream of Shepparton.

This potential mechanism needs further analysis. We would need improved tributary forecasting to more accurately predict Broken River and Seven Creeks flow rates and travel times. This would allow translucent flows at Goulburn Weir to be better defined and controlled so that flow peaks match up to create a managed high-flow event of a specific flow rate, river height and duration.

Option 4 — Translucent flows at Goulburn Weir combined with releases from Eildon Dam

For greatest environmental watering flexibility, options 2 and 3 could be combined. Releases from Eildon Dam and translucent flows at Goulburn Weir could contribute to unregulated high tributary inflows, and top up the flow peak or extend the duration of the managed flow event downstream of Shepparton. Further analysis is needed to determine:

- what sorts of conditions would contribute to successful watering events
- which emerging risks should limit environmental watering.

Proof of concept — an example of how a overbank flow could be created

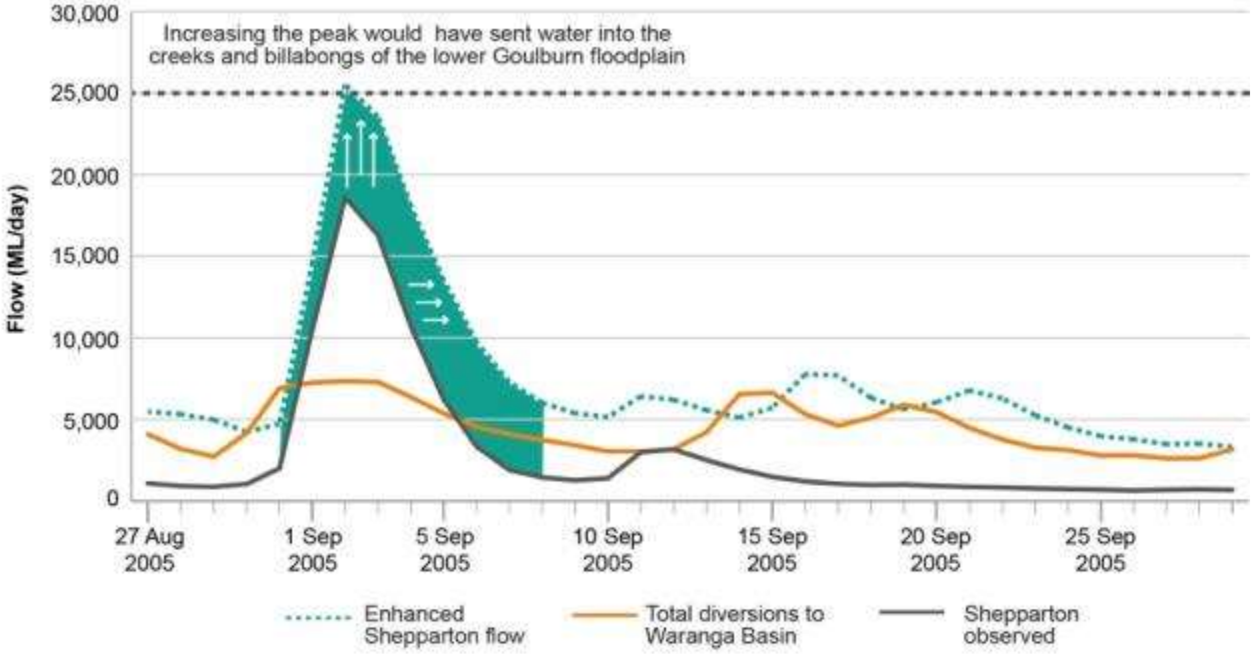
We examined actual river flows at Shepparton to determine if there were any events in recent history where translucent Goulburn Weir flows could have increased flows to 25,000 ML/d at Shepparton.

The flow rates that Goulburn Weir could potentially contribute downstream were calculated by assuming that any diversions to Waranga Basin could have been continued on downstream, rather than being diverted along the irrigation canals (translucent flow). Summing the Stuart Murray Canal and Cattanach Canal flow data gave the total daily diversion flow to Waranga Basin. These diversions were lagged by two days, to approximate travel time from Goulburn Weir to Shepparton (noting that, in reality, travel times will vary with different flow rates). The lagged diversions were then added to the observed Shepparton flow to determine what an increased Shepparton flow might have looked like.

It is important to note that this initial analysis of increasing the flow at Shepparton does not factor in any losses, and it assumes that diversions to Waranga Basin can be reduced to zero when this may not always be possible. GMW must also manage rates of rise and fall in the canals to prevent slumping. Nevertheless, there were several candidate events where passing flows at Goulburn Weir rather than diverting to Waranga would have sufficiently increased Shepparton flows to reach 25,000 ML/d.

For example, on 3 September 2005, there was a flow peak at Shepparton of 18,600 ML/d (Figure 9). By using translucent flows at Goulburn Weir, the 25,000 ML/d flow rate would have been met for an additional two days, using around 15,000 ML of water.

This was during the drought when Waranga Basin water levels were low, and the Stuart Murray and Cattanach canals were harvesting at full capacity with a total diversion of 7,360 ML/d. With the assumption that these flows could have been passed downstream and debited from environmental water entitlements, then the increased flow at Shepparton would have reached 25,530 ML/d (Figure 11). (Noting that there would have been enough allocation at that time to provide the event).



Note: The increased (enhanced) flow is an estimate of what the flow at Shepparton might have looked like if water had have been passed downstream of Goulburn Weir rather than diverted into Waranga Basin. The dashed line represents the flow rate of 25,000 megalitres (ML)/d, where water would fill the creeks, wetlands and billabongs of the lower Goulburn floodplain.

Figure 11 Actual flow and potentially increased flow at Shepparton, September 2005

Although the 2005 example illustrates that translucent flows at Goulburn Weir could be useful for delivering overbank flows, the relative window of availability for using Waranga Basin diversions needs to be better understood. This is especially in relation to understanding when reducing Waranga Basin diversions may or may not be possible due to irrigator demands, and if there are periods when reduced diversions would affect reliability of irrigator supply.

How often this option could be used

MDBA has also made an initial analysis of how often the potential to use Goulburn Weir translucent releases coincides with high river flows.

The greatest opportunities for increased flows at Goulburn Weir (by not harvesting into Waranga Basin) typically occur in the winter before Waranga Basin is full. These flows can provide good freshes in their own right, as well as provide the operational flexibility to top up unregulated tributary inflow events. Analysis of the Shepparton hydrograph and Waranga Basin operational data showed that Goulburn Weir translucency flows could have helped provide 25,000 ML/d events in June, July and August in about one-third (i.e. 12) of the 37 years between 1976 and 2012.

However, the top-up flows created by translucent flows at Goulburn Weir typically would not contribute to creating 40,000 ML/d events. Although Goulburn Weir translucency adds useful flows to the river, the high-flow events in winter during the past 37 years are typically not close enough to 40,000 ML/d to get to this size of flow.

The 40,000 ML/d events tend to occur after Waranga Basin is effectively full and ceasing diversions only adds a few thousand ML/d, at best. Initial analysis demonstrates that, although

Waranga Basin diversions can contribute small amounts of flow, they will not drive the achievement of the 40,000 ML/d flows at Shepparton.

Releases from Eildon Dam would be required to help achieve 40,000 ML/d events. However, because Eildon Dam is near the top of the catchment, there is much more uncertainty about the flow contributions of downstream tributaries and potential rainfall events after a release is made at Eildon.

To consider releases from Eildon Dam at times when unregulated tributary flows are predicted to be high, the catchment is wet or additional rainfall events are forecast, improved rainfall and tributary forecasting is required to more accurately predict mid-Goulburn tributaries (e.g. Yea River, where nearly half the river is ungauged), and Broken River and Seven Creeks flow rates and travel times. Improved tributary forecasting and predictions will be needed to enable Eildon Dam environmental release triggers to be accurately defined and controlled so that releases and downstream flow peaks create a managed high-flow event of a desired flow rate and duration.

Goulburn River downstream of Lake Eildon. When Lake Eildon is in storage mode, flows downstream are often significantly less than inflows. *Photo: Janet Pritchard, MDBA.*

What might be the effect of the proposed flows in the Goulburn River?

At a glance

The flows have the potential to benefit a number of species, particular river red gum forests and a range of fish species. They also have the potential to improve soil and water quality.

Different levels of change would bring about different effects for the lower Goulburn floodplain. For example, the small-scale change at Shepparton would reach 45% of flood-dependent vegetation on the floodplain, the moderate change would reach 74% and the large change would reach 89% (see 'What flows are being considered for the Goulburn River?').

The flows would have a range of effects on local communities, who have indicated that the effects from small to moderate change flows may be tolerable if suitable mitigation measures are put in place.

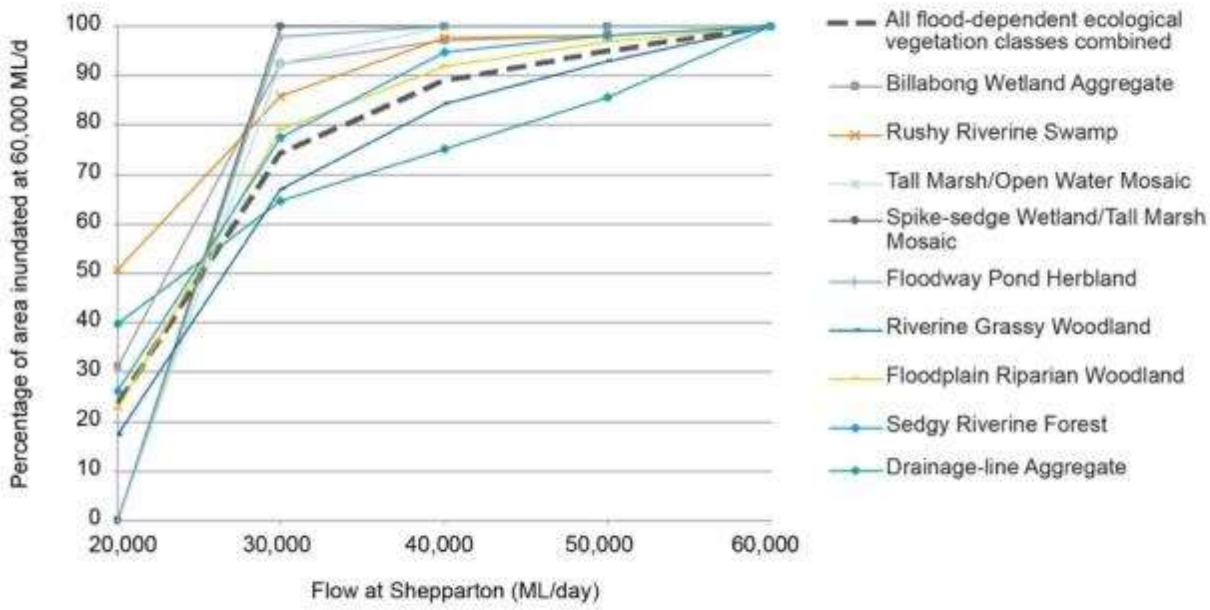
Environmental effects

Environmental water flows bring a range of benefits (see 'Why is the Strategy important?'), particularly for native species.

In the Goulburn River, although there have been significant declines in the numbers and distribution of many river plants and animals, there is still the potential for recovery.

Recent surveys of fish populations have detected that breeding populations of catfish, trout cod and silver perch still exist in the lower Goulburn River (e.g. Koster et al. 2012). Effective environmental flows have a key role in providing the right types of habitats and conditions to support and reinvigorate native species.

We already know that different flows affect different species (Figure 12). Our aim is to deliver the flows that will benefit the most species, while not adversely affecting local communities and industries.



ML = megalitre

Source: DSE (2011)[3]

Figure 12 Relationship between flow and flood-dependent vegetation in the Lower Goulburn

Case study — what environmental water can achieve

In 2011 and 2012, in-channel flows were delivered in the Goulburn River to try to trigger the spawning of golden perch (yellowbelly). This was unsuccessful.

Therefore, in December 2013, two larger in-channel flows were delivered that aimed to be as high as possible, to give the largest possible cue for fish breeding.

A series of flows were sent down the river in November and December, peaking at 6,000–8,500 megalitres per day (ML/d) on 2–4 December, and staying above 5,600 ML/day until about December 16. The flows saw the river level at Shepparton increase from about 2.7 m to 5.5 m.

The height and duration of the flows successfully allowed fish to breed. More than 80 golden perch eggs were collected at one location at Yambuna. In addition, the duration of the flows allowed time for the water to seep into the riverbank to regenerate vegetation on the lower banks. This vegetation had been lost during the 2010–11 floods and only slowly returned in response to variable in-channel flows.

A 2012 report by the Arthur Rylah Institute for Environment Research, *Status of fish populations in the lower Goulburn River (2003–12)* (Koster et al. 2012), found that the lower Goulburn River now has more Murray cod and golden perch than 20 years ago, and that golden perch spawning appeared to be associated with increases in environmental flows.

3 www.dse.vic.gov.au/conservation-and-environment/native-vegetation-groups-for-victoria/simplified-native-vegetation-groups/native-vegetation-group-18-wetlands#172

Change options and their effects

We are investigating three options for change (see 'What flows are being considered for the Goulburn River?'). These will each have different effects on the environment (Table 3).

Table 3 Environmental benefits of different levels of change

Environmental benefits	'Small' change 25,000 ML/d 9.4 m at Shepparton	'Medium' change 30,000 ML/d 9.8 m at Shepparton	'Large' change 40,000 ML/d 10.3 m at Shepparton
Wetlands	**Most** (**75%**) of nationally important wetlands • 9 out of 12 high-value wetlands • 1,012 ha (90%)	**Most (83%)** of nationally important wetlands • 10 out of 12 high-value wetlands • 1,086 ha (97%)	**All (100%)** of nationally important wetlands • 12 out of 12 high-value wetlands • 1,110 ha (99%)
Floodplain vegetation	**Around half (45%)** of flood-dependent vegetation on floodplain • 5,059 ha native vegetation inside levees	**Most** (**74%**) of flood-dependent vegetation on floodplain • 9,147 ha native vegetation inside levees	**Nearly all** (**89%**) of flood-dependent vegetation on floodplain • 10,227 ha native vegetation inside levees
River Murray	Channel freshes	Channel freshes and **some** floodplain wetland outcomes	Channel freshes and **multiple** floodplain wetland outcomes

ha = hectare; m = metre; ML/d = megalitre per day

The range of flows constraints work is investigating builds on the initial recommendations of the 2011 Department of Sustainability and Environment study, to ensure that water stays within the leveed floodplain of the lower Goulburn. This recognises that the land within the levees tends to be largely native bush and national park, whereas immediately outside the levees there is productive farmland.

Essentially, environmental water managers are seeking to water native vegetation inside the levees, and minimise or avoid effects on productive farmland outside of the levees.

Typical landscape immediately outside of the lower Goulburn levees

Typical landscape immediately inside the lower Goulburn levees

Community effects

The proposed flows will affect the community in a number of ways. Effects include localised flooding in some low-lying rural paddocks and closure of some local roads.

Initial feedback from landholders suggests that some of the small and moderate flows may create a tolerable level of inconvenience flooding **if** suitable mitigation measures are put in place. What is of concern to the community is an insufficient risk buffer (e.g. 10.3 metres is too close to the river height at Shepparton that triggers the opening of the Loch Garry regulator — 10.36 metres).

For further information on community effects, particularly effects on riparian landholders, see the subreach reports in 'What is happening in the subreaches?'.

What overbank flows in the lower Goulburn mean for people elsewhere along the river

The main environmental benefit being looked at is floodplain watering for the lower Goulburn, which would be achieved by overbank flows in the minor flood level range. This is why flow rate recommendations are based at the Shepparton gauge. However, there are also potential floodplain benefits right along the Goulburn River. Allowing river water onto river flats between Eildon Dam and the River Murray will improve agricultural productivity and vegetation growth, and recharge groundwater stores.

To give communities downstream of Eildon Dam some boundaries around the scale of possible change that is being looked at, three change scenarios have also been defined for the other Bureau of Meteorology flood gauges along the main stem of the Goulburn River.

Constraints work is only considering flows in the minor flood level range at each one of these gauges (Table 4). The aim here is not to be prescriptive about how flows may be delivered in the future, but to define possible boundaries for new flow rates and river levels for managed overbank flows (see further detail in 'What is happening in the subreaches?').

Table 4 Change scenarios compared to Bureau of Meteorology flood levels

Gauge location	'Small' change	'Medium' change	'Large' change	Minor flood level*	Moderate flood level*	Major flood level*
	Gauge height (metres)					
Eildon	2.8	3.1	3.5	3.0	4.0	5.0
Seymour	3.1	3.6	4.5	4.0	5.2	7.0
Murchison	7.9	8.6	9.5	9.0	10.2	10.7
Shepparton	9.4	9.8	10.3	9.5	10.7	11.0
McCoy Bridge	8.7	9.1	9.6	9.0	10.0	10.2
	Flow rate (megalitres/day)					
Eildon	12,000	15,000	20,000	14,500	25,980	39,380
Seymour	15,000	20,000	30,000	24,850	40,000	81,310
Murchison	25,000	30,000	40,000	33,130	60,410	89,280
Shepparton	25,000	30,000	40,000	26,000	54,000	72,000
McCoy Bridge	25,000	30,000	40,000	28,333	52,115	61,743

* As defined by the Bureau of Meteorology, noting that the categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

What does the community think?

At a glance

Advisory groups have contributed their knowledge to this report. Overall, there was concern as to the potential impact of large or unmanaged flows, but recognition that smaller overbank flows can have benefits. With smaller flow footprints, mitigation measures can be put in place, but the community needs reassurance that the risks of unintended adverse consequences are being planned for and can be adequately managed.

The river plays an important role in local communities, and community members often have an in-depth knowledge of river behaviour. It is essential that we gather this knowledge so that it can be used in the development of the Constraints Management Strategy (the Strategy).

Overbank flows up to the minor flood level range are the flows that constraints work is particularly interested in for the benefit of the lower Goulburn floodplain and the River Murray. Minor floods are typically events that people 'manage through'. These floods often don't make the newspapers, they often don't trigger significant emergency management responses and their impacts are often not recorded beyond a brief mention in floodplain studies. Very little detail about who and what is affected by overbank flows is available, especially outside of urban areas. Constraints work needs to understand how people are affected to identify what is possible and what mitigation measures are needed.

In 2013, MDBA formed three advisory groups to help answer the following questions:

- When and how are people and businesses affected by different flow footprints along different stretches of the Goulburn River?
- How accurate are the flow footprint maps?
- For different stretches of the river, what range of flow rates may be worth governments investigating further, and what flow rates are considered unacceptable?
- What sort of mitigation measures would be needed before being able to allow a bigger regulated flow range?

The first group is a community leaders group (including local council chief executive officers and senior staff, water service committee members, and irrigator and conservation group representatives) who provide a broad perspective on issues and initiatives influencing the Goulburn catchment.

The other two groups are the mid Goulburn and lower Goulburn technical advisory groups, made up of people who live and work on the river, and who understand what the river and its tributaries do at different river flows (farmers, council engineers, tourism businesses, etc.).

For membership of the groups, MDBA sought recommendations from Victorian Government agencies, local councils and community members, and from the advisory group members themselves. Each group had around 15 members. In addition to the advisory groups, MDBA staff met with individual riverbank landholders and undertook a number of local council and regional authority briefings.

A total of 47 regional meetings were held between April 2013 and March 2015. The 47 regional meetings included 16 advisory group meetings, 12 landholder meetings (individuals and groups), 10 public forums, and 9 local council/regional authority briefings.

Before publication on the MDBA website, an early draft of the report was shared with the three advisory groups in August 2014 so that their feedback could be included in the draft. The report was published on the website in September 2014, and was also emailed and/or posted to a range of other stakeholders that had been involved in previous conversations with MDBA about constraints throughout 2013–14. Further engagement included:

- drop-in meetings to discuss the report held in Kotupna, Bunbartha, Shepparton, Murchison, Seymour and Alexandra on 23–26 September 2014, which were attended by 52 people
- letters sent to all potentially affected local council regions to keep councils informed of progress, and direct briefings were offered; the City of Greater Shepparton and Murrindindi Shire council requested briefings which were held at council meetings in September 2014
- an additional public meeting held in Yea in November 2014, which was attended by over 35 landholders and local residents
- a meeting of the mid-Goulburn advisory group to discuss updating the reach report in March 2015
- email feedback via the constraints email address was also received from several landholders in the mid-Goulburn region.

The revisions in this final report reflect the comments made by stakeholders over September 2014 to March 2015.

When the next phase of collecting detailed information for the Strategy proceeds, consultation with more individuals and businesses likely to be affected by river flows will be essential.

Key Goulburn community messages

Opportunities

Generally, there was recognition that water on river flats can be good for farming, the environment and the productivity of the land:

> *Once floodwaters drain away, a lot of river silt remains on the floodplain. Following the next rain, this washes away and the nutrients can be as good as a bag of fertiliser.*
> *Farmer near Alexandra*

Some long-time residents believe that the river flats are not as good as they used to be when smaller overbank flows used to happen more often:

> *A lot has been taken out and nothing has been put back in.*
> *Long-time farmer and resident from the mid-Goulburn region*

Concerns

However, these sentiments were balanced with concerns about flows happening too often, lasting too long or happening at the wrong time of year:

> *There are benefits to a flood, but there are issues as well. We may be able to live with a few inconveniences — shifting a few cattle is not too big an issue if we get enough notice. However, although there is a level of inconvenience that we can all tolerate, there are flow events that are just too big and too damaging that should not be considered.*
> *Cattle farmer near Molesworth*

Potential effects on farm production include uncertainty in farm planning, loss of access to productive pastures and damage to pastures, interruption to pumping and damage to pumps, and clean up and repair costs after floods.

Other general issues identified that would affect the community included road closures and loss of access; damage to the riparian zone, including erosion and bank slumping; spread of pest species such as carp; and interruption to recreational activities and tourism businesses.

The community identified a number of specific potential issues:

- If unregulated and unpredictable tributary flows and/or rainfall events coincide with environmental releases from Eildon Dam, this may result in higher than planned river flows and unintended adverse consequences. Unregulated tributaries are a significant influence on the regulated Goulburn River and should not be underestimated.
- Inundation of areas of private land around Alexandra and Molesworth is highly likely, as the channel capacity is very limited in this reach and even small increases in water levels downstream of Eildon Dam will start inundating private land.
- A flow of 40,000 megalitres per day (ML/d) at Shepparton is too close to triggering the statutory release formula for opening the Loch Garry flood protection scheme (removing bars and allowing water to enter the Deep Creek floodway to reduce pressure on downstream levees). This is highly undesirable.
- A flow of 40,000 ML/d also presents a risk of overtopping levees in some places.
- Extended environmental water releases from Eildon Dam could affect private properties in tributaries due to backing-up effects, with high river flows in the main Goulburn River preventing tributary flows from draining freely.

What people said about the scales of possible change being considered

‘Small change’

> *Goulburn River flows can create access issues including road closures. These would start happening in the Lower Goulburn at all scales of change that constraints work is looking at, especially for roads such as Yambuna Bridge Road.*
> *Local council engineer*

Increases in water levels don't have to be large to start affecting landholders in the mid-Goulburn, downstream of Eildon Dam. It should be acknowledged that Goulburn–Murray Water specifically constrains releases from Eildon Dam because of the risks of inundating private land in this reach.
Goulburn–Murray Water

25,000 ML/day is almost a minor flood at Shepparton. Environmental flow planning for events this size would have to include key flood agencies in the region such as State Emergency Services, local councils and the Bureau of Meteorology. Around 25,000 ML/day at Shepparton is the level at which flood briefings and agency coordination commences.
Local council engineer

The load on stormwater drainage infrastructure during river flows up to around minor flood level is a concern, especially for towns right on the river like Seymour.
Local council engineer

Changes to water level can damage irrigation pumps and interrupt pumping. This is particularly true around Murchison.
Murchison irrigator

The backing-up effects of Goulburn River flows on tributaries means that it is not just main-stem landholders that could be affected. This could affect a number of landholders in tributaries, including the Yea, Acheron, King Parrot Creek, etc.
Beef farmer near Yea

‘Medium’ change

It doesn’t feel like a big flood in Yambuna forest until the flows at Shepparton get past 34 feet (10.36 metres, when they start pulling the bars at Loch Garry). For flows under 34 feet all the lagoons fill up, which is great. You get a bit of inconvenience, but not a huge flood.
Long-term farmer and resident in the lower Goulburn region

‘Large’ change

40,000 ML/day at the Shepparton gauge won’t flood houses or sheds, but it will create access issues. Some roads could be blocked for longer than a week. This would result in periods with limited communication and the need to support people in the community who may get isolated.
Local council engineer

A 40,000 ML/day flow at Shepparton will be less than 40,000 ML/day at McCoy Bridge as water moves out onto the floodplain.
Long-term farmer and resident in the lower Goulburn

40,000 ML/day is getting up towards a moderate-sized flood at Shepparton. Environmental flow planning for events this size would have to include key flood agencies in the region such as State Emergency Services, local councils and the Bureau of Meteorology. They would all need to be informed about the process as the flows will trigger the need for emergency agency coordination and response including flood watchers.
Local council engineer

40,000 ML/day at Shepparton may be too risky as if a local rainfall event occurs as well, it could become a damaging flood. There may be a risk of unintended adverse consequences. Can you manage the system with enough confidence when there is that much water moving around and the catchment is likely to be wet?
Long-term farmer and irrigator from near Wakiti Creek

40,000 ML/day at Shepparton (10.31 metres) is too close to the river height that triggers the pulling of bars at Loch Garry (10.36 metres).
Many farmers and residents near McCoy Bridge

The thing about a 40,000ML/day flow — that is a lot of water moving, it's going to have a lot of energy. There could be quite a bit of power and erosion in a flow that size.
Dairy farmer near Bunbartha

What people said about the time of year, duration and frequency of the flows being considered

Timing

Not all flows of the same size have the same affects. What we experience during a flow of a given size very much depends on whether there has been a flow previously. The state of the catchment is important. A series of flow events can have cumulative effects. How wet or dry the catchment is makes a big difference to how and where the water flows.
Long-term irrigator and resident from near Wakiti Creek

Timing should explicitly consider the gap between watering events (e.g. if there has been a dry sequence and you get a first flush, then from 2010 experience, you have to watch out for a second flush). The second flush is when the ponded blackwater was washed back into the river — that was devastating in the summer of 2010.
Dairy farmer in the lower Goulburn region

Late spring is too late for paddocks to be inundated.
Mixed enterprise farmer in the lower Goulburn region

Concern that environmental water releases in spring is the very time when farmers are trying to put fertiliser on, grow silage and put cattle on the most productive areas.
Beef farmer near Yea

The 'June to November' window is too long. Suggest constraints work consider shortening the window to 'June to early September'. The reason is that the agriculture impacts would be much larger if a managed watering were to occur between September and November. This is the time when crops are sensitive to flow (especially around October when irrigating and November near harvest time). If a managed flow happens earlier than September, then there is still time for crops and paddocks to recover from inundation, and/or farmers can re-sow, etc. (therefore reducing agricultural impact).
Long-term farmer and resident in the lower Goulburn region

Some concern about timing, especially if flows edge into October and November. I worry about the possible increased risk of poor water quality as water temperature rises.
Dairy farmer in the lower Goulburn region

Stock must have high ground to move them onto and farmers need enough advance warning to move them (two to three days).
Beef farmer near Molesworth

Duration

Short flow spikes are not an issue for farmers, it is when water stays on the floodplain for longer that damage occurs.
Beef farmer near Alexandra

Depth and duration is critical. Depth is important early in the growing season — young plants are small and can be easily drowned, but larger plants that have their 'heads out of the water' are okay.
Irrigator from the lower Goulburn region

I welcome floods, but they come up and down quickly and there can be 4 or 5 tributary floods in a year. However, environmental flows in the Goulburn must be careful not to cause extended backing up in the tributaries. This type of thing happened in 2012 because of the long duration of Eildon pre-releases (8–9,000 ML/d for several weeks) — the Yea couldn't get away and ran a banker for weeks and flooded out for more than 10 days. Duration is a key issue. The concern for tributary landholders is that extended environmental releases from Lake Eildon could behave like pre-releases and cause backing-up flooding in tributaries.
Yea River farmer

Short duration is okay, but anything longer than a week is damaging.
Mixed enterprise farmer in the lower Goulburn region

In the summer of 2010 in the lower Goulburn, the floodwaters (from 8 inches of rainwater) were on one landholder's paddock for about 10 days. Even after only 10 days they lost the crop due to the impact of the high summer temperatures and blackwater.
In contrast, in 1974, the winter floodwater didn't do much damage. The floodwaters were on the property for about two weeks before they were pumped off. But the grass was green already so it was okay and recovered.
Long-term farmer and resident in the lower Goulburn region

Frequency

There are heavy clay soils in some areas — the year or two after a flood are best because of the benefit of extra moisture. The year of the flood can be too wet for sowing.
Mixed enterprise farmer in the lower Goulburn region

On average every 10 years you get a bumper year, 3-4 average years, and 5 years that are below average or bloody awful: if you change the frequency of floods which are very disruptive, people won't get time to recover.
Yea River farmer

Near the river at Shepparton. Regular watering of the floodplain fills billabongs and supports a wide range of species. *Photo: Janet Pritchard, MDBA.*

What happens next?

At a glance

The reach reports contributed to the development of a Constraints Management Strategy annual report in 2014. That report made recommendations to the federal government and state governments of the Murray–Darling Basin about what next steps and further work is required.

In late 2014, state and federal governments decided to continue investigations in all of the seven priority areas. The 2014 decision was about whether to proceed with collecting more information including technical and community studies to better understand the feasibility of overbank flows and the mitigation measures needed for delivering the proposed flow footprints. The 2014 decision was not a green light to build, do or change anything about how the Goulburn River is currently managed.

Further to this, state and federal governments agreed the flow limits that should be considered in future investigations. In the Goulburn region, it was decided that 40,000 ML/d at Shepparton should be the upper limit for future investigations. It was agreed that the work for the feasibility phase would be led by the Victorian Government, which includes preparing a business case in 2015 for easing constraints in the Goulburn.

State and federal governments will decide by June 2016 whether to proceed with planning and implementing mitigation measures between 2016 and 2024. Mitigation measures have to be in place before overbank flows can be delivered.

The publication of the reach reports and the development of recommendations are just the start of a much longer process (Figure 13). There will be no change to the current regulated flow limit in the Goulburn for some years to come, if at all.

Figure 13 Phases of the Constraints Management Strategy

2014 Phase 1 — Prefeasibility

Phase 1 of the Strategy has been about collecting information about the management and impacts of higher flows. MDBA:

- investigated options to modify constraints, looking at different potential flow footprints
- assessed the effects of these changes, including talking to landholders and communities about how different flow footprints might affect them
- costed options to avoid or mitigate inundation effects (e.g. building bridges, upgrading roads, infrastructure options or paying for easements).

Information for the Goulburn was then drawn together with information from the six other areas into the Constraints Management Strategy annual report, which was published in late 2014. This report informed decisions by Basin ministers as to which areas will be the subject of more detailed investigation.

At the end of Phase 1, MDBA recommended to Basin governments that they continue to explore the potential to relax constraints in each of the seven key focus areas in the feasibility phase (2015 to June 2016).[4]

Basin ministers (state and federal) have agreed that detailed investigations should proceed for higher managed flows in all seven key focus areas as part of feasibility investigations. This is a commitment to undertake further studies, not a commitment to go ahead with planning and implementation of mitigation measures to allow higher managed flows.

2015–16 Phase 2 — Feasibility

The Australian Government Department of the Environment has made funding available for the key focus areas to provide states with the resources needed to conduct detailed studies and prepare business cases.

In Phase 2 of the Strategy, MDBA and Basin states will need to:

- do more detailed hydrologic analysis to determine the best flow rates to relax constraints to in each key focus area
- assess inundation impacts and options to mitigate those impacts
- improve cost estimates and
- undertake further community consultations.

MDBA will lead the feasibility assessment for the River Murray on behalf of Basin states. An integrated package of constraints business cases for the three River Murray key focus areas — Hume to Yarrawonga, Yarrawonga to Wakool junction, and South Australian River Murray — will be finalised by November 2015

Ministers have requested that further studies be done on constraint measures in the Gwydir, Lower Darling, Murrumbidgee and the Goulburn. The Victorian Government is taking the lead

4 www.mdba.gov.au/media-pubs/publications/cms-annual-progress-report-to-ministers-2014

with the next phase of constraints work in the Goulburn, with MDBA's support. Victoria will prepare a constraints business case for the Goulburn by November 2015.

The decision about whether or not to go ahead with easing constraints (planning and implementing mitigation measures that then allow higher managed flows) will be made by June 2016 by state and federal governments.

2016–24 Phase 3 — Planning and implementation

State and federal governments will decide by mid-2016 about whether to go ahead with easing constraints (planning and implementing mitigation measures that then allow higher managed flows). This decision will be based on the environmental gains, whether any effects on communities can be overcome, and the costs involved.

If constraint measures move ahead to planning and implementation (mid-2016 to 2024), it is likely the states will undertake this work, although in some circumstances MDBA could act as the lead agent on behalf of the states (as has occurred for the River Murray key focus areas in Phase 2).

To ease constraints, proponent states would need to formalise and pay for land-based agreements with landholders, such as easements, to allow water to flow onto private land (for flows to reach an environmental asset or allow sufficient water to flow down a channel). For further detail about easements, see Appendix 6.

Post 2024 Higher managed flows will only be possible when mitigation options are fully implemented

It is essential that measures are in place to mitigate the adverse effects on private landholders and community assets before overbank flows can be considered.

Further work needed

MDBA met with advisory groups and other members of the Goulburn community, and asked about what sorts of things governments would need to do before regulated overbank flows could be considered.

A wide range of possible mitigation activities for overbank flows have been suggested, including the following.

On-ground works

Works to fix existing minor flooding issues in rural and urban areas (e.g. road closures that already happen, such as Yambuna Bridge Road).

Acquiring (negotiating) the right to put water onto private land.

Upgrading roads, bridges and other infrastructure to make sure critical roads and access routes are kept open.

Upgrading ageing flood control measures (e.g. ensuring levees and regulators such as Loch Garry are to a standard strong enough to contain flows).

Upgrading fixed in-channel structures, such as boat ramps and jetties.

Investigating new engineering options to be able to limit when and where nuisance flooding occurs. For example, a number of effluents move water away from the Goulburn River downstream of Loch Garry into creek systems outside of the levees. Extended effluent flow causes significant nuisance flooding and access issues for private landholders outside of the lower Goulburn levees.
Regulators to control flow into these effluents would give more control of when water is kept in the main channel or when it is moved into effluents (e.g. Hancocks Pipes and Wakiti Creek, Deep Creek outlet, and Bunbartha Creek). Detailed investigation of engineering options would be required, as well as studies to make sure that the flow regime and health of the effluent creeks are maintained.

Implementing a companion river health program to manage any risk of higher flows increasing erosion and reducing water quality.

Considering an irrigation infrastructure upgrade scheme. Rather than notifying a large number of landholders to move pumps whenever there is a change in river flow, could consider an upgrade program. Floating pontoons, or pumps on slides to prevent damage due to variable river levels.

Mitigate impacts on specialist businesses operating in the catchment, such as caravan parks and trout farms.

Hydrological information

Better understanding of tributary flow inputs to the Goulburn River would improve forecasting accuracy and confidence for operational decision-making around catchment condition and potential risk when making releases from storage. The gauging network needs to be improved to better understand unregulated tributary behaviour.

The existing Goulburn catchment gauging sites are inadequate for planning regulated releases on top of tributary flows, especially around Molesworth and Ghin Ghin and for tributaries such as the Yea River. Additional metering and monitoring, and/or improved sites are required to be able to manage overbank environmental flows. The identification of possible additional gauging sites will require detailed analysis of how they match in with existing systems and gauging networks, and how they will be used in decision-making processes for environmental flow releases.

Developing a rainfall run-off and river operation model is needed to better understand unregulated tributary flow behaviour in response to rainfall.

Improved modelling of floodplain inundation. Recalibrate the hydraulic models used to develop flow footprint maps. The community has identified some inaccuracies in existing maps — the models need to be rerun with new calibration data in order to accurately understand likely inundation at different flow rates. This is important as the flow footprint maps are the basis for understanding what public and private assets are likely to be affected.

Hydraulic and hydrological modelling of the interactions between tributary flows and main-stem flows, to better understand how tributary landholders could be impacted by a range of main-stem flow sizes.

Operations and management

Developing planning and operational scenarios about when environmental flows would and would not be considered.
A decision tree of responses that explicitly considers what would happen under a wide range of scenarios.
Identifying possible tributary flow conditions that would trigger a regulated release, taking into account risks of additional rain or tributary flow, and the hydrological context (state of the catchment). Equally, identifying when water orders should be postponed/cancelled if risks are too high and how water orders should be varied in real time to minimise potential backing-up effects on tributaries, or what to do if a downstream tributary has an unexpected spike in flow, and so on.

More detailed investigations into the potential to change Waranga Basin diversions in order to assist with environmental water delivery. This includes assessing whether there would be any impact on regulated system operations, Waranga customers and their entitlement reliability.

Planning for worst case scenarios. Clearly and transparently describing the process and actions that would be triggered if a regulated release is made on top of unregulated tributary flows and the resultant downstream flows are larger than intended. This is so people know what the process would be in advance, and how 'residual risk' will be managed.

Considering the need for an 'insurance policy' around managed environmental watering, to protect people if things go wrong. This should include policies, processes and resources to compensate any affected business and public assets and clearly identify who is liable for managed flooding effects.

If you don't want to trigger the opening of Loch Garry, what could you have in place to make sure this doesn't happen? Could there be an 'override' amendment to the existing Loch Garry rules, so that if there is an environmental watering event, then the Loch Garry regulator is not opened?

Further work on the broader social and economic impacts of a changed flow regime. This work would help identify how people and businesses may be indirectly and directly affected by the implementation of higher managed flows. This work could also help identify potential mitigation measures to help people adapt such as farm planning support.

Availability of information

Developing a 'multipronged' high flow/flood warning and notification system, relevant for rural landholders and recreational river users.
Advance warning is critical. This is for planning purposes (affects cropping or farm planning decisions) and before the event is delivered (so that assets can be moved or protected where possible). This should include advice on river heights and flows at different gauging stations, not just Bureau of Meteorology flood classifications).

Developing a river flow information base and raising community awareness about where to go to get river information in real time.

Monitoring to measure and evaluate the process, effects and outcomes of being able to move towards higher regulated flows.

For measuring impacts, it would be useful to have a network of on-ground people in place who can measure and report on what different size flows are doing in different places. Then you would get good real-time information about what happens.

What is happening in the subreaches?

The Goulburn River was split into five subreaches downstream of Eildon Dam:

1. **Eildon Dam to Killingworth**
   includes Thornton, Alexandra and Molesworth townships
   Flood gauge at Eildon
2. **Killingworth to Mitchellstown**
   includes town of Seymour
   Flood gauges at Trawool and Seymour
3. **Mitchellstown to Kialla**
   includes Nagambie and Murchison
   Flood gauge at Murchison
4. **Kialla to Loch Garry**
   includes Shepparton and Mooroopna
   Flood gauge at Shepparton
5. **Loch Garry to the River Murray**
   Flood gauge at McCoy Bridge.

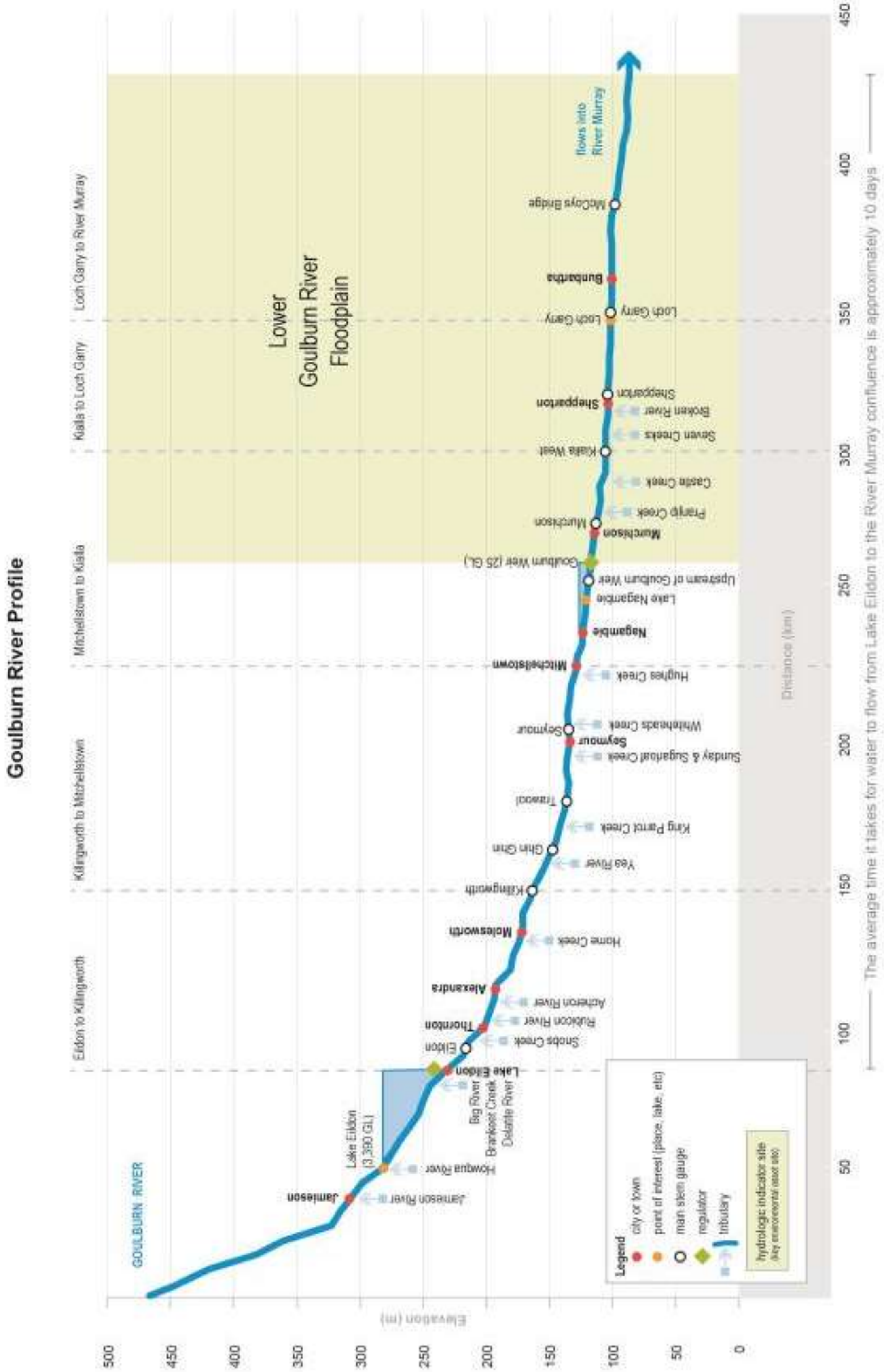
The possible impact of changed flows in these subreaches has been analysed in detail, including flow footprint maps and community consultation.

In general, feedback from local councils and landholders have indicated that the flow footprint maps generally look about right, although they are overestimated or underestimated in some areas. Further work will be done to adjust and calibrate the models and maps. Constraints work is continuing to collect information about the effect of overbank flows below and in the minor flood range in these reaches.

The following sections provide information on the current characteristics and possible future flow footprints being considered for each of the subreaches (Table 5).

Table 5 Flow footprints being considered in each of the Goulburn River subreaches (that include the flow contributions of tributaries)

Goulburn River subreach	Flow footprint 1 (ML/d)	Flow footprint 2 (ML/d)	Flow footprint 3 (ML/d)
Eildon to Killingworth	12,000	15,000	20,000
Killingworth to Mitchellstown	15,000	20,000	30,000
Mitchellstown to Kialla	25,000	30,000	40,000
Kialla to Loch Garry	25,000	30,000	40,000
Loch Garry to the River Murray	25,000	30,000	40,000



Goulburn River elevation profile

Tributaries in the Goulburn

The tributaries in the Goulburn have different characteristics and therefore different effects on the flow of the main Goulburn stem. If river operators are to safely release managed environmental flows on top of natural rain events, it is important to understand how these tributaries behave. In 2009, some research and analysis of this was undertaken by Water Technology on behalf of the Goulburn Broken CMA. The *Goulburn River environmental flows hydraulics study* is available on the Goulburn Broken CMA website.[5]

For further detail about flow interactions between tributaries and the main stem of the Goulburn, see Appendix 7.

What we know based on available data

Water Technology analysed historical flow data in the Goulburn River and its tributaries. From this research we have a general, but incomplete, understanding of tributary behaviour in the Goulburn catchment.

Gauging inadequacies:
A relatively large amount of the mid-Goulburn catchment between Lake Eildon and Goulburn Weir is ungauged. Some tributaries have no gauges, others are partially gauged, some gauges have missing or poor quality data, but there are some tributaries with good gauging data[6]. With the data available, we cannot yet fully understand tributary characteristics and behaviour. Based on the analysis by Water Technology, we have found that;

- 57% of the catchment between Eildon and Trawool is ungauged
- 65% of the tributary catchment between Seymour and Murchison is ungauged
- there are large ungauged sections on the Yea River and King Parrot Creek (i.e. the gauge is high up in the catchment)
- there is a lack of data and gauging uncertainties below Murchison; tributaries include the Pranjip, Castle, Seven Creeks and Broken River.

Flow characteristics:
While there are gauging inadequacies in the Goulburn catchment, based on the data we do have we can understand some of the flow characteristics of the tributaries. Water Technology used available gauging data for July–November (a time when rainfall events are more common) to build a picture of each gauged tributary. This analysis looked at the mean daily flow (MDF), the mean maximum flow (MMF), the amount of flow to catchment size (MDF to km^2) and the 'peakiness' of the catchment.

The 'peakiness' of a catchment is the ratio of the MDF to the MMF. A high peakiness value means the catchment can rise and fall with a large difference in volume. A lower peakiness value means the catchment is steadier and does not rise and fall with a large difference in volume.

[5] www.gbcma.vic.gov.au/downloads/goulburnriverhydraulicstudy/goulburn_hydraulics_hydrologic_analysis_final.pdf

[6] Good: <2% of the record is poor/no data, Fair: 2% - 10% of the record is poor/no data, Poor: >10% of the record is poor/no data

The gauging data used for this analysis was classified as being of 'fair to good' quality. The analysis of available data suggests that:

- The Acheron is the tributary that contributes the most to flows in the Goulburn (as a percentage of total flow rate, measured at Trawool).
- The mid-Goulburn catchment above Trawool produces a higher rate of run-off per unit area (MDF to km^2). This is due to the higher rainfall and steeper slopes. There is also less losses of rainfall to the ground or to dams. For example, the Rubicon has the highest unit run-off (2.4 ML/d of run-off per km^2) of catchment area in the Goulburn. In contrast, tributaries in the middle reaches of the Goulburn downstream of Trawool generally contribute only 0.1 to 0.3 ML/d of run-off per km^2 of catchment area.
- The tributaries entering the Goulburn near Seymour have a high degree of 'peakiness' (i.e. subject to flashy flows). This includes Sunday Creek, Sugarloaf Creek, Whiteheads Creek and Major Creek.
- Home Creek has a high peakiness value. Two large flood events in 1988 and 1993 (peak flows 14,400 ML/d and 17,300 ML/d respectively) resulted in a higher peakiness value than adjacent catchments.
- As you move down the floodplain, towards the River Murray, there is a reduction in the amount of flow contributed per km^2 of catchment. This reflects smaller tributary contributions, transmissions losses in the river and floodplain, and diversions for irrigation and water supply purposes.
- The months of August and September are when the Goulburn and tributaries have their highest flows. This reflect the larger number of rainfall events in late winter/early spring.

The tributaries and hydrographs

Hydrographs for Goulburn River tributaries are available in the subreach reports. Data for these hydrographs were sourced from the Victorian Water Measurement Information system (http://data.water.vic.gov.au/monitoring.htm).

A range of tributary flow statistics have been generated as part of a flow analysis undertaken by Water Technology in 2009. Definitions and processes for the analysis included:

- **Data time period:** The gauge data used to generate the flow statistics used was from the start of July to end of November. Data was limited to 1956 onwards to reflect the flow regime after the enlargement of Eildon Dam. Available gauge data was analysed up until the end of 2007.
- **Instantaneous data**: Flow rate is measured every hour at a particular gauge. 'Average' daily flow rates are calculated by averaging flows over 24 hours. By measuring flow rate every hour, the rise and fall of tributaries that can happen in a short time is more accurately captured.
- **Data quality**: Flow data gathered at gauges is classified based on its quality and accuracy. For the purpose of the flow analysis undertaken by Water Technology, the following definitions of data quality were determined.
    - Good: <2% of the record is poor/no data
    - Fair: 2–10% of the record is poor/no data
    - Poor: >10% of the record is poor/no data
- **Flow contribution at Trawool:** In the flow analysis undertaken by Water Technology, a percentage flow contribution was measured at Trawool. This contribution was calculated using the MDF (ML/d) of each tributary for July–November. This MDF (ML/d) was

calculated as a proportion of the MDF at Trawool (7,578 ML/d) for the same period. This established a baseline flow against which the relative flow contribution of each tributary could be compared.

Eildon Dam to Killingworth

At a glance

The flow footprints constraints work is investigating are 12,000–20,000 megalitres/day (ML/d) between Eildon Dam and the Killingworth gauge on the Goulburn River, including the flow contributions of tributaries. Extended duration releases from Lake Eildon and releases on top of high tributary flows are not being investigated. Flow footprints higher than 20,000 ML/d are not being investigated, which are large events like 2010 which reached over 40,000 ML/d at Trawool. The overbank flows that constraints work is looking at occurred more frequently in the past.

Feedback from local councils and landholders was that the 12,000 ML/d flow footprint map looked about right and would not be expected to cause too many issues. However, the 15,000 ML/d and 20,000 ML/d flow maps underestimate the flow footprint.

Initial feedback from landholders suggests that up to a maximum 12,000 ML/d flow footprint around Molesworth and a 15,000 ML/d flow footprint elsewhere in the subreach may be a tolerable level of inconvenience flooding if suitable mitigation measures are put in place. Flows of up to 12–15,000 ML/d could be created by releases from Eildon with no tributary inflows, tributary flows on their own, or a mix of tributary flows and Eildon releases.

Reach characteristics

This subreach flows from Eildon Dam to the Killingworth gauge (405329) on the Goulburn River (Figure 15). Water in this stretch of river comes from releases from Eildon Dam and inflows from several unregulated tributaries. The quick rising and falling, or ‘flashy’, Rubicon River, Acheron River, Spring Creek, and Home Creek all enter this stretch of Goulburn River.

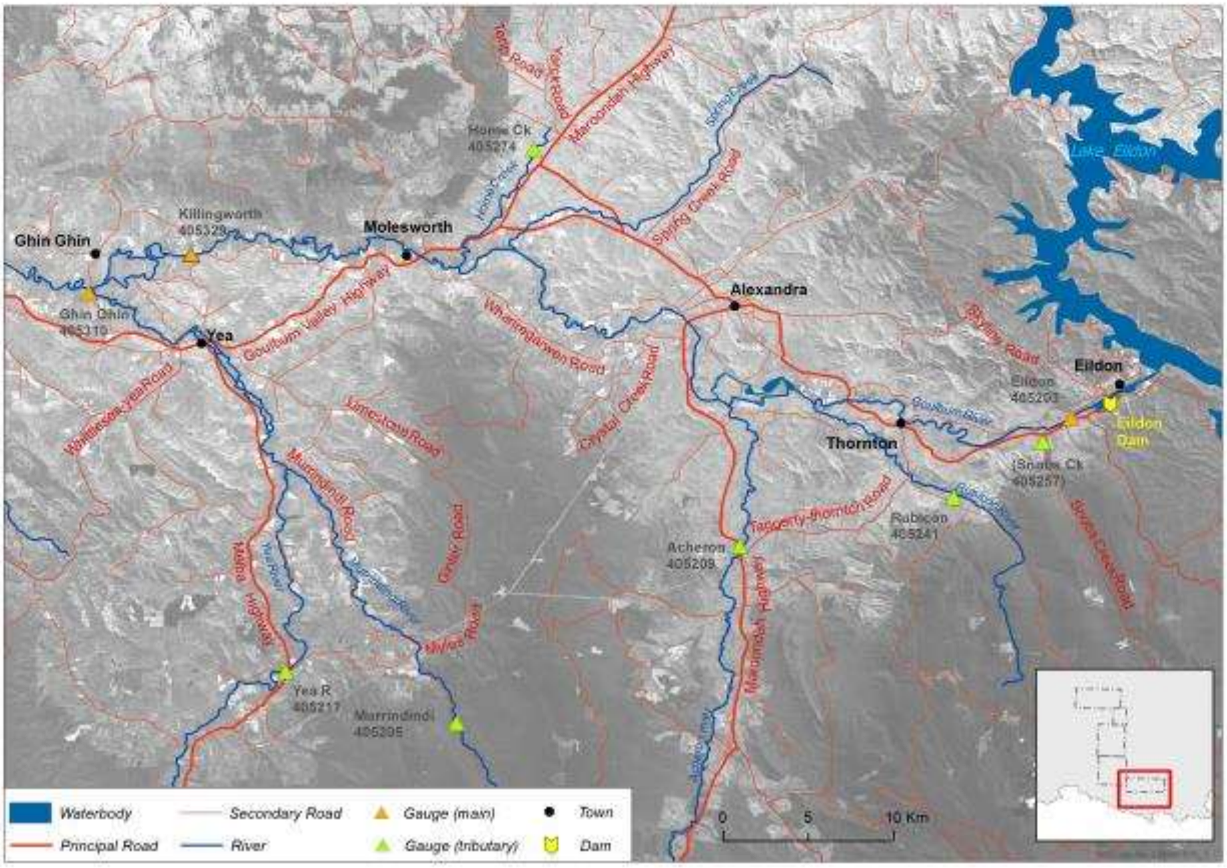
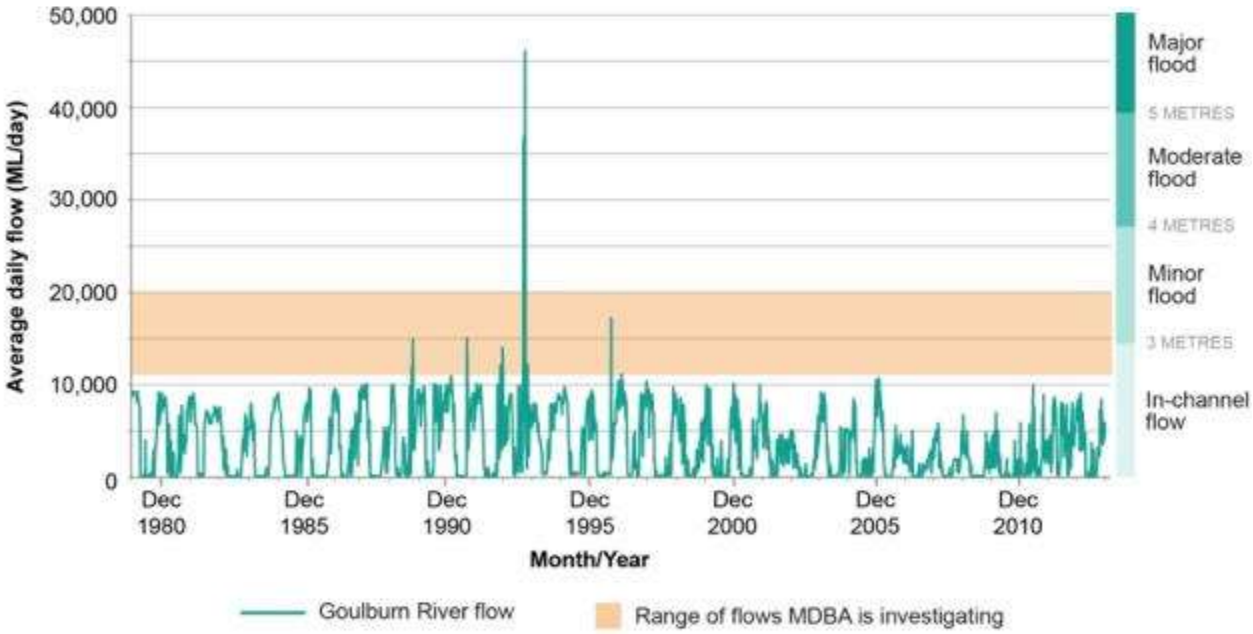


Figure 15 Eildon Dam to Killingworth subreach

One flood gauge used for Bureau of Meteorology flood forecasting purposes is located in this subreach: station number 405203 at the Goulburn River downstream of Eildon Dam. The river flows for the Goulburn River gauge at Eildon between 1979 and 2013 can be seen in Figure 16. Because this flood gauge is close to Eildon Dam, it provides a history of the releases from the dam but doesn't provide a clear picture of the range of flows that have been experienced over the entire Eildon to Killingworth subreach due to flows from unregulated tributaries. Although outside the subreach, the Trawool flood gauge, station number 405201 has been included at Figure 17 to show the range of flows that passed through the subreach incorporating a variable combination of Lake Eildon releases and tributary inputs.



MDBA = Murray–Darling Basin Authority; ML = megalitre

Note: The shaded box outlines the range of flows that constraints work is investigating (12–20,000 ML/day). The flood categories (minor, moderate and major floods) are as defined by the Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 16 Flows in the Goulburn River at the Eildon gauge, 1979–2013

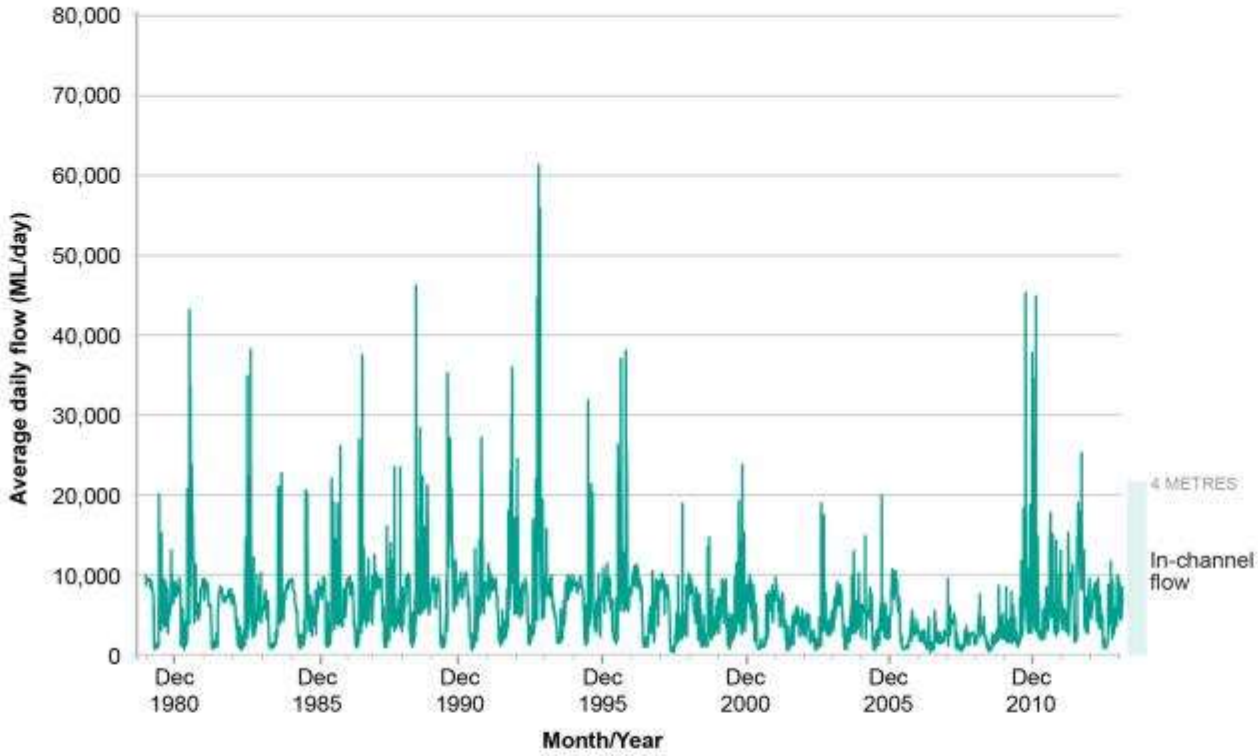


Figure 17 Flows in the Goulburn River at the Trawool gauge, 1979–2013

Eildon Dam was constructed in the 1950s to replace the original Sugarloaf Dam and increase water storage, and is very effective at providing flood protection for those living downstream of the dam. Only one major flood at the Eildon gauge has occurred since 1980, peaking at more than 5.0 metres and flowing at more than 40,000 ML/day. However, there have been several major floods further downstream in the subreach due to unregulated tributary flows (e.g. January 2011, September 2010). The overbank flows below and in the minor flood range that constraints work is looking at have occurred occasionally in the past. These historical data are presented in Table 6.

A range of flows has been provided as background context for the river levels that people have experienced first-hand. Some are far larger and more damaging than the flow footprints constraints work is investigating; they are not the aim of this Strategy. Smaller historical events are also included in Table 6 that are in the range of the managed overbank flow footprints being investigated. This is so people can think about the types of effects that have occurred at flows of these sizes.

Table 6 Examples of recorded flows for the Eildon to Killingworth subreach

Date	Season	Lake Eildon, # 405203, (ML/d)	Assume 1–2 day travel time	Trawool, # 405201, (ML/d)	Difference between Trawool and Lake Eildon flows (ML/day)	Amount of tributary contribution	Is constraints work investigating these kinds of flow footprints?
Historical subreach flows around 12,000 ML/day							
25/02/2006	Summer	12,793	→	10,812	-1,981	Very little/none	yes
12/01/2006	Summer	10,970	→	11,363	+393	Small	yes
17/02/2004	Summer	11,519	→	8,755	-2,765	Very little/none	yes
18/03/2002	Autumn	11,067	→	7,735	-3,332	Very little/none	yes
19/12/2001	Summer	12,122	→	10,223	-1,899	Very little/none	yes
8/02/2001	Summer	11,165	→	9,913	-1,252	Very little/none	yes
3/02/2000	Summer	12,100	→	9,706	-2,394	Very little/none	yes
4/04/1999	Autumn	12,801	→	9,361	-3,440	Very little/none	yes
12/12/1998	Summer	11,934	→	10,449	-1,485	Very little/none	yes
9/01/1998	Summer	11,183	→	10,506	-677	Very little/none	yes
10/03/1995	Autumn	11,385	→	10,222	-1,162	Very little/none	yes
10/12/1992	Summer	12,747	→	14,693	+1,946	Small	yes
2/02/1992	Summer	11,492	→	10,062	-1,430	Very little/none	yes
5/03/1991	Summer	11,573	→	10,898	-675	Very little/none	yes
21/02/1975	Summer	11,918	→	9,034	-2,884	Very little/none	yes
Historical subreach flows around 15,000 ML/day							
27/09/1991	Spring	15,210	→	21,115	+5,905	Moderate	yes
4/11/1989	Spring	15,076	→	19,364	+4,288	Moderate	yes
Historical subreach flows around 20,000 ML/day							
7/01/1997	Summer	17,819	→	10,673	-7,147	Very little/none	yes
10/10/1996	Spring	17,304	→	23,902	+6,598	Moderate	yes
1/09/2005	Spring	227	→	20,010	+19,783	Large	yes
25/07/2003	Winter	210	→	19,047	+18,837	Large	yes
25/09/1998	Spring	337	→	18,471	+18,134	Large	yes
8/08/1995	Winter	619	→	18,467	+17,848	Large	yes
12/09/1988	Spring	191	→	21,281	+21,090	Large	yes
24/10/1986	Spring	194	→	20,851	+20,657	Large	yes
Historical subreach flows larger than the flows being investigated for the Strategy							
15/01/2011	Summer	128	→	28,432	+28,304	Very large	no
7/09/2010	Spring	434	→	40,411	+39,977	Very large	no
3/10/1996	Spring	1,189	→	35,445	+34,256	Very large	no
7/10/1993	Spring	46,626	→	51,709	+5,083	Moderate	no
20/09/1975	Spring	44,767	→	56,131	+11,364	Large	no

* Note that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Goulburn–Murray Water manages the day-to-day river operations of Eildon Dam to limit flows to 2.5 metres at the river gauge, equivalent to flows of 9,500 megalitres/day (ML/d) (outside of flood operations). This is to prevent water moving onto private land in the Molesworth region where the channel capacity of the Goulburn River is low (natural restriction or choke point). This kind of release is only performed when there is very little flow coming down the tributaries (Acheron, Yea, etc.).

Due to the steepness of the local topography, rainfall can rapidly increase flows in several tributaries downstream of the Eildon gauge, and these flows can affect riverbank farmers and communities between Eildon and near Yea. Water releases from Eildon Dam are therefore not made when there are high flows coming down the tributaries.

What flows are being considered

Constraints work is investigating flow rates of between 12,000 and 20,000 ML/d (Table 7, and as indicated by the shaded box on Figure 16).

This would be overbank flows up to around the minor flood level range. At below minor flood level, river levels are not high enough to trigger emergency management or flood warnings from the Bureau of Meteorology. At minor flood level, there is some inconvenience. Low-lying areas next to rivers and creeks start to get inundated, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged (see also 'What is the Constraints Management Strategy?').

Constraints work is **not** considering flows at moderate or major flood levels. Flows significantly higher than the minor flood level range are damaging and disruptive, and outside the bounds of active river management. Constraints work is collecting information about what effects river flows have at different places along the Goulburn River, but only up to the minor flood level range.

Table 7 Comparison of flow footprints being investigated for the Eildon to Killingworth subreach and flood categories at the Eildon gauge

Measure	Flow footprints being looked at for the Eildon to Killingworth subreach (that include the flow contribution of tributaries)			Eildon gauge, Minor flood level[1]	Eildon gauge, Moderate flood level[1]	Eildon gauge, Major flood level[1]
Flow rate (megalitres/day)	**12,000**	**15,000**	**20,000**	14,500	25,980	39,380
e.g. Eildon Gauge height (m)	**2.8**	**3.1**	**3.5**	3.0	4.0	5.0

[1] As defined by the Bureau of Meteorology, noting that flood classes are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

What these flows look like

Linking a gauge reading at Eildon with the actual flow downstream is not always accurate, because of the effect of tributaries inflows and localised rainfall run-off. To assist MDBA to understand how landholders and community assets could be affected by different flows, flow footprint maps were developed to help visualise the flows.

Flow footprint maps were created using hydraulic models to show how flows of different sizes move down the river and spread across the landscape. Flow footprint maps let you look at what is likely to get wet for different-sized river flows, not tied to particular river gauges.

When interpreting the maps, it is important to bear in mind that they are from a model of a generalised event, not a real event. Therefore, some caution should be used when interpreting the ‘typical flow’ footprints presented in this report. They are not intended to mimic real flow events, but to be an initial representation of what could get wet for a flow of a particular size.

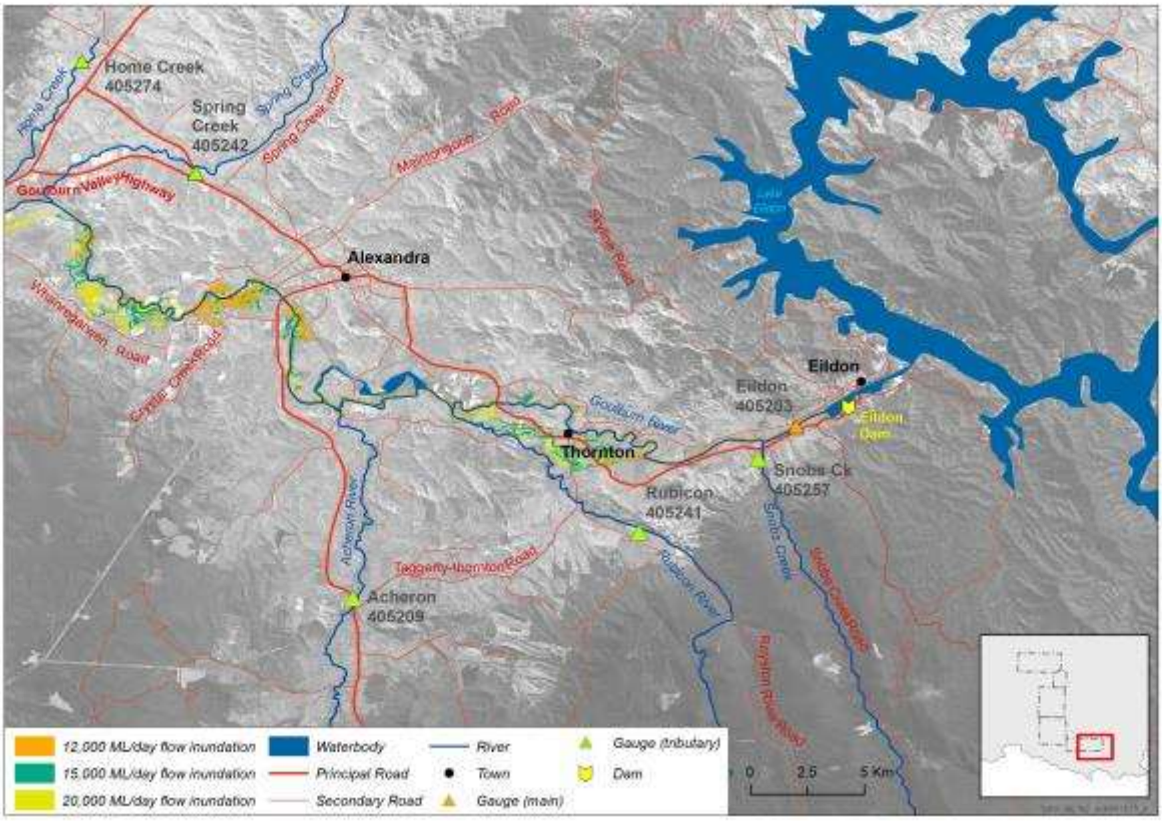
Figures 18a and b show flow footprint maps for 12,000, 15,000 and 20,000 ML/d flows downstream of Eildon Dam. The maps clearly show the old Goulburn River course near Alexandra becoming active at all flow rates (the breakaway), and areas of localised overbank flooding between Alexandra and Molesworth.

Feedback from local councils and landholders was that the 12,000 ML/d flow footprint map looked about right and would not be expected to cause too many issues.

However, the 15,000 ML/d and 20,000 ML/d flow maps underestimate the flow footprint. For example, Breakaway Caravan Park noted that the 20,000 ML/d map shows most of the caravan park dry, when in reality a large area would be underwater. In particular, it was suggested that there would be a lot more water on the flats around Molesworth, Killingworth, and upstream of Ghin Ghin Bridge.

Further, due to modelling assumptions, the maps did not capture the possible effect of the tributaries backing up (not being able to drain freely due to high Goulburn River levels). If work in the Goulburn proceeds, then additional modelling of potential inundation for landholders in tributaries should be included.

The accuracy of the maps is currently limited by the amount of data available to calibrate the hydraulic model. Mapping accuracy is a particular issue for the mid-Goulburn, as calibration data to reflect the complexity of the river channel were limited. The maps should therefore be viewed as a first estimate, with more accurate mapping required.



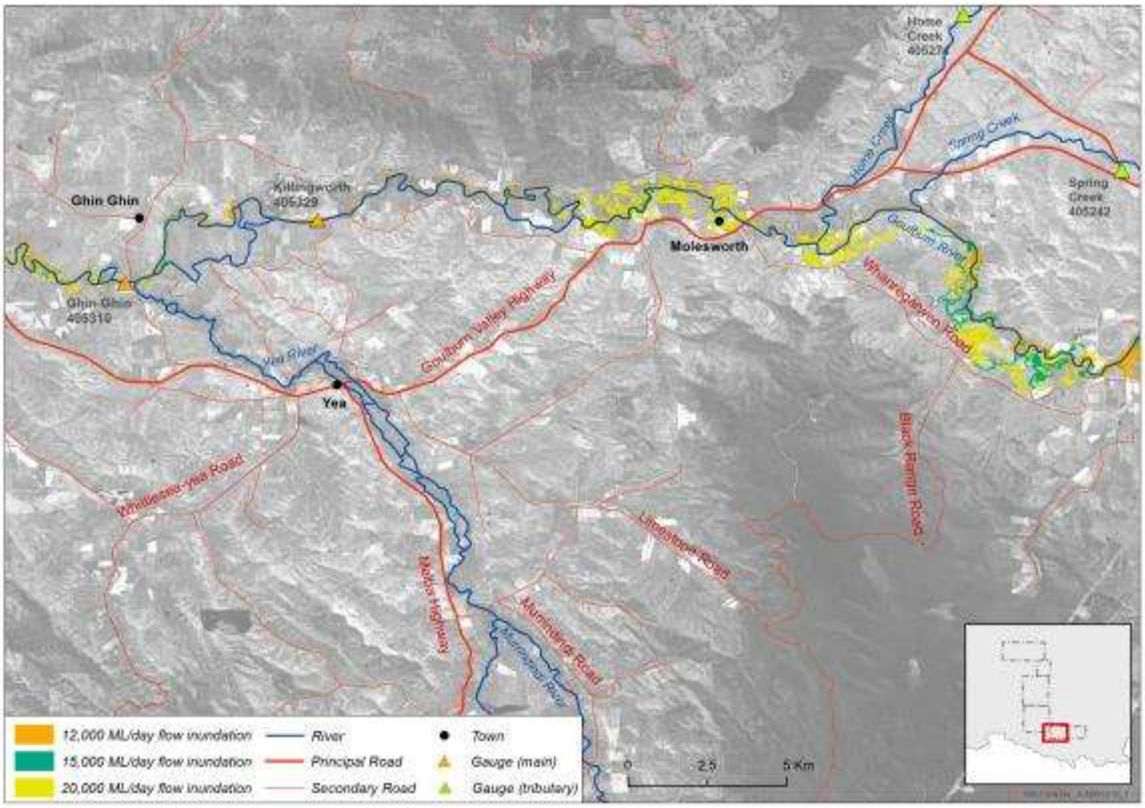


Figure 18 a and b Flow footprints for flows of 12,000, 15,000 and 20,000 megalitres (ML)/day between Eildon Dam and Killingworth

Tributaries

The tributaries in the Goulburn have different characteristics and therefore different effects on the flow of the main Goulburn stem. Water Technology analysed historical flow data in the Goulburn River and its tributaries to provide a general, though incomplete, understanding of the tributaries in the Goulburn catchment. This information is summarised for each tributary below.

Snobs Creek

Snobs Creek has a catchment area of 51 km^2. The creek has one gauge at Snobs Creek Hatchery. This gauge has 41 years of instantaneous data (Figure 19), classified as 'poor' because there are a lot of missing data (from a 41 year record, 1987 to 2007 is missing and the rest is patchy).

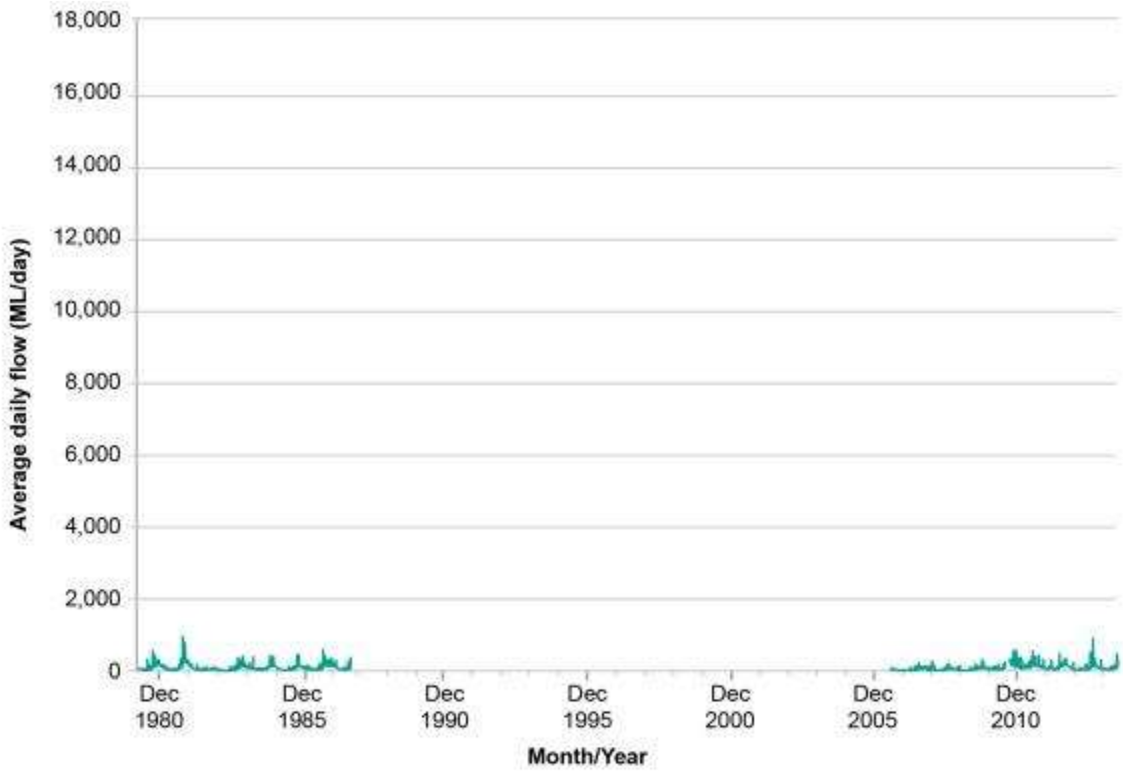


Figure 19 Average daily water flow in Snobs Creek at Snobs Creek hatchery (gauging station 405257), December 1980 – December 2013

Rubicon River

The Rubicon River has a catchment area of 129 km^2. The catchment is steep and rocky, and includes the Royston River, which joins the Rubicon River at Rubicon. The Rubicon River has one gauge at Rubicon. This gauge has 31 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 492 ML/d (Figure 20). The Mean of the Seasonal max flow is 2,578 ML/day. The Rubicon River contributes 6.5% of the Goulburn flow at Trawool. The 'peakiness' ratio value of the catchment is 5.34.

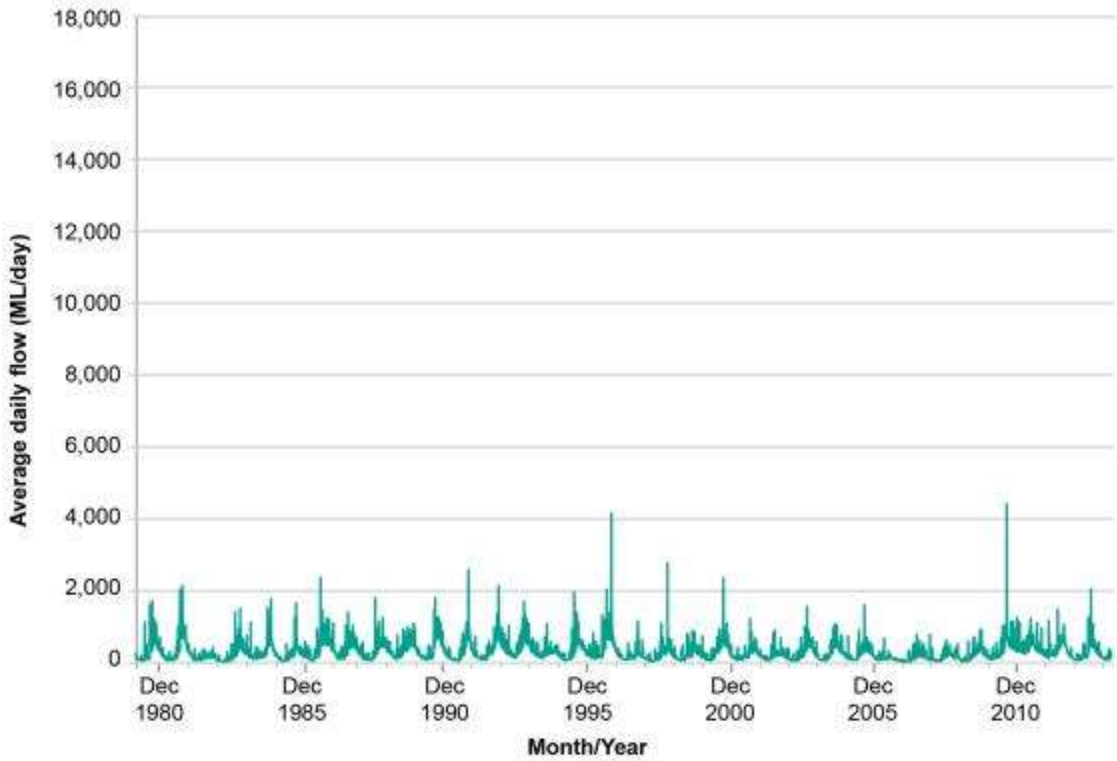


Figure 20 Average daily water flow in Rubicon River (gauging station 405241), December 1980 – December 2013

Acheron River

The Acheron River has a catchment area of 619 km^2. The Acheron River has one gauge at Taggerty. This gauge has 32 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 1,367 ML/d (Figure 21). The Acheron River contributes 18% of the Goulburn flow at Trawool. The 'peakiness' ratio value of the catchment is 3.94. It has a relatively high 'base flow index' value (0.71) which means there is large base flow (groundwater) contribution to flows at this site (Taggerty) consistent with the strongly perennial nature of the flow regime of streams in this area.

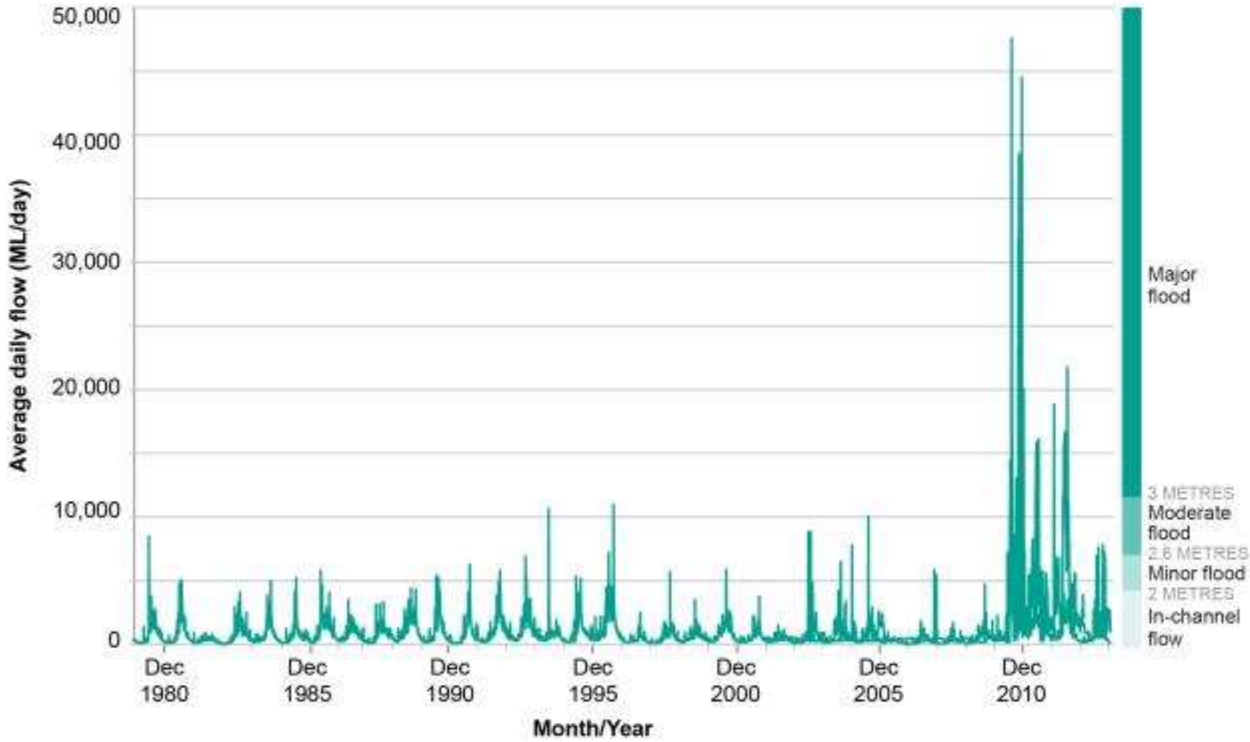


Figure 21 Average daily water flow in Acheron River at Taggerty (gauging station 405209), December 1980 – December 2013

Home Creek

Home Creek has a catchment area of 187 km^2. The creek has one gauge with 28 years of instantaneous data, classified as 'fair to good'. The mean daily flow for July–November is 138 ML/d (Figure 22). The creek contributes 1.8% of the Goulburn flow at Trawool. The 'peakiness' ratio value of the catchment is 43.40, however a number of major floods affect this data.

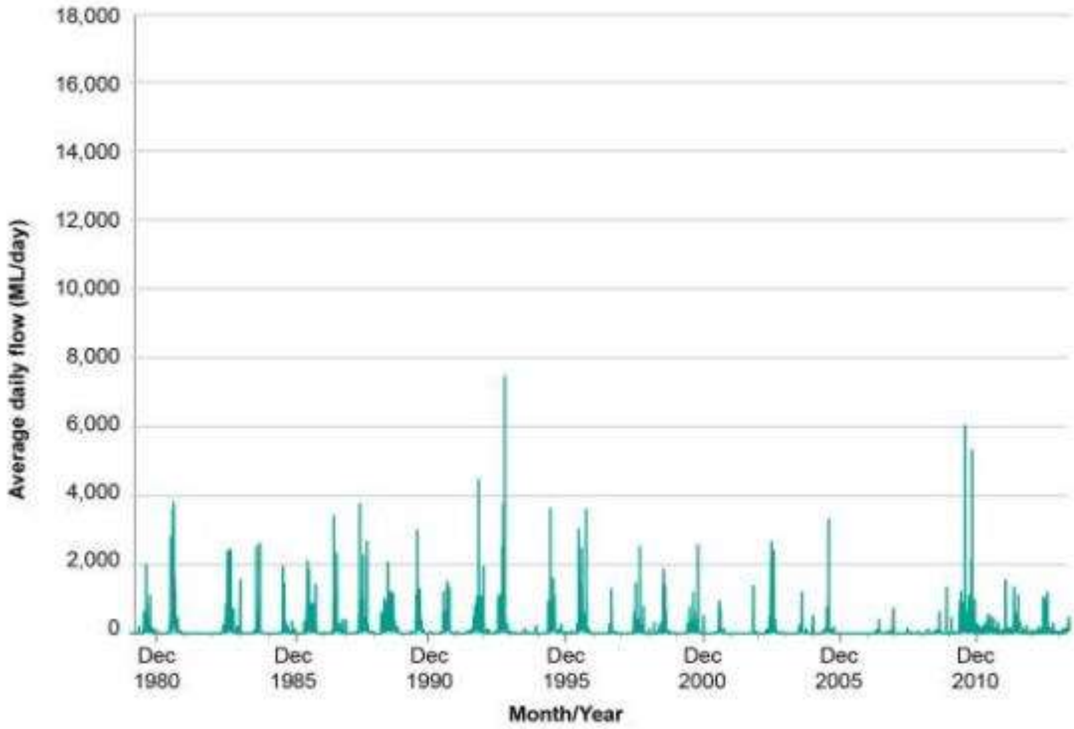


Figure 22 Average daily water flow in Home Creek at Yarck (gauging station 405274), December 1980 – December 2013

What could be affected by these flows

The following information about what might happen at different river levels is a guide only. Information has been sourced from community feedback, local flood guides and council reports, where available.

Below minor flood level — examples of areas affected by overbank flows below minor flood level include:

- Breakaway Caravan Park's river flats start to get wet
- localised flooding in low-lying rural paddocks, especially around Molesworth
- Goulburn River is brimming at Molesworth at around 12,000 ML/d.[7]

Minor flood level — examples of areas affected by overbank flows around minor flood level include:

- old Goulburn River at Thornton floods
- localised flooding in rural paddocks throughout the subreach impeding access for stock and causing pasture management and drainage issues
- Breakaway Caravan Park's river flats and mini golf area start to flood
- drainage issues start at trout farm
- lagoons at Molesworth flooded
- Molesworth Caravan Park's low areas start to get wet
- stormwater drainage in Molesworth starts flooding.

Low-lying river flats, caravan parks and recreation reserves near the townships of Thornton and Molesworth and the old Goulburn River course near Alexandra are particularly vulnerable to overbank river flows because the channel capacity is limited at these locations.

What the community thinks about the suggested flows

Initial feedback from landholders suggests that less than a 12,000 ML/d flow footprint around Molesworth and less than a 15,000 ML/d flow footprint elsewhere in the subreach may be a tolerable level of inconvenience flooding if suitable mitigation measures are put in place. The flow footprints of up to 12,000 ML/d to 15,000 ML/d may occur through a combination of releases from Eildon with no tributary inflows, tributary flows on their own, or a mix of tributary flows and Eildon releases. More detail on risks and successful combinations of tributary inflows and Eildon Dam releases is required.

Impacts include:

- **12,000 ML/day footprint** — will cause private property impacts, especially around Molesworth (water through anabranches isolating paddocks); these are potentially tolerable if suitable mitigation measures in place first
- **15,000 ML/day footprint** — will cause significant private property impacts and disruption around Molesworth (paddocks under water, impeded access) and some private property

[7] This is often when water level is 5.2 m at the Goulburn River gauge at Ghin Ghin. The flow history for the Goulburn River at Ghin Ghin has not been included in this report, as the Ghin Ghin gauge has only been operational since September 2001 and is not part of the Bureau of Meteorology's flood warning system.

impacts that will be widespread elsewhere along the subreach (water through anabranches isolating paddocks)

- **20,000 ML/day footprint** — is considered an untenable level of impact along the subreach, including widespread and significant inundation between Thornton and Killingworth (paddocks under water, impeded access, loss of productive use of the river flats).

Given that Molesworth would be one of the first affected areas, several farm and business visits were made in April–May 2015 to better understand potential farm level impacts. An initial landholder case study describing potential impacts at different flow footprints is included at the end of this subreach report.

Local councils and landholders in this region provided a number of other key points in relation to considering any change to regulated river flows.

Effects

In the mid-Goulburn, the main issue is about the risk of the flow getting higher than you intended, because of all the 'flashy' unregulated tributaries involved. Flows quickly rise and fall in a matter of hours in these creeks and rivers after rain events. There is not a lot of warning and people have been caught out by rapidly rising water when trying to move stock to higher ground.

There can be backing-up effects in tributaries, depending on how high the Goulburn River is running. This affects the river flats of properties along the tributaries, not just properties along the Goulburn River.

I welcome floods, but they come up and down quickly, and there can be 4 or 5 tributary floods in a year. However, environmental flows in the Goulburn must be careful not to cause extended backing up in the tributaries. This happened in 2012 because of the long duration of Eildon pre-releases (8–9,000 ML/d for several weeks) — the Yea couldn't get away and ran a banker for weeks and flooded out for more than 10 days. Duration is a key issue. The concern for tributary landholders is that extended environmental releases from Eildon Dam could behave like pre-releases during flood operations and cause backing-up flooding in tributaries. In the future, perhaps GMW [Goulburn–Murray Water] could vary the pre-release to avoid prolonged inundation; for example, high-low-high releases. The low release period would allow the tributaries to drain away.

Bank erosion and slumping are issues, especially in winter when the riverbank is wet. Higher flows more often could increase riverbank erosion and decrease water quality.

There have been significant investment in riverbank tree plantings and these can be at risk (depending on species, and life stage or size) of being killed if they are wet for too long or if the flows are too fast.

At about 8,000 ML/d, flow starts going down the old course of the river, effectively turning the Goulburn into two rivers.

We entered our business on the knowledge of the risk profile based on Eildon Dam being in existence. If humans are now trying to change how the dam is managed, then that will change the risk profile and it will affect businesses and their practices. This is especially the case directly below Eildon Dam before any of the tributaries come in.

Thornton is still on septic, so it is critical that flows do not hit this level. However, noting that the flows that get Thornton wet would be much larger than 20,000 ML/d.

It is not necessarily inundation that is the problem. Drainage can be an issue at high river flows, and at certain river levels some businesses have to switch to using pumps to get rid of excess water rather than allowing gravity to do its work (e.g. the Eildon trout farm uses pumps to get rid of extra water flowing through the fish farm when flows get above 15–20,000 ML/d).

Groundwater is connected to the river in some places by a gravel layer about 10 feet below ground. Some wetland water levels go up and down with the river level, whereas others don't.

Having a flood on the river flats can have some benefits for productivity and ecologically, SO LONG as it doesn't stay too long.

Access

At Molesworth Caravan Park, water comes up around the oval at around a 10,000 ML/d release from Eildon Dam (plus a little bit coming down from the tributaries — about 2,000 ML/d maybe). There is a high piece of ground and a low piece of ground. Anyone that wants to put the van on the low piece of ground does so at their own risk. They set up on these 'annual holiday sites' and they are not permanently occupied. They are weekenders, although many now have awnings and semi-permanent fixtures. When a flood comes through often people just wait for it to pass and clean out afterwards.

Management

Back a few years ago, Goulburn–Murray Water used to allow 12,000 or 13,000 ML/d releases from Eildon when the tributaries were dry. That type of flow would look absolutely different to an event when they release 7,000 or 8,000 ML/d and the tributaries are also contributing. It is vital that the tributaries are properly understood.

We need to have better forecasting for how the unregulated tributaries behave. A good understanding of the flow characteristics for each of the different rivers and *creeks that join the Goulburn River will be essential. This is so that river operators have enough confidence and forecasting power to safely add Eildon Dam releases to tributary flows.*

A number of properties and infrastructure assets in the mid-Goulburn are already protected from nuisance flooding by levees and/or raised floors.

There are remnants of levees in the mid-Goulburn. Indeed levees on the riverbanks may have been the reason that the Goulburn has a breakaway near Alexandra. Two stories for the origin of the breakaway were heard — it was a neighbourly dispute with landholders on opposite sides of the riverbank building up the levees in competition until eventually one side blew and the breakaway formed with a new river course. Another version is that the breakaway started in 1912 following a big flood (the watercourse went through three properties, splitting them up). The breakaway was then further entrenched by feuding farmers raising levees on their own property to prevent flooding.

Landholder case study — Molesworth

The flow footprints being investigated in the Strategy affect landholders along the Goulburn differently. Molesworth is of significance as a natural 'pinchpoint'. Molesworth is the location along the Goulburn where riverbank landholders would first start to be affected by higher managed flows. Given this, and recognising the significance of landholder knowledge, a number of farm and business visits were made in April–May 2015 to better understand potential impacts of higher managed flows at a farm level.

> *Families living along the Molesworth river flats have been observing and caring for the river, lagoons and flats for much of their lives. A good number of Molesworth families have lived in the area for many generations; our family alone has been farming here from 1901.*
>
> *The farmers here have walked every inch of the river lands in all weather conditions. They've learnt how the tributaries work alongside the river and the billabongs, ponds and lagoons. They've seen the damage potential and the health of the river and its systems. They've watched the river flats through droughts and also floods, how it behaves and how it recovers.*
>
> *These families and farmers in Molesworth are also the reason why so many of the lagoons, billabongs and pond systems are healthy in this area as they care for and about the land and waterways. They take on advice from authorities and experts and work hard to try to implement strategies to maintain and improve the river's health. As one of the many land owners of this unique fragile and sensitive environment our family has had intimate knowledge of the Molesworth river flats and so we feel qualified to present an environmental impact statement from our perspective.*
>
> *Molesworth landholders, Andy and Karen Williamson, Bonnie Brae Farmstay*.

Inundation of some areas of private land around Molesworth will happen at all of the flows being looked at (12,000, 15,000 and 20,000 ML/d). This is because the channel capacity is very limited at Molesworth (9,500 ML/d). Currently, Goulburn–Murray Water specifically limits releases from Eildon Dam because of the risks of inundating private land around Molesworth.

Landholders in Molesworth are concerned that the flow footprints under investigation will have a negative impact on the use of their farms and livelihoods. In this case study, we report the scale of likely impacts across the range of flow footprints being looked at.

Landscape and socio-economic context

At Molesworth, in the mid-Goulburn reach, the floodplain is narrow, bordered by steep hills (Figure 23). Several unregulated tributaries join the Goulburn River near here and the channel capacity of the main stem of the Goulburn is lower than in areas upstream and downstream.

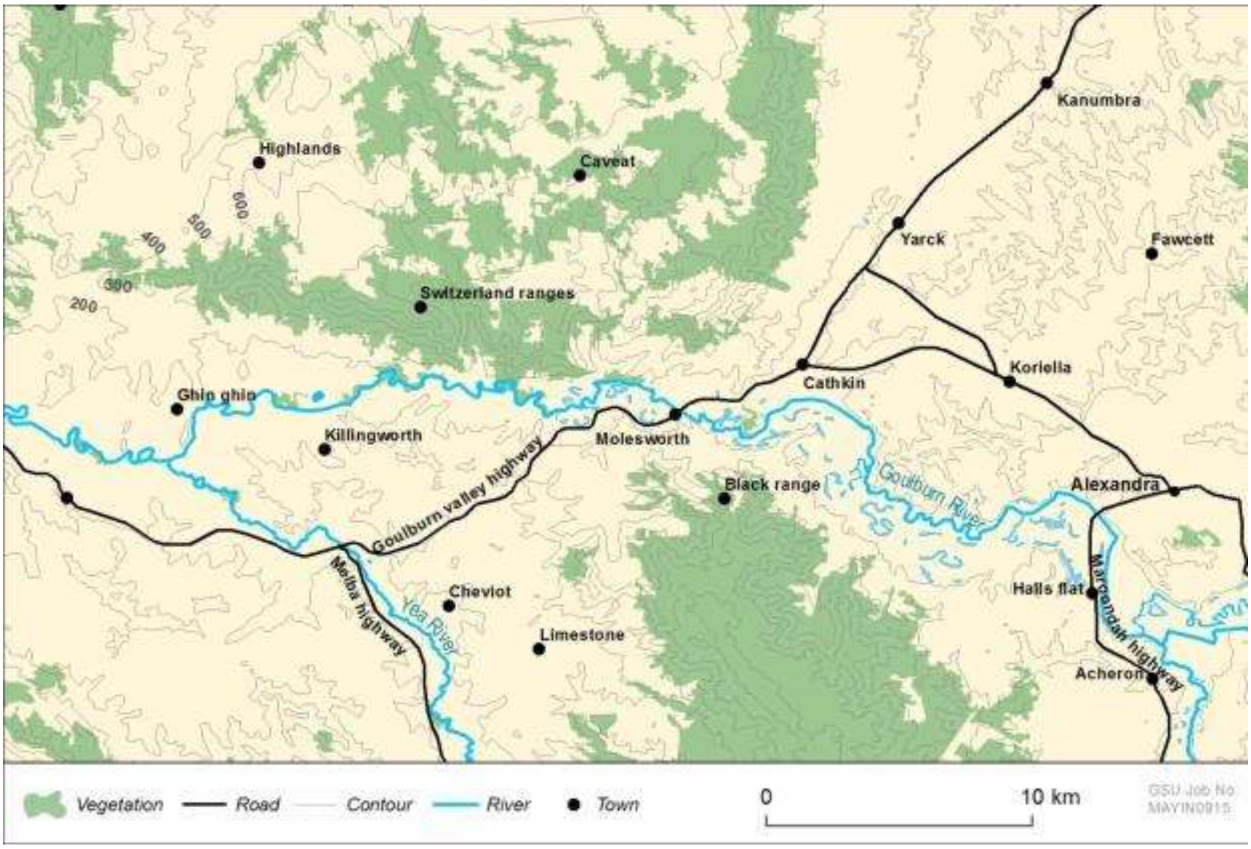


Figure 23 Topography of the Molesworth region

Example of a river flat property with a range of terraces and billabongs near Native Dog Creek, just downstream of Molesworth. Flows fill the old channel networks and billabongs first, then spread overland onto pastures.

Overlooking riverflats running below the Whanregarwen Road. This is an example of a Molesworth property with flatter topography without a network of depressions and billabongs. Flows spread overland onto pastures straight away. *Photo: Emma Hampton, MDBA.*

The river is confined by hills either side, leaving a relatively narrow section of fertile river flats to farm. Landholders in this section of the catchment farm right up to the riverbank, and in-between the network of billabongs and depressions that can meander through the river flats.

Landholders depend on the river flats because they are often the most productive parts of their farm. River flats provide good quality spring pasture that stays greener for much longer than the surrounding hill country. This land is therefore used for grazing and hay and silage production, which provides reliable income and feed through summer and dry times, and fodder for over winter. For many landholders, river flats are used for sheltered locations for calving between July and September, and for growing pastures between September and November.

The dependence on river flat productivity means riverbank farmers in Molesworth are particularly susceptible to how often water flows over their land, for how long and at particular times of year. Some farms have access to higher ground to move their cattle, others don't.

The hills either side of the river are steep, unsuitable for cropping, and have limited grazing potential. Without the value and feed that the pasture on the river flats produces, and without access to sufficient higher country, the concern is that some of the smaller Molesworth farms may not be viable.

Molesworth in the 1800s. ***Photo provided by A&K Williamson***

The majority of landowners in and around Molesworth are farmers, most with some connection and reliance on the river flats, lagoons, billabongs, ponds, river and tributaries for their business and farm welfare. They have survived droughts, fires, wars, floods and depressions and still looked after each other and their land. They may not be young, educated, pretty, huge earners or international businesses but they are the mainstay for the local economies.

It is their expenditure that provides the local towns with income in the off tourist seasons. Indirectly and directly these farmers are the major employers in the district, they influence sale yards, stock agents, the sale of stock products, equipment, machinery, seed, stock and vehicles. They have a huge economic impact on the district and their livelihoods and financial viability is directly linked to the health of the river and its associated wetlands.

Molesworth is the town that doesn't seem to rate much of a mention in this proposal other than with released flows of larger than 12,000ML/day it becomes a wildcard. You can drive through Molesworth in a blink, there's a pub, an old general store, a proud old community hall and a beautiful church that stops travellers in their tracks. You'd think Molesworth was empty but it's probably the fullest town you'd find in the district. It's full of people that know each other, work together and can identify as Molesworth residents.

Molesworth has been on the maps since around 1824 and generation's later still has many families living here that are descendants of the original families settled in the area. These families have handed down their farms and their knowledge and spent their lives working with and living for this land. Many still hope to be able to hand their *homes and their histories onto the next generation. Molesworth also has a huge extended family. People from all around Australia have strong links with Molesworth through family, holidays and work and it is considered one of the most beautiful places. On more than one occasion Molesworth has been described as 'Gods own office'. We are close to Melbourne but we reflect so much of the older values where time slows and people take that time to talk and care. Molesworth is where you can come across wildlife, peace and quiet, welcoming faces, healthy land and waters, all these things become so rare.*

Molesworth farmers are also on the endangered list with land values pushing rates up and the cost of living and working pushing their livelihoods into survival of a lifestyle. Yet top of the list of these farmers is always working on helping the land, clearing pests and weeds, preventing erosion, planting and fencing to protect the environment is part of their daily lives. Anyone with knowledge of agriculture would know that diversity is important for resilience and these farmers represent diversity. Having different kinds of farms, the older and newer farming styles, understanding systems and also natural processes is vital to agricultural resilience and progress. They provide pockets of knowledge, skills, techniques as well as the genetics in their pastures and livestock that are a buffer in an agricultural society that is becoming more centralised and uniform.

Molesworth landholders, Andy and Karen Williamson, Bonnie Brae Farmstay.

Impacts of overbank flows

Landholders in Molesworth have shared with us some of the impacts they face when water flows onto their land.

However, before describing the scale of impacts that are likely to be experienced under a range of flow footprints, it is important to assess how easy it is for people to be able to accurately connect impacts to specific flows. There are two particular challenges for the Lake Eildon to Killingworth subreach (including Molesworth): the long distance between main-stem gauge locations and issues with flow footprint mapping accuracy.

There are several significant tributaries that join the Goulburn River, but only two gauges on the main stem of the Goulburn a long way apart, Eildon and Trawool (Killingworth gauge is a relatively recent addition, and has a limited range of measurement). The Goulburn River between Eildon and Trawool has 57% of the total catchment ungauged and within this some tributaries are well gauged, some are partially gauged (e.g. Yea River) and some are ungauged. The main-stem gauges let people know what the flow levels are in terms of releases from Eildon and what could have passed their property before ending up at Trawool, but it is difficult to be exact. This means that there is some uncertainty for mid-Goulburn mainstem landholders in describing the scale of impact around each of the flows.

The flow footprint maps have been prepared from a hydrodynamic model of how the river works. Sufficient calibration data is important, to make sure that the model's representation of how water moves across the landscape matches what people experience in real life. We know that we do not have enough calibration data for the mid-Goulburn. Landholders have told us that our flow footprint maps underestimate where water spreads and that the 20,000 ML/d footprint perhaps looks more like a 15,000 ML/d footprint. Further calibration data and work is needed to improve map accuracy.

Our current understanding of the increasing scale of impacts of a range of flow footprints is therefore based on several detailed landholder interviews around Molesworth which are described below. This understanding may change in the future as new information emerges.

Summer irrigation:

- Landholders value the wetlands, trees and wildlife on their properties and actively look after them.
- Current regulated irrigation flows in summer have an impact on some landholders (around 9,000 ML/day released from Eildon). For example, water from the main Goulburn channel begins to flow into lagoons on private property, cutting off access tracks to some farm areas (see photo). One Molesworth landholder has told us that when summer irrigation flows increase to around 9,500 ML/day, some crossings between paddocks become impassable — above car bonnet depth.
- Typically these are minor impacts that landholders already have ways to work around.

Stock crossing between billabongs that is impassable to cars even at summer irrigation levels (too deep, over-bonnet depth). ***Photos: Beatrix Spencer, MDBA.***

12,000 ML/d flow footprint — in addition to the above

- For a 12,000 ML/d footprint the Goulburn River flows into billabongs and lagoons close to the river. Landholders have a network of pastures in and around these billabongs and watercourse on the river flats. There are a number of 'flood runners' that weave across pastures and some start to fill at this flow footprint. This can affect landholders by impeding access to areas of their farm, which can affect overall farm planning (e.g. where stock are grazed or hay is stored).
- The filling up of billabongs and lagoons is valuable to some landholders. Flow footprints of this size may 'top up' water in lagoons that stock use.
- For other properties, there is no longer a network of old channels and billabongs to fill, so water starts spreading over the grazing land rather than staying within channels. There are some depressions and terraces, but the land is largely flat and productively grazed and thus immediately affected.
- Flows of this size start to enter the Molesworth Recreation Reserve and caravan park, filling up the billabongs in the Parks Victoria reserve next door, then starting to flow through the drains under the loop road near the boat ramp. There is already a partial levee bank surrounding the caravan park alongside the river. The caravan park could be protected by extending the levee around two sides of the park to protect assets, upgrading two butterfly drainage valves under the park's ring road to better control water

coming into and out of the park; and upgrading the main access road to the caravan park (which gets cut) through raising and larger capacity drainage pipes under the road.

A flow footprint of this size could be largely described as 'inconvenient'. Subject to timing and duration and investment in on-farm mitigation measures to improve access and drainage, the impacts created by this size flow could be acceptable.

15,000 ML/d flow footprint — in addition to the above

- At 15,000 ML/d, most of the 'flood runners' and depressions would be filled. There would be more water flowing into billabongs and lagoons would become connected to the main Goulburn River channel.
- Some farm areas may be completely isolated and access tracks inundated. This has impacts for accessing stock and pastures and moving machinery.
- There is a channel that runs below the Whanregarwen Road (the old river course). When this fills, it cuts access to the river flats for several properties. The water in this channel can run in both directions — from the river or rainfall from the surrounding steep hills to the river. This channel means that you can't necessarily move stock out to higher ground and it also makes it difficult to get feed in.
- At this flow, flooding is relatively confined to wetlands (land not grazed) but also some low-lying depressions and terraces (land grazed). There is concern that water will remain in depressions for extended durations, leading to water logging of soils and damage to pastures.
- Inundation of low-lying areas of farms could reduce the area of land available to grazing and hay or silage production, with impacts on farm productivity. If areas are inundated for a long time, there will be issues if the production of feed for the next year is compromised.
- Landholders are concerned that more regularly connecting lagoons to the main channel may result in the spread of weeds or invasive species such as carp. Landholders in this area are conscious of the environmental value of their billabongs and lagoons.
- There is also concern that more regularly connecting the main Goulburn River to these lagoons could damage the uniqueness of these environments: their ecology could become more similar to the riverine habitat rather than isolated wetlands and lagoons with divergent habitat characteristics and ecology.
- Time of year and duration are key to impacts — short, sharp flows at the right time of the year would be good for the soil and productivity so long as they don't occur every year. But flows that are too long and/or at the wrong time of year and without warning would have a very big impact on landholders.
- Most farm infrastructure (sheds and pumps) appear to be already protected up to large flood levels (e.g. 1993, 1975, 2010).

Overall, a flow footprint of this size is likely to create a larger number of impacts for landholders that would require more effort and resources to manage through. Flow footprints of this size could be quite disruptive to farmers around Molesworth and would require significant on-farm mitigation efforts to reduce impacts.

20,000 ML/d flow footprint — in addition to the above

- For 20,000 ML/day, water is likely to be flowing overland onto productive pastures. Once all the channels and flood runners in the landscape have filled, the water spills out onto higher pasture areas which may or may not drain effectively when river levels recede.

- Flows of this size for an extended duration (more than several days), would have detrimental effects on farm productivity in Molesworth.
- Flows of this size would cut the main access road to the Molesworth Recreation Reserve and caravan park.
- Landholders in this reach have invested in improving higher pastures on the river flats (e.g. $30,000–$40,000 for seeds, soil preparation for even relatively small paddock sizes etc.). Investments have also been made in weed management such as blackberries. If a flow footprint of 20,000 ML/d resulted in more regular inundation of higher pasture areas, it could negatively affect existing and future investments in pasture improvements.
- Inundation of low depressions and higher pastures leads to growth of both native saplings and weeds. Landholders have to invest time in clearing up these weeds and saplings as they reduce areas of grazing and pasture growth. More regular inundation would increase the time spent on managing undesirable species.
- Flow footprints of this size will cut access tracks and potentially impede access to significant areas of river flats in the Molesworth region.
- Further upstream along the Whanregarwen Road the floodplain widens, which means cattle can still be moved to higher ground, however in the constricted floodplain area around Molesworth, cattle are difficult to move because of access issues and become stranded. Even if you can round them up, they have to be trucked off-farm. Some farms have higher ground to move their cattle, others don’t.
- Removal of debris and damage to fencing is often a major cost to landholders.
- People and livestock could be at risk if flooding was extended and frequent, where increased erosion could change the river’s course.

Overall, a flow footprint of this size is likely to create a significant number of impacts for landholders that would require significant long-term efforts and resources to manage through. Flow footprints of this size could be disruptive to a large number of farmers around Molesworth, and are likely to be unacceptable to many in the community.

Greater than 20,000 ML/d flow footprint — in addition to the above:

- Higher flow footprints, such as the floods of 2010, cause significant damage to private property (e.g. 2010 was 40,600 ML/d at the Trawool gauge).
- Flows of this size threaten the safety of humans and stock. During 2010, a number of animals were stranded and a number of landholders were put in dangerous situations when rapidly rising floodwaters cut off sections of farm with little notice.
- Flows of this size also damage roads and properties (e.g. in the 2010 and 1993 floods the access road to the Molesworth Recreation Reserve was cut and many caravans flooded).
- There is potential for the river to change course, cutting through farmland. There are places where billabongs on the river flats are separated from the main river channel by only a few metres. Any increase in riverbank erosion from larger or sustained high river flows could increase the chance of the river 'breaking away' and forming a new course.

These large damaging flow footprints are well above what is being investigated as part of the constraints work. A flow footprint such as what occurred during the 2010 floods is recognised as very damaging to landholders in the Molesworth region. Flows footprints of this size will still happen naturally in the future as a result of large rainfall events. As is currently the case, this is part of living alongside a river, and landholders will continue to manage the short- and long-term after effects of damaging flows of this size.

Property photographs highlighting a range of management issues of concern to Molesworth landholders

Raised entrance road to property, built up to enable access to stock after difficulties during 2010 flood.

Area of active tunnel erosion, with landholder concern that overbank flows could increase property erosion issues.

Paddock trees that died after prolonged waterlogging in depressions in 2010.

Property has a number of terraces at different levels which get wet at different flow rates.

Depressions that fill with overland flows that don't always drain well, and can have pasture re-establishment and long-term weed issues.

Billabongs on-farm with varying levels of grazing access and water permanence. *Photos: Beatrix Spencer, MDBA.*

Flow footprint mapping at an individual landholder scale

Current mapping shows the 12,000 and 15,000 ML/day flow footprints as staying largely in channel (Figure 24). Further model calibration is required to improve mapping accuracy given that these are understood to be overbank flows in the Molesworth region.

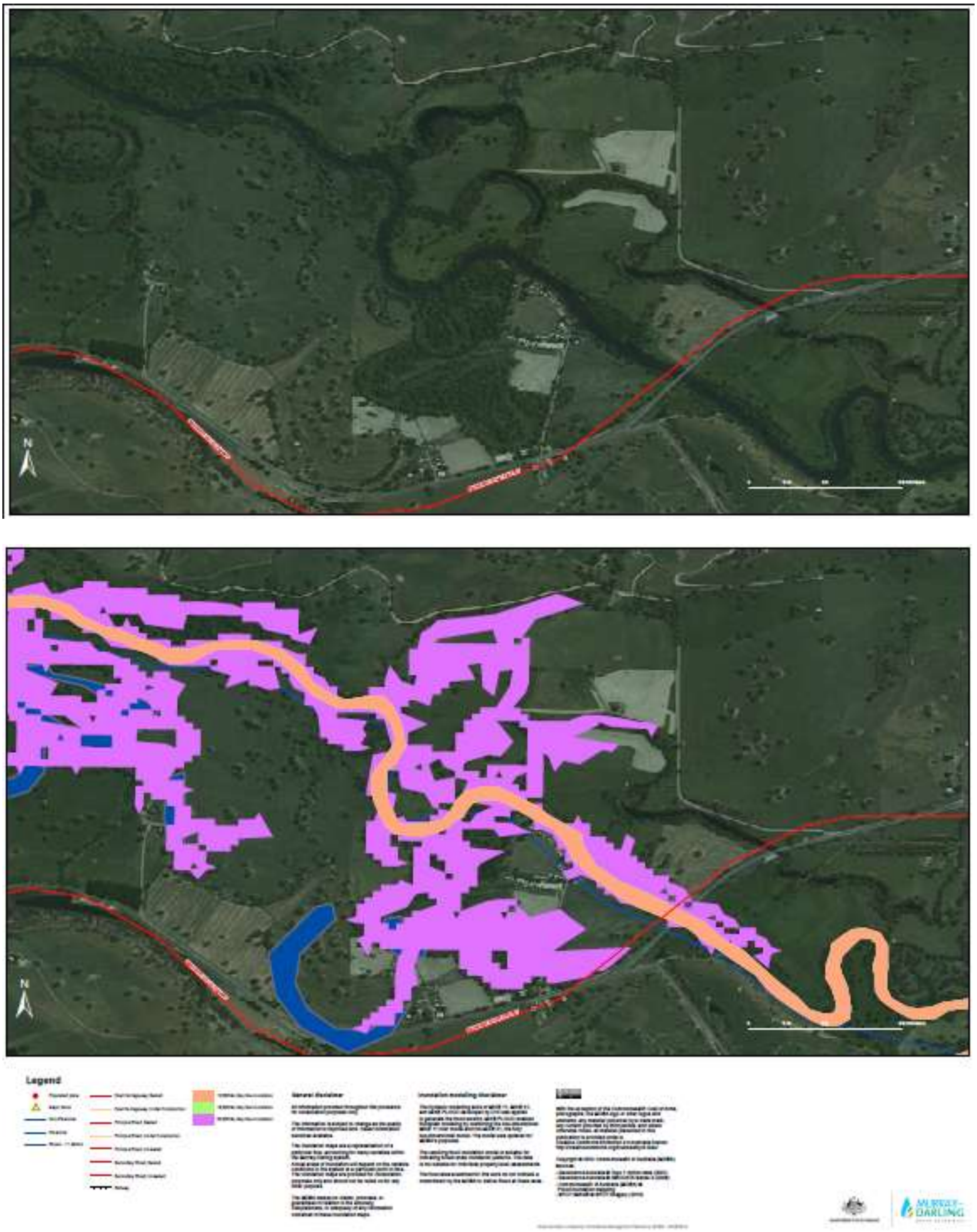


Figure 24 Molesworth flow footprint map at 12,000, 15,000 and 20,000 ML/day

Killingworth to Mitchellstown

At a glance

The flow footprints constraints work is investigating are between 15,000 and 30,000 megalitres/day (ML/d) between the Killingworth gauge on the Goulburn River and Mitchellstown, including the flow contributions of tributaries. Extended duration releases from Lake Eildon and releases on top of high tributary flows are not being investigated. Flow footprints higher than 30,000 ML/d are not being investigated (e.g. flows greater than 4.5 m at Seymour, gauging station 405202). The overbank flows that constraints work is looking at occurred more frequently in the past.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although the 20,000 ML/d flow footprint may be somewhat underestimated.

Initial feedback from landholders suggests that flow footprints up to 20,000 ML/d (e.g. 3.6 m at Seymour, gauging station 405202) may be a tolerable level of inconvenience flooding, if stormwater drainage issues at Seymour are addressed as well as any inundation of private land. The flow footprint up to 20,000 ML/d, nearing minor flood level, may occur through a combination of releases from Eildon with no tributary inflows, tributary flows on their own, or a mix of tributary flows and Eildon releases.

Reach characteristics

This subreach flows from the Killingworth gauge on the Goulburn River (405329) to Mitchellstown (Figure 25). Four creek and rivers contribute flows to the Goulburn River, including Yea River (and Murrindindi River, which joins the Yea), King Parrot, Whiteheads and Sunday creeks (and Sugarloaf Creek, which joins Sunday Creek). These tributaries are unregulated, and rise and fall rapidly in response to rain.

The town of Seymour is located in this stretch of the Goulburn River, right on the Goulburn floodplain. The town has been moved to higher ground three times because of flooding. Floods in 1847, 1870 and 1916–17 caused the town’s commercial centre to be moved. However, since ‘Big Eildon’ dam was built in 1955, its water harvesting operations have greatly reduced the impact and frequency of minor and moderate Goulburn River floods occurring in Seymour.

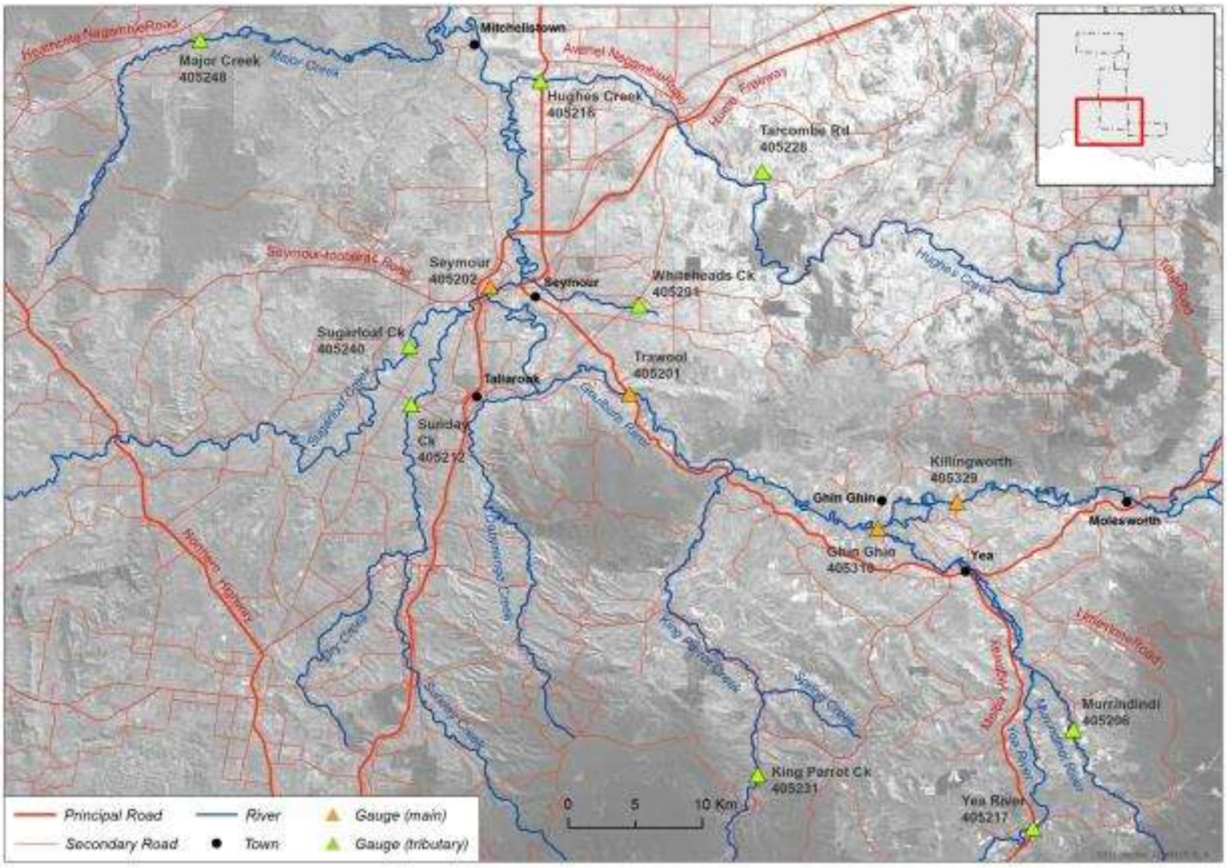
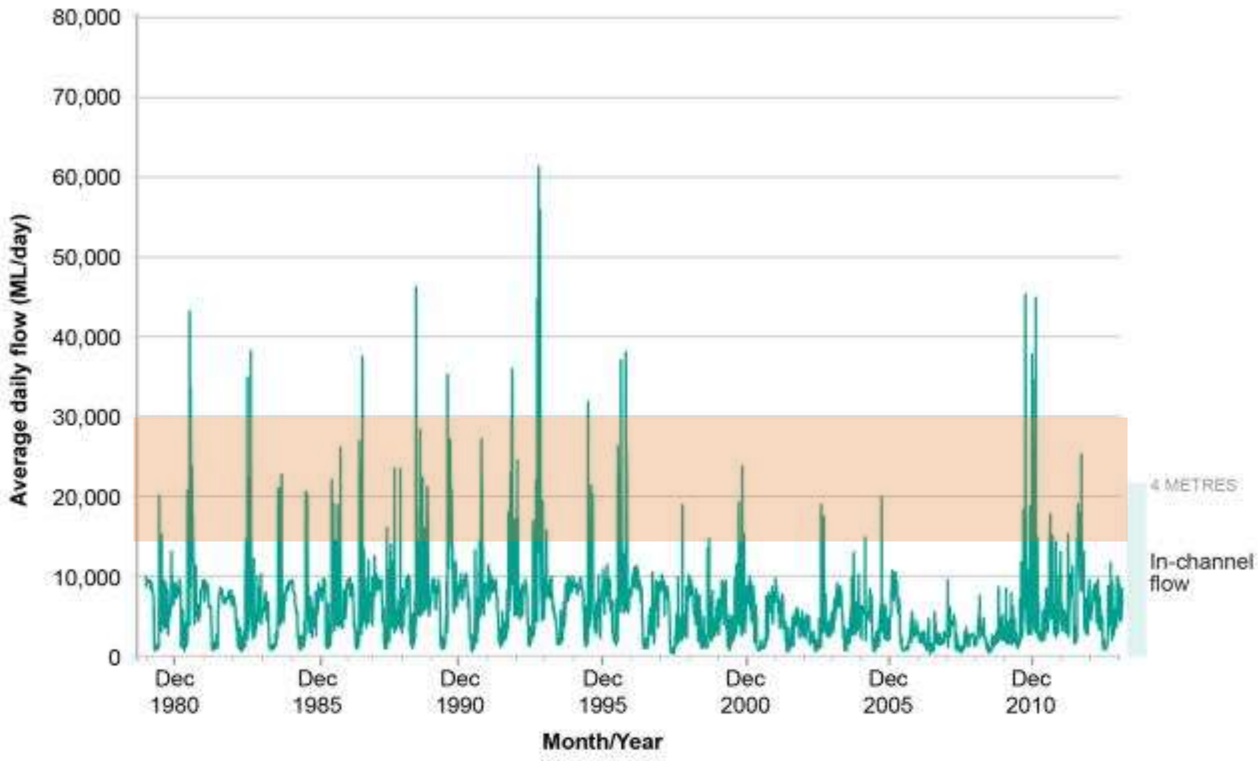


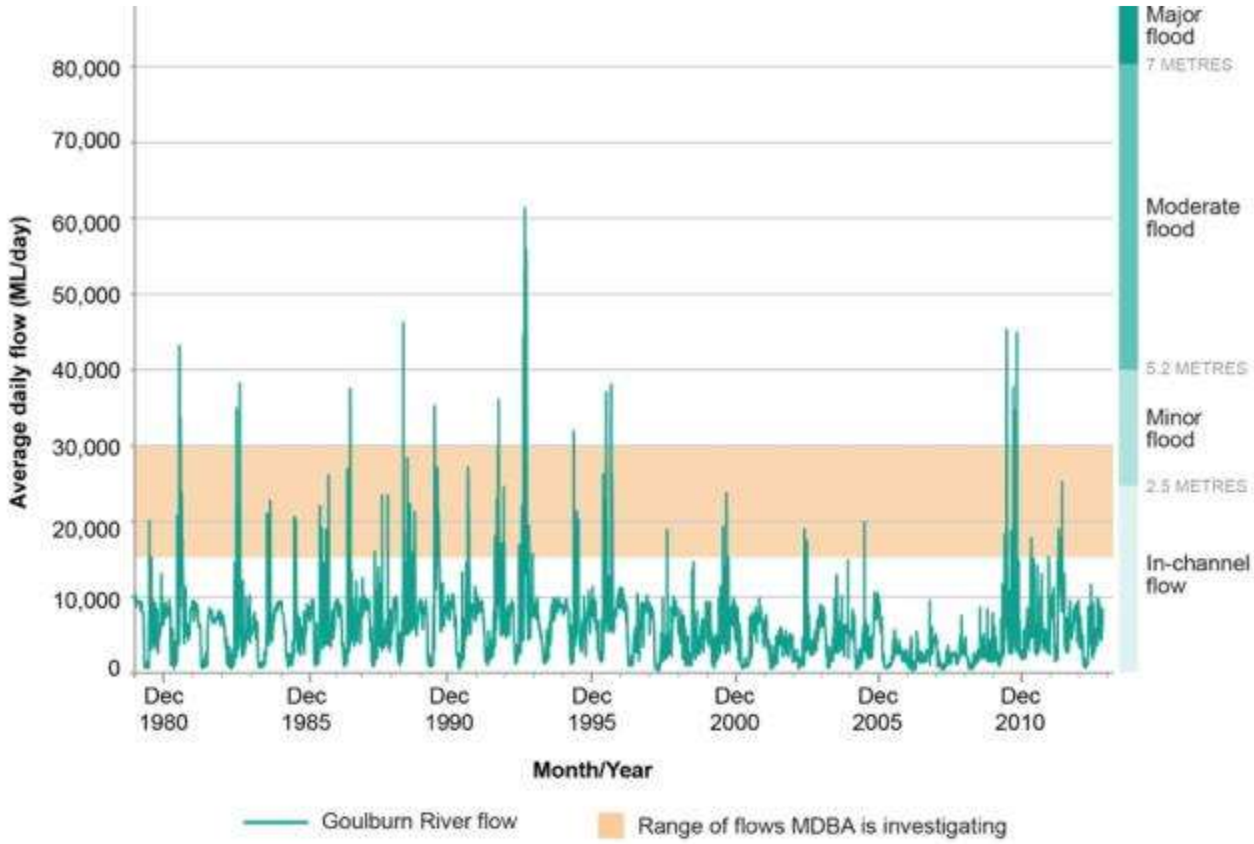
Figure 25 Killingworth to Mitchellstown subreach

There are four flood gauges in this subreach that are used by the Bureau of Meteorology for flood forecasting purposes. Two are located on the Goulburn River at Trawool and Seymour, one is located at Sunday Creek at Tallarook, and one at Whiteheads Creek at Seymour. The river flows recorded at the Goulburn River gauge at Trawool and Seymour between 1979 and 2013 can be seen in Figure 26 and Figure 27.



Note: The shaded box outlines the range of flows that MDBA is investigating (15–30,000 ML/day).
Noting that as you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 26 Flows in the Goulburn River at the Trawool gauge, 1979–2013



MDBA = Murray–Darling Basin Authority; ML = megalitre

Note: The shaded box outlines the range of flows that MDBA is investigating (15–30,000 ML/day).

The flood categories (minor, moderate and major floods) are as defined by the Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 27 Flows in the Goulburn River at the Seymour gauge, 1979–2013

The previous major floods recorded by gauging station 405202 at Seymour occurred in 1974 (7.64-m peak) and 1975 (7.03-m peak), flowing at more than 80,000 ML/d. Historically, floods have gone even higher, such as in 1916, when flows were above 8 m. As can be seen from Figure 27, moderate flooding at Seymour has occurred five times since 1979, with the most recent event in September 2010. In 2010, flood levels peaked at 6.2 m, flowing at 58,700 ML/d. These historical data are presented in Table 8, together with other examples of moderate and minor flood events. A range of flows has been provided as background context for the river levels that people have experienced first-hand. Many are far larger and more damaging than the flows constraints work is investigating; they are not the aim of this Strategy. Some of the smaller historical events are also included in Table 8 that are in the range of the managed overbank flows being investigated. This is so people can think about the types of effects that have occurred at flows of these sizes.

Table 8 Example recorded flows for Goulburn River at Seymour (gauging station 405202)

Flood class	Date	Gauge height (m)	Flow (megalitres/day)	Is constraints work considering these sorts of flows?
Major	18 September 1975	7.03	81,985	No
Moderate	20 September 1993	6.65	70,298	No
Moderate	5 September 2010	6.21	58,714	No
Moderate	1 October 1996	5.33	42,034	No
Minor	19 August 2012	4.04	25,260	Yes
Below minor	2 September 2005	3.61	20,487	Yes

Heavy rainfall can rapidly increase flows in several tributaries near the Seymour flood gauge, and these flows regularly affect riverbank farmers and the Seymour township. For example, in February 2012, heavy rainfall (130–170 mm on local gauges) caused the Whiteheads and South creeks to burst their banks in Seymour. The flows from the tributaries (but not the Goulburn River) caused extensive damage and made the township almost impassable. The flood risk to Seymour from the Goulburn River and its tributaries is now being addressed by the Seymour Flood Mitigation Project. This project is supporting the design and construction of a levee bank to protect the area of Seymour between the railway line, Whiteheads Creek and the Goulburn River.

What flows are being considered

Constraints work is investigating flow rates between 15,000 and 30,000 ML/d (e.g. 3.1–4.5 m at Seymour gauging station 405202) (Table 9 and as indicated by the shaded box on Figure 27).

This would be overbank flows up to the minor flood level range. At below minor flood level, river levels are not high enough to trigger emergency management or flood warnings from the Bureau of Meteorology. At minor flood level, there is some inconvenience. Low-lying areas next to rivers and creeks start to get inundated, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged (see also 'What is the Constraints Management Strategy?').

Constraints work is **not** considering flows at moderate or major flood levels. Flows significantly higher than the minor flood level are damaging and disruptive, and outside the bounds of active river management. Constraints work is collecting information about what effects river flows have at different places along the Goulburn River, but only up to the minor flood level range.

Table 9 Comparison of flow footprints for the Killingworth to Mitchellstown subreach and flood categories at the Trawool and Seymour gauges

Measure	Flow footprints being looked at for the Killingworth to Mitchellstown subreach (that include the flow contribution of tributaries)			Minor flood level[1]	Moderate flood level[1]	Major flood level[1]
				Trawool		
Flow rate (megalitres/day)	**15,000**	**20,000**	**30,000**	21,700	41,500	83,000
e.g. Gauge height (m) at Trawool	**3.1**	**3.8**	**4.8**	4.0	5.6	7.5
				Seymour		
Flow rate (megalitres/day)	**15,000**	**20,000**	**30,000**	24,850	40,000	81,310
e.g. Gauge height (m) at Seymour	**3.1**	**3.6**	**4.5**	4.0	5.2	7.0

MDBA = Murray–Darling Basin Authority

[1] Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

The flows that constraints work is looking at occurred more frequently in the past. The hydrographic record shows that flows around the minor flood level have happened more than 15 times since 1979. They are therefore not an unusual type of flow. People in the region are already managing through flow events of this size at least every few years.

What these flows look like

Linking a gauge reading at Seymour with the actual flow downstream is not always accurate, because of the effect of tributaries inflows and localised rainfall run-off. To assist MDBA to understand how landholders and community assets could be affected by different flows, flow footprint maps were developed to help visualise the flows.

Flow footprint maps were created using hydraulic models to show how flows of different sizes move down the river and spread across the landscape. Flow footprint maps let you look at what is likely to get wet for different-sized river flows.

When interpreting the maps, it is important to bear in mind that they are from a model of a generalised event, not a real event. Therefore, some caution should be used when interpreting the ‘typical flow’ footprints presented in this report. They are not intended to mimic real flow events, but to be an initial representation of what could get wet for a flow of a particular size.

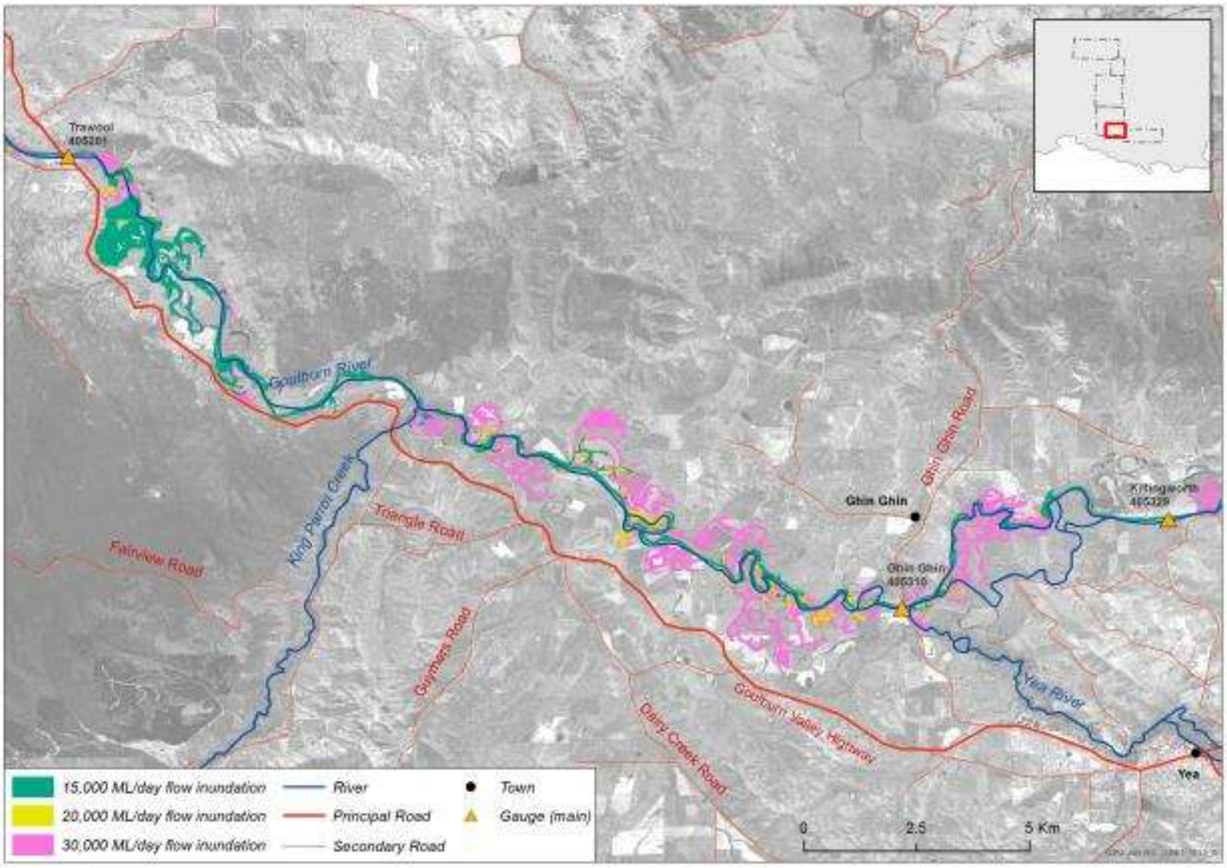
Figures 28a and b show flow footprint maps for 15,000, 20,000 and 30,000 ML/d flows downstream of Killingworth to near Mitchellstown.

The maps show a number of river flats and anabranches being inundated downstream of Ghin Ghin Bridge towards Trawool. Downstream of Trawool and past Seymour, a much smaller area of river flats and anabranches are inundated. This is because the channel capacity of the Goulburn River increases as you move downstream.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although the 20,000 ML/d flow footprint may be somewhat underestimated.

Due to modelling assumptions, the maps did not capture the possible effect of the tributaries backing up (not being able to drain freely due to high Goulburn River levels). If work in the Goulburn proceeds, then additional modelling of potential inundation of land in tributaries should be included. This is particularly important for Seymour and the effective operation of its stormwater drainage system.

The accuracy of the maps is currently limited by the amount of data available to calibrate the hydraulic model. Mapping accuracy is particularly an issue for the mid-Goulburn, as calibration data were limited. The maps should therefore be viewed as a first estimate, with more accurate mapping required.



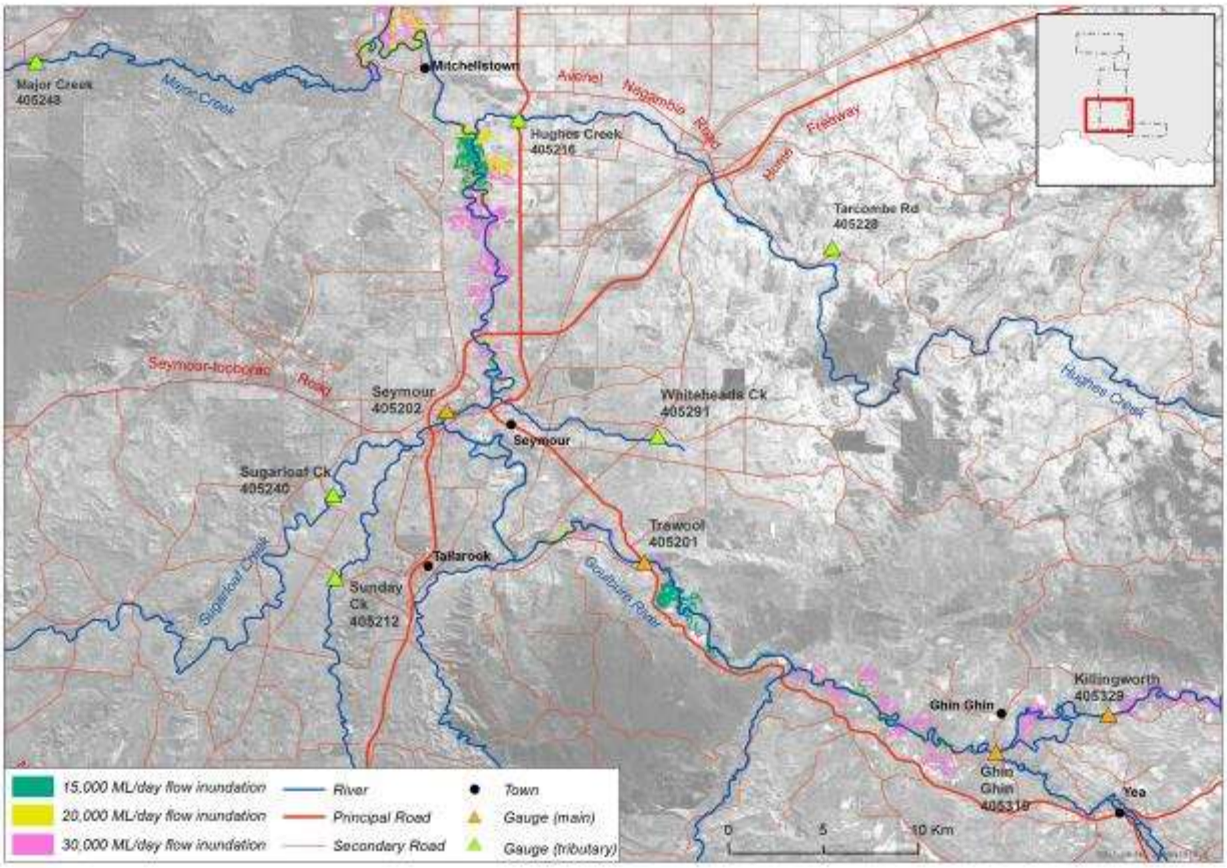


Figure 28 a and b Flow footprints for flows of 15,000, 20,000 and 30,000 megalitres (ML)/day between Killingworth and Mitchellstown

Tributaries

The tributaries in the Goulburn have different characteristics and therefore different effects on the flow of the main Goulburn stem. Water Technology analysed historical flow data in the Goulburn River and its tributaries to provide a general, though incomplete, understanding of the tributaries in the Goulburn catchment. This information is summarised for each tributary below.

Yea River

The Yea River has a catchment area of 360 km^2. The catchment includes the Murrindindi River, which is a tributary to the Yea River. The Yea has one gauge at Devlins Bridge, but located a considerable distance upstream from the confluence with the Goulburn River (over 20km). This gauge has 30 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 476 ML/d (Figure 29). The Yea contributes 6.3% of the flow measured at Trawool. The 'peakiness' ratio value of the catchment is 8.52.

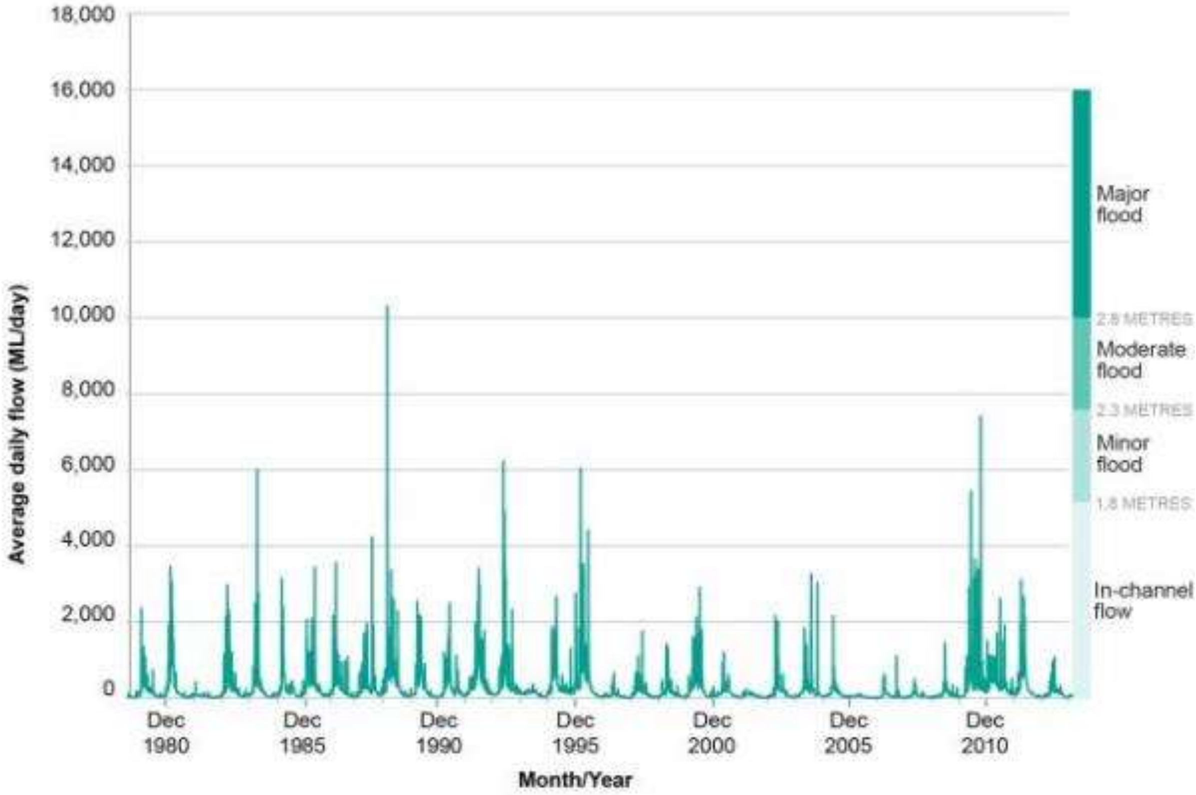


Figure 29 Average daily water flow at Devlins Bridge, 23 km south of Yea (gauging station 405217), December 1980 – December 2013

King Parrot Creek

King Parrot Creek has a catchment area of 181 km^2. The creek has one gauge at Flowerdale. This gauge has 29 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 165 ML/d (Figure 30). King Parrot Creek creek contributes 2.2% of the Goulburn flow at Trawool. The 'peakiness' ratio value of the catchment is 11.09.

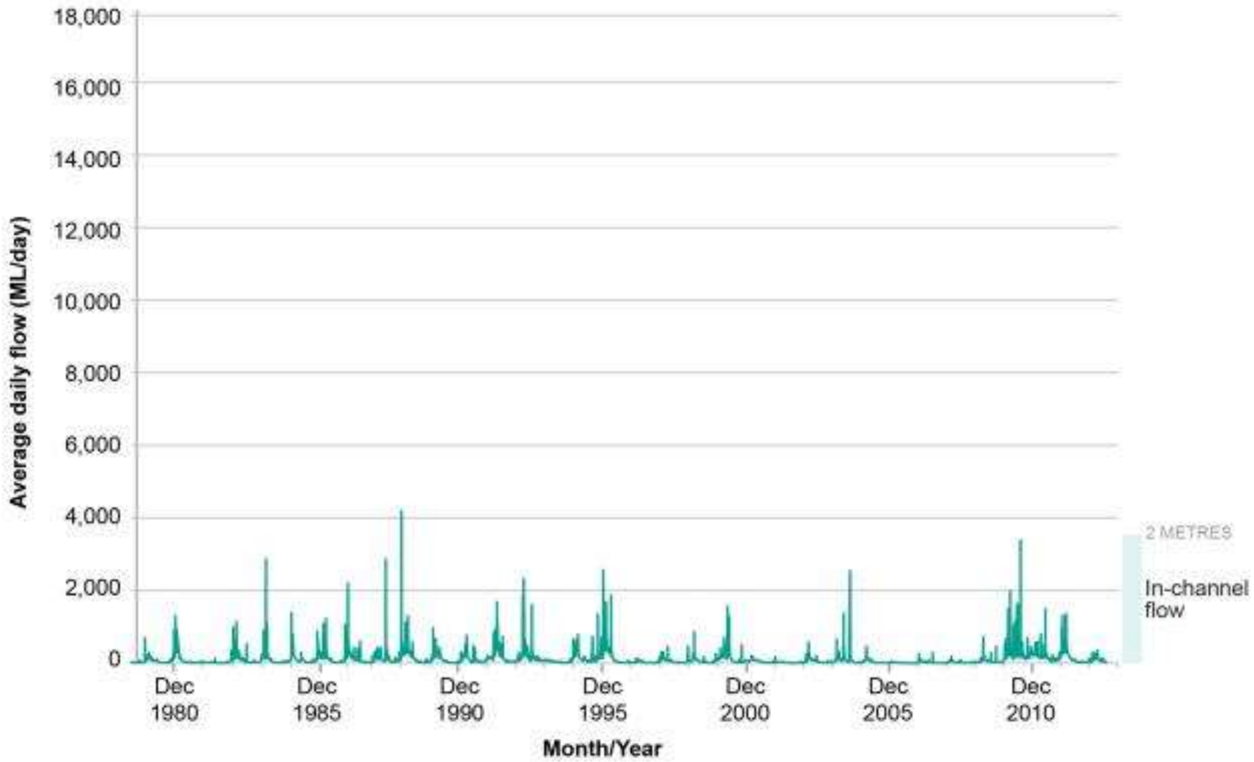


Figure 30 Average daily water flow in King Parrot Creek at Flowerdale (gauging station 405231), December 1980 – December 2013

Sunday Creek

Sunday Creek has a catchment area of 337 km^2. The catchment includes Sugarloaf Creek, which is a tributary to Sunday Creek. The creek has one gauge at Tallarook. This gauge has 45 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 173 ML/d (Figure 31). The 'peakiness' ratio value of the catchment is 32.73. It has a low baseflow index, typical of the more intermittent flow regime of the tributaries in the lower part of the mid-Goulburn towards Goulburn Weir (0.29).

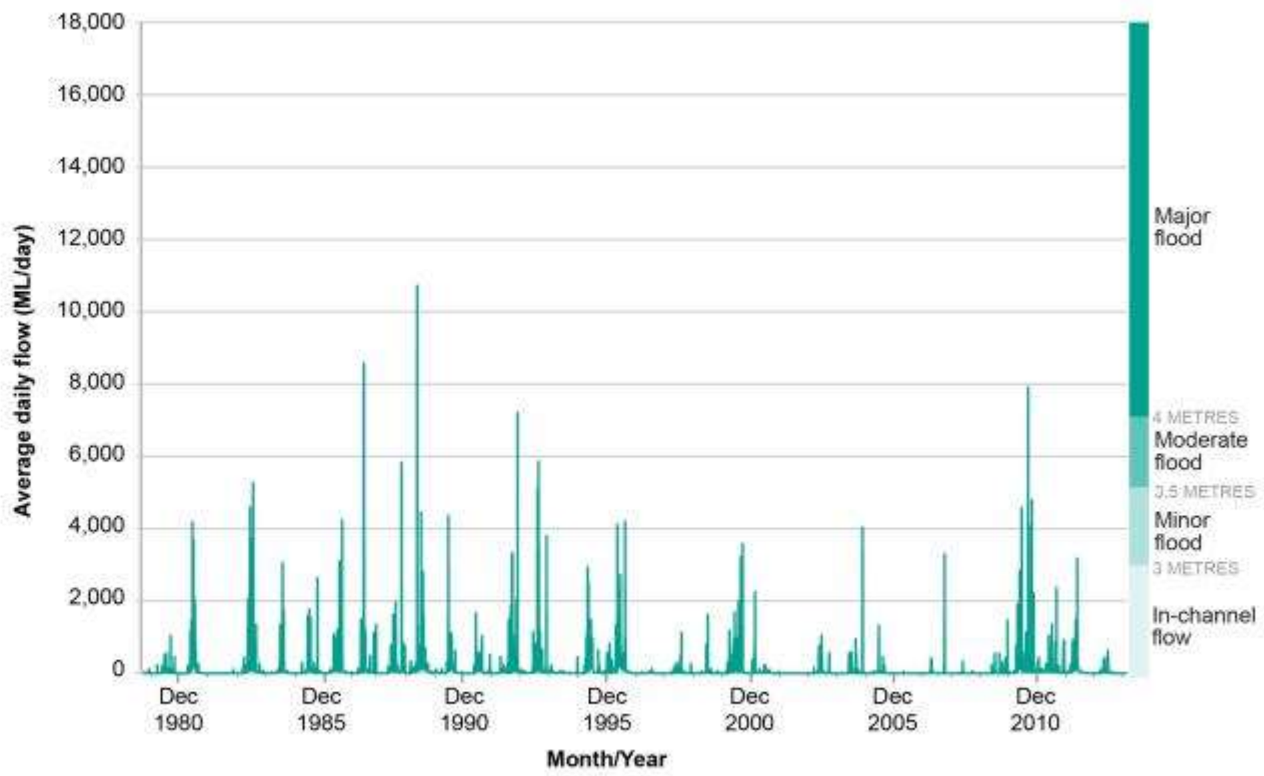


Figure 31 Average daily water flow in Sunday Creek at Tallarook (gauging station 405212), December 1980 – December 2013

Sugarloaf Creek

Sugarloaf creek is a tributary to Sunday Creek. Sugarloaf Creek has a catchment area of 609 km^2. The creek has one gauge at Ash Bridge. This gauge has 33 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 331 ML/d (Figure 32). The 'peakiness' ratio value of the catchment is 39.99.

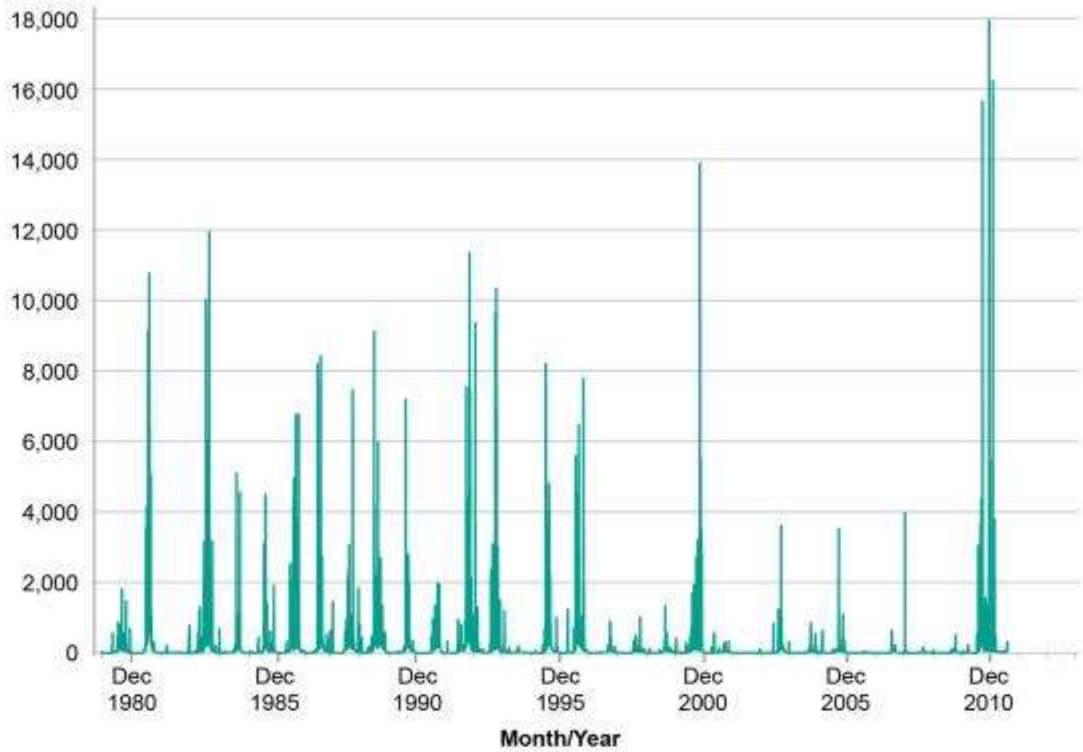


Figure 32 Average daily water flow in Sugarloaf Creek at Ash Bridge (gauging station 405240), December 1980 – December 2013

Whiteheads Creek

Whiteheads Creek has a catchment area of 51 km^2. The creek has one gauge at Whiteheads Creek. This gauge has 16 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 46 ML/d (Figure 33). The 'peakiness' ratio value of the catchment is 20.04.

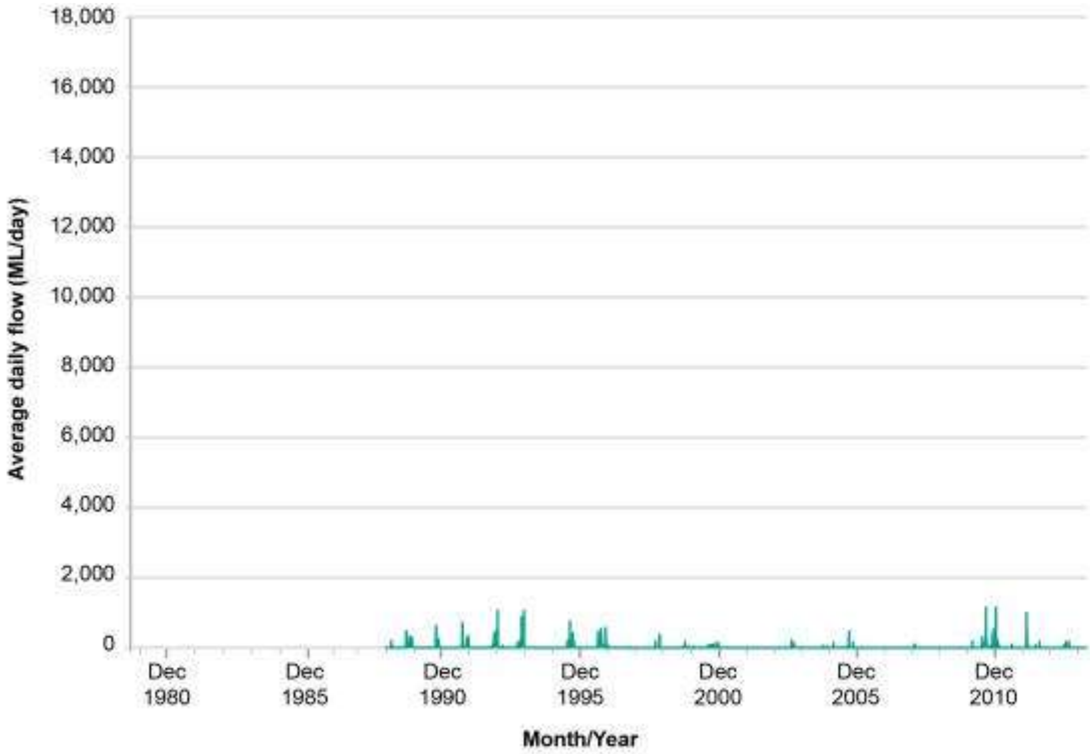


Figure 33 Average daily water flow in Whiteheads Creek (gauging station 405291), December 1980 – December 2013

What could be affected by these flows

The following information about what might happen at different river levels is a guide only. Information has been sourced from community feedback, local flood guides and council reports, where available.

Below minor flood level — examples of areas affected by overbank flows below minor flood level include:

- localised flooding in some low-lying rural paddocks.

Minor flood level — examples of areas affected by overbank flows around minor flood level include:

- localised flooding in rural paddocks
- Goulburn River Caravan Park, Seymour, starts to flood
- river frontage at Seymour starts to experience localised flooding, especially between Kings Park and the old Hume Highway
- Seymour stormwater drainage starts to be affected.

What the community thinks about the suggested flows

Initial feedback from landholders suggests that flows up to **20,000 ML/d** may be a tolerable level of inconvenience flooding. This is subject to stormwater drainage issues at Seymour being addressed, as well as any inundation of private land.

The flow footprint up to 20,000 ML/d, nearing minor flood level, could be created by releases from Eildon with no tributary inflows, tributary flows on their own, or a mix of tributary flows and Eildon releases.

Local councils and landholders in this region provided a number of other key points in relation to considering any change to regulated river flows.

> *Drainage is the main issue for Seymour. Whiteheads Creek flows right through the town. When the Goulburn River is running high, Whiteheads Creek cannot drain freely into the Goulburn and ends up backing up the creek. Problems with Whiteheads Creek and stormwater drainage start at around minor flood level.*

> *When river flats get inundated by the river, it takes time for the silt to be washed from the pasture so that cattle will eat it again. This changes how and when paddocks can be rotated and used, and therefore directly affects the fattening of cattle.*

> *River flows can wash away fertiliser applications and bring in weed species. This means extra cost and time to farmers to re-apply fertilisers and manage weeds.*

> *Mitchell Shire Council is in the process of developing designs to build a flood levee around Seymour. The levee will provide flood protection to the township for flows much higher than the minor flood level that the Constraints Management Strategy is considering.*

Mitchellstown to Kialla

At a glance

The flow footprints constraints work is investigating are 25–40,000 megalitres/day (ML/d) between Mitchellstown and Kialla (e.g. 7.9–9.5 m at Murchison gauging station 405200, around the minor flood level). Flow footprints higher than 40,000 ML/d are not being investigated (e.g. flows greater than 9.5 m at Murchison, gauging station 405200). The overbank flows that constraints work is looking at occurred more frequently in the past.

Feedback from local councils and landholders was that the flow footprint maps looked about right; however, feedback was limited. MDBA encourages other residents to review the maps to check their accuracy and identify any inundation effects we may be missing.

There has not been enough communication of the flow footprint maps for MDBA to be able to determine if there is any tolerable level of inconvenience flooding and what mitigation measures are required in this subreach. The flow footprints between 20,000 and 30,000 ML/d at Nagambie, and 25,000 and 40,000 ML/d at Murchison could be created by releases from Eildon Dam in combination with unregulated tributary flows.

Reach characteristics

This subreach flows from Mitchellstown to Kialla just upstream of Shepparton (Figure 34). The townships of Nagambie and Murchison are located in this part of the Goulburn. Four unregulated creeks contribute flows to the Goulburn River: Hughes Creek upstream of Mitchellstown, Major Creek, Pranjip Creek and Castle Creek.

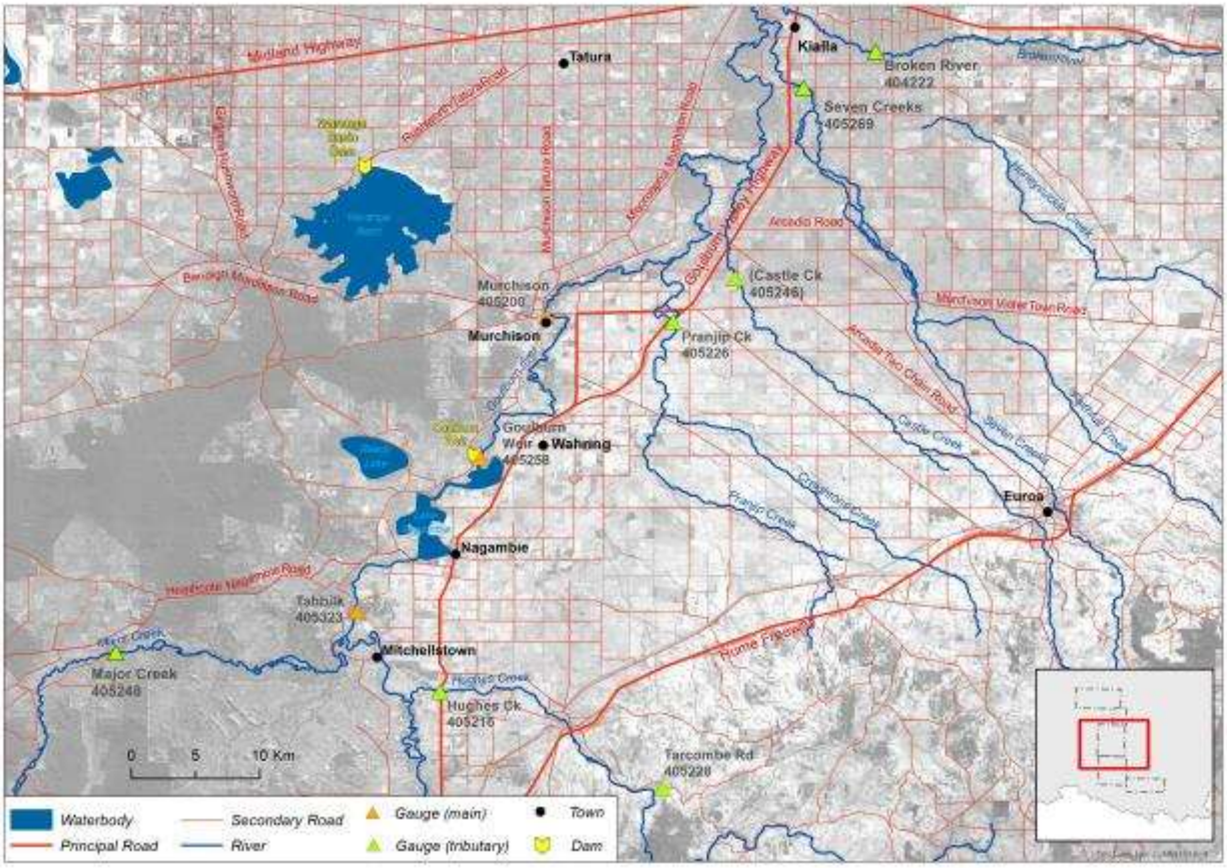


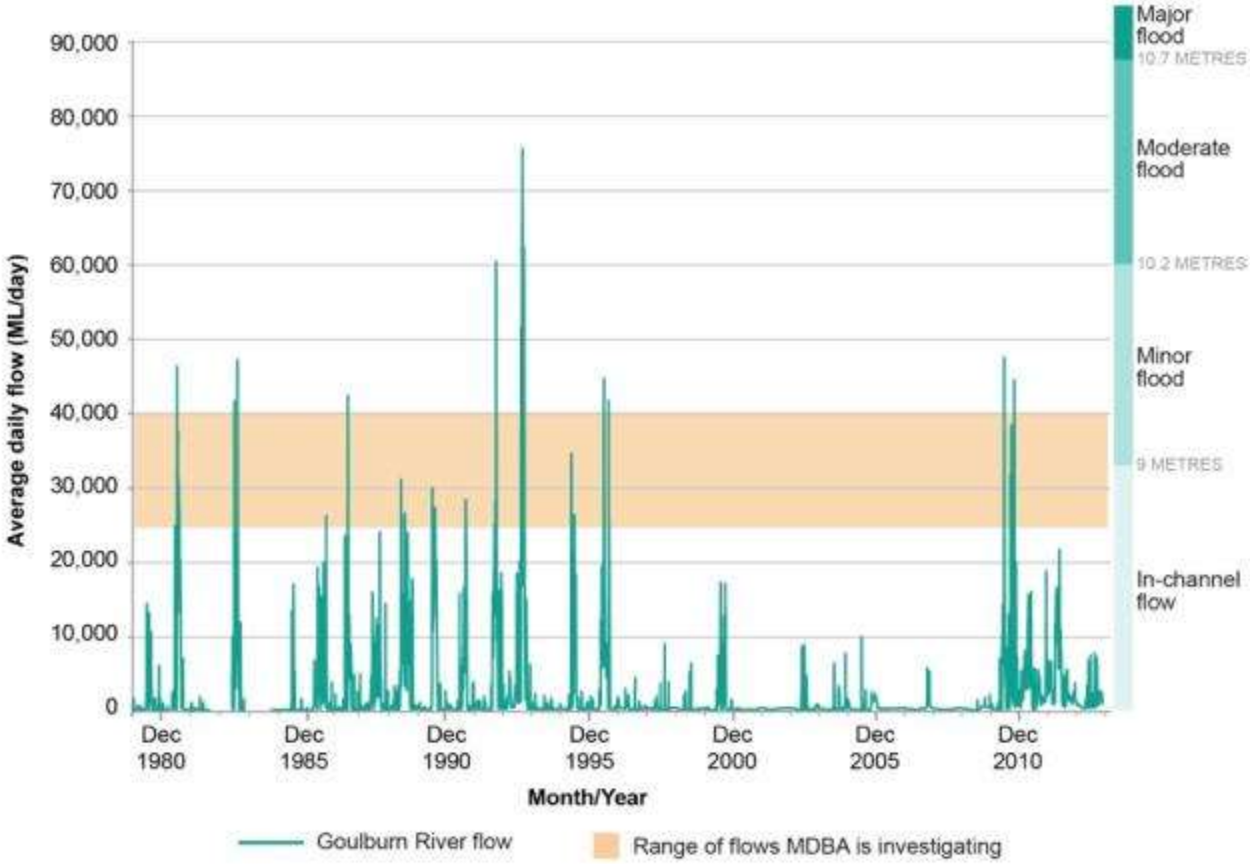
Figure 34 Mitchellstown to Kialla subreach

This subreach includes Goulburn Weir, which is an important mid-river regulating structure approximately 235 kilometres downstream of Eildon Dam. Water is diverted at Goulburn Weir to the large off-stream storage Waranga Basin for irrigation, and stock and domestic purposes (Cattanach canal and Stuart Murray canal). Water is also diverted through the East Goulburn main channel to supply the Shepparton Irrigation Area. Goulburn Weir forms Lake Nagambie, which is a significant recreation site and also supplies local farming and residential water needs. The waterways of Lake Nagambie are popular with locals and tourists for boating activities, fishing, swimming, cycling, walking, hunting and camping. Major sporting events are held every year, including rowing regattas and waterskiing.

Goulburn Weir is usually held at close-to-full capacity to keep water levels high, so that water can be diverted via gravity along the three irrigation canals.

Goulburn–Murray Water operates Goulburn Weir primarily for water supply to customers. Although operational decisions, including water levels and release patterns do consider effects on recreational users in Lake Nagambie, the primary consideration is to supply water entitlement holders. The entitlement holders primarily fund the storage operation and maintenance cost of Goulburn Weir.

There is one flood gauge in this subreach (at Murchison) that is used by the Bureau of Meteorology for flood forecasting purposes. The river flows recorded at the Goulburn River gauge at Murchison between 1979 and 2013 can be seen in Figure 35.



MDBA = Murray–Darling Basin Authority; ML = megalitre

Note: The shaded box outlines the range of flows that MDBA is investigating (25–40,000 ML/day).

The flood categories (minor, moderate and major floods) are as defined by the Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 35 Flows in the Goulburn River at the Murchison gauge, 1979–2013

Previous major floods at Murchison occurred in 1974 and 1975, with flows well above 100,000 ML/d. As can be seen from Figure 35, moderate flooding at Murchison has occurred twice since 1979, with the most recent event in September 1993. In 1993, flood levels peaked at 10.6 m, flowing at more than 80,000 ML/d. These historical data are presented in Table 10, together with examples of smaller minor flood events that are around the size of flows constraints work is looking into. A range of flows has been provided as background context for the river levels that people have experienced first-hand. Many are far larger and more damaging than the flows constraints work is investigating; they are not the aim of this Strategy. Some of the smaller historical events are also included in Table 10 that are in the range of the managed overbank flows being investigated. This is so people can think about the types of effects that have occurred at flows of these sizes.

Table 10 Example recorded flows for Goulburn River at Murchison (gauging station 405200)

Flood class	Date	Gauge height (m)	Flow (megalitres/day)	Is constraints work considering these sorts of flows?
Major	19 September 1975	12.29	382,112	No
Major	17 May 1974	11.29	142,269	No
Moderate	21 September 1993	10.57	80,229	No
Minor	7 September 2010	9.94	50,217	No
Minor	16 January 2011	9.77	45,807	No
Minor	11 June 1995	9.27	36,158	Yes
Below minor	24 September 1991	8.46	28,543	Yes

What flows are being considered

Constraints work is investigating flow rates of between 25,000 and 40,000 ML/d (e.g. 7.9–9.5 m at the Murchison gauge, station 405200) (Table 11 and as indicated by the shaded box on Figure 35).

These would be overbank flows up to around the minor flood level range. At below minor flood level, river levels are not high enough to trigger emergency management or flood warnings from the Bureau of Meteorology. At minor flood level flows, there is some inconvenience. Low-lying areas next to rivers and creeks start to get inundated, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged (see also 'What is the Constraints Management Strategy?').

Constraints work is **not** considering flows at moderate or major flood levels. Flows significantly higher than the minor flood level are damaging and disruptive, and outside the bounds of active river management. Constraints work is collecting information about what effects river flows have at different places along the Goulburn River, but only flows up to the minor flood level range.

Table 11 Comparison of flows footprints for the Mitchellstown to Kialla subreach and flood categories at the Murchison gauge

Measure	Flow footprints being looked at for the Mitchellstown to Kialla subreach (that include the flow contribution of tributaries)			Murchison gauge, Minor flood level[1]	Murchison gauge, Moderate flood level[1]	Murchison gauge, Major flood level[1]
Flow rate (megalitres/day)	**25,000**	**30,000**	**40,000**	33,130	60,410	89,280
e.g. Gauge height (m) at Murchison	**7.9**	**8.6**	**9.5**	9.0	10.2	10.7

[1] Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

The range of overbank flows that constraints work is looking at occurred more frequently in the past. Although Goulburn Weir provides a small amount of flood mitigation capacity (limited operating range due to needing to be kept at near full supply level), the hydrographic record shows that flows in the range that constraints is investigating have occurred almost 10 times since 1979. They are the type of flow that people in the region may have experienced in recent years (e.g. flows less than the 45,807 ML/d in January 2011).

What these flows look like

Linking a gauge reading at Murchison with the actual flow upstream or downstream is not always accurate, because of the effect of tributaries inflows and localised rainfall run-off. To assist MDBA to understand how landholders and community assets could be affected by different flows, flow footprint maps were developed to help visualise the flows.

Flow footprint maps were created using hydraulic models to show how flows of different sizes move down the river and spread across the landscape. Flow footprint maps let you look at what is likely to get wet for different-sized river flows.

When interpreting the maps, it is important to bear in mind that they are from a model of a generalised event, not a real event. Therefore, some caution should be used when interpreting the 'typical flow' footprints presented in this report. They are not intended to mimic real flow events, but be an initial representation of what could get wet for a flow of a particular size.

Figure 36 shows flow footprint maps for 20,000 and 30,000 ML/d (includes Lake Nagambie), and Figure 37 shows flow footprint maps for 25,000, 30,000 and 40,000 ML/d (includes Murchison).

The maps show that Lake Nagambie is not really affected by 20,000 and 30,000 ML/d flows, with little change to the area that gets wet. There is, however, inundation upstream near Mitchellstown in the network of wetlands in the Tahbilk Lagoon Conservation Reserve. Further work is needed to determine if water in the Tahbilk lagoons has any effect on limiting access for private landholders, as well as access by visitors to a number of significant wineries nearby.

Downstream of Goulburn Weir, flows from 25,000 to 40,000 ML/d steadily increase the area of near-riverbank land that gets wet. Most of this is native vegetation in streamside reserves along the Goulburn River. The township of Murchison is not affected by the range of flow footprints that constraints work is investigating. However, low-lying properties, farmland, fishing spots and camping areas may start to be affected at the flows we are looking at.

Feedback from local councils and landholders was that the flow footprint maps looked about right. However, the number of people from this area who have viewed the flow footprint maps is quite limited. MDBA encourages other residents to review the maps to check their accuracy and identify any inundation effects we may be missing.

Due to modelling assumptions, the maps did not capture the possible effect of the tributaries backing up (not being able to drain freely due to high Goulburn River levels). If work in the Goulburn proceeds, then additional modelling of potential inundation of land in tributaries should be included.

The accuracy of the maps is currently limited by the amount of data available to calibrate the hydraulic model. The maps should therefore be viewed as a first estimate, with more accurate mapping required.

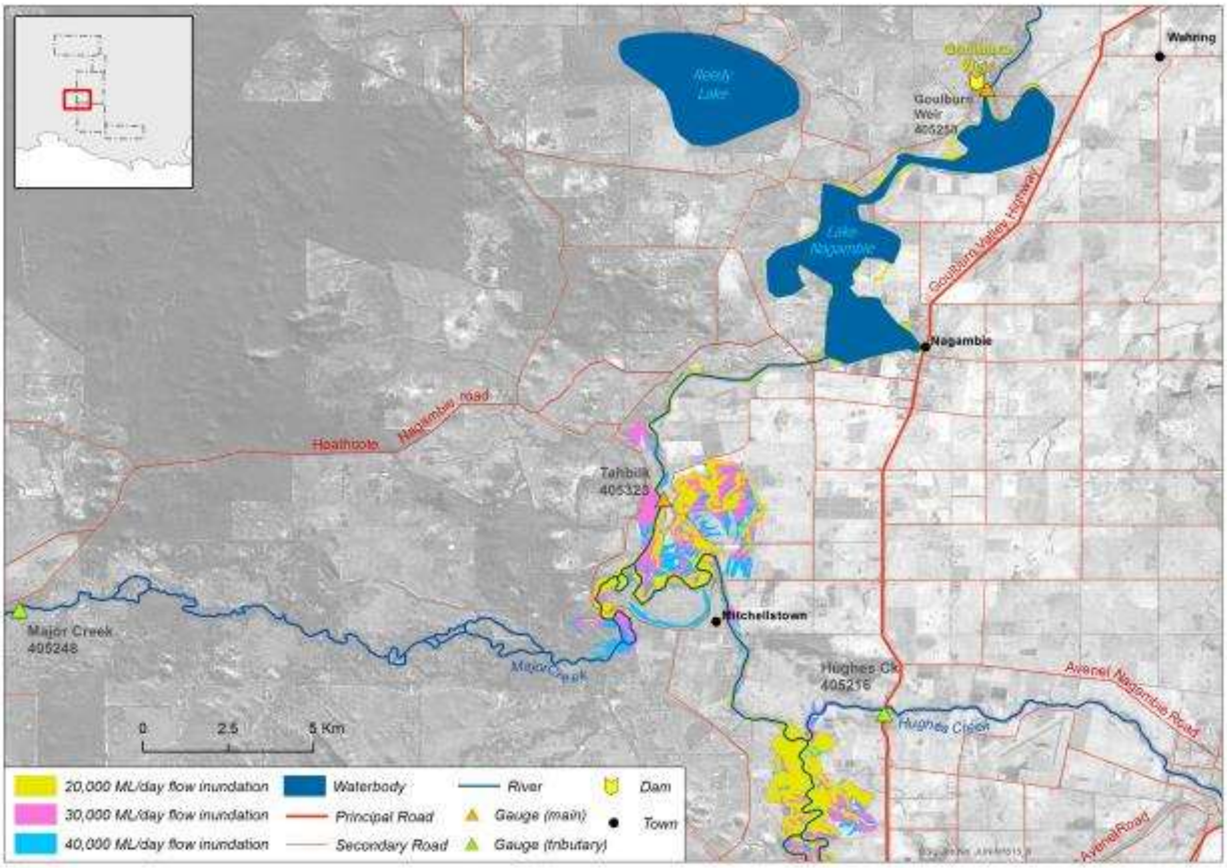


Figure 36 Flow footprints for flows of 20,000, 30,000 and 40,000 megalitres (ML)/day between Mitchellstown and Wahring

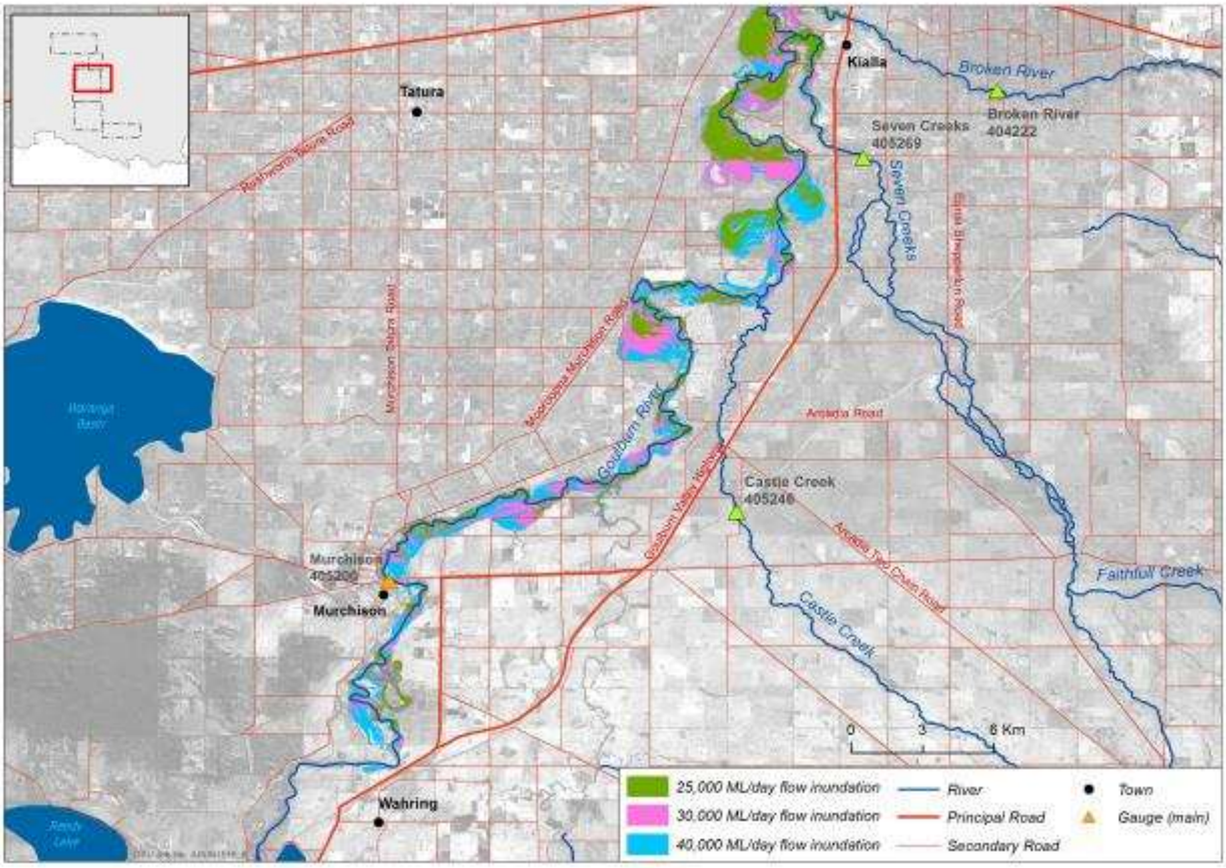


Figure 37 Flow footprints for flows of 25,000, 30,000 and 40,000 megalitres (ML)/day between Wahring and Kialla

Tributaries

The tributaries in the Goulburn have different characteristics and therefore different effects on the flow of the main Goulburn stem. Water Technology analysed historical flow data in the Goulburn River and its tributaries to provide a general, though incomplete, understanding of the tributaries in the Goulburn catchment. This information is summarised for each tributary below.

Hughes Creek

Hughes Creek has a catchment area of 471 km^2. The creek has one gauge at Tarcombe Road. This gauge has 29 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 379 ML/d (Figure 38). The creek contributes 5% of the Goulburn flow at Trawool. The 'peakiness' ratio value of the catchment is 21.03.

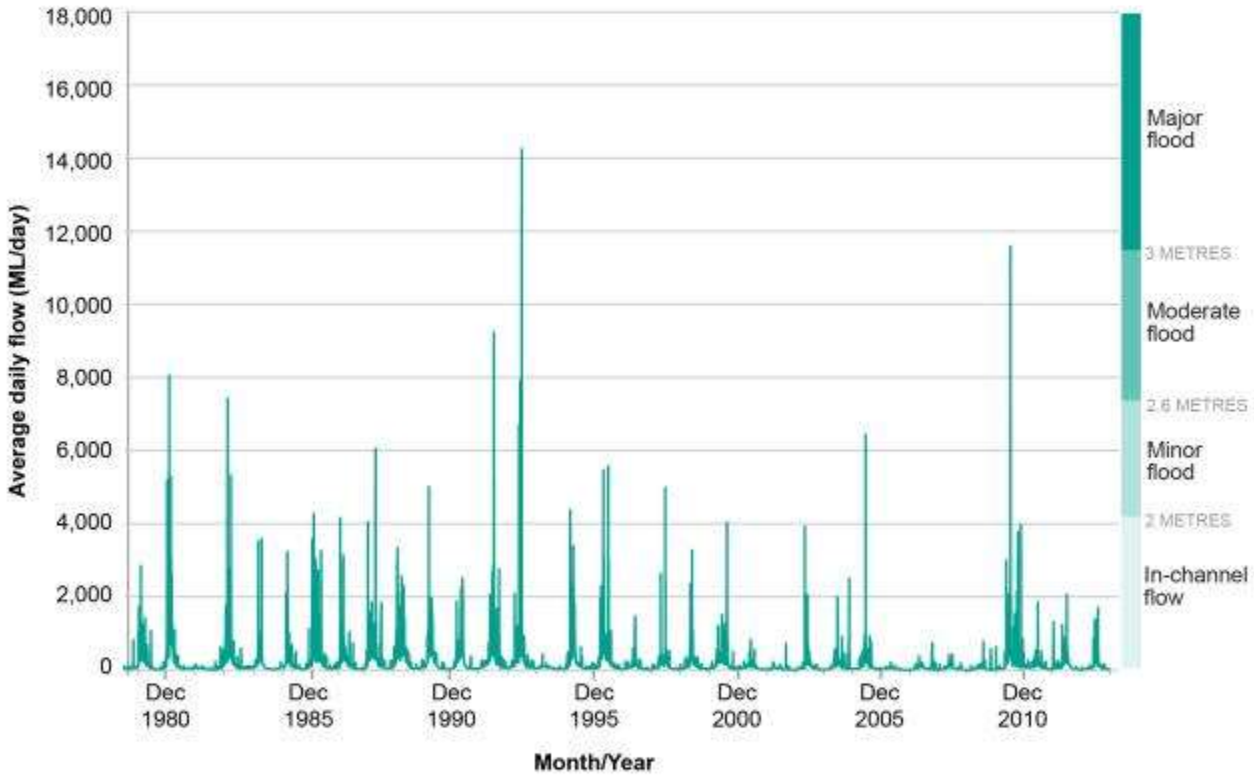


Figure 38 Average daily water flow in Hughes Creek at Tarcombe (gauging station 405228), December 1980 – December 2013

Major Creek

Major Creek has a catchment area of 282 km^2. The creek has one gauge at Graytown. This gauge has 33 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 71 ML/d. The 'peakiness' ratio value of the catchment is 59.19.

Pranjip Creek

Pranjip Creek has a catchment area of 787 km^2. The creek has one gauge at Moorilim. This gauge has 32 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 315 ML/d. The 'peakiness' ratio value of the catchment is 10.33.

Castle Creek

Castle Creek has a catchment area of 164 km^2. The creek has one gauge at Arcadia. This gauge has 33 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 75 ML/d. The 'peakiness' ratio value of the catchment is 15.53.

What could be affected by these flows

The following information about what might happen at different river levels is a guide only. Information has been sourced from community feedback, local flood guides and council reports, where available.

Below minor flood level — examples of areas affected by overbank flows below minor flood level include:

- localised flooding in some low-lying rural paddocks.

Minor flood level — examples of areas affected by overbank flows around minor flood level include:

- localised flooding in rural paddocks
- closure of some local roads and camping and fishing spots north of the Murchison Bridge.

What the community thinks about the suggested flows

There has not been enough communication of the flow footprint maps for MDBA to be able to determine if there is any tolerable level of inconvenience flooding and what mitigation measures are required in this subreach.

Flows of between 20,000 and 30,000 ML/d at Nagambie, and 25,000 and 40,000 ML/d at Murchison could be created by releases from Eildon Dam in combination with unregulated tributary flows. Tributary flows passing down the river could also potentially be topped up by temporarily stopping the transfer of water into Waranga Basin and allowing it to continue to move downstream of Goulburn Weir (noting that this would be outside of the irrigation season and that environmental water entitlements held in Eildon Dam would still be debited for any water used this way).

Limited MDBA consultation to date has provided some other key points in relation to considering any change to regulated river flows.

> *Many pumps are not far above summer irrigation flow levels. Moving pumps can be very difficult. Pumps are situated close to the river to maximise pumping effectiveness*

and efficiency. Often it is more about protecting pumps in situ from being flooded rather than moving them.

Interruption to irrigation pumps is an issue; therefore, the proposed timing of environmental flows is important as well as getting enough advanced warning before they happen.

Kialla to Loch Garry

At a glance

The flow footprints constraints work is investigating are 25–40,000 megalitres/day (ML/d) between Kialla and Loch Garry (e.g. 9.4–10.3 m at Shepparton, gauging station 405204, around the minor flood level). Flow footprints higher than 40,000 ML/d are not being investigated (e.g. flows greater than 10.3 m at Shepparton gauging station 405204). The overbank flows that constraints work is looking at occurred more frequently in the past.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although they probably overestimate the Shepparton flow footprint at 40,000ML/d.

Initial feedback from landholders suggests that flow footprints up to 30,000 ML/d at Shepparton (9.8 m) may be a tolerable level of inconvenience flooding. This is subject to suitable mitigation measures being in place (e.g. improved roads and drainage, reliable level of rural levee protection). The flow footprint of flows between 25,000 and 30,000 ML/d, around minor flood level, could be created by releases from Eildon and/or Goulburn Weir in combination with tributary flows.

Reach characteristics

This subreach flows from Kialla just below Shepparton to Loch Garry near Bunbartha (Figure 39). Mooroopna and Shepparton are located in this part of the Goulburn. Two unregulated tributaries contribute flows to the Goulburn River: the Broken River and Seven Creeks.

There are a number of regionally and nationally significant wetlands around Shepparton–Mooroopna and downstream (e.g. Reedy Swamp Wildlife Reserve, Gemmills Swamp, Mooroopna Common and Loch Garry).

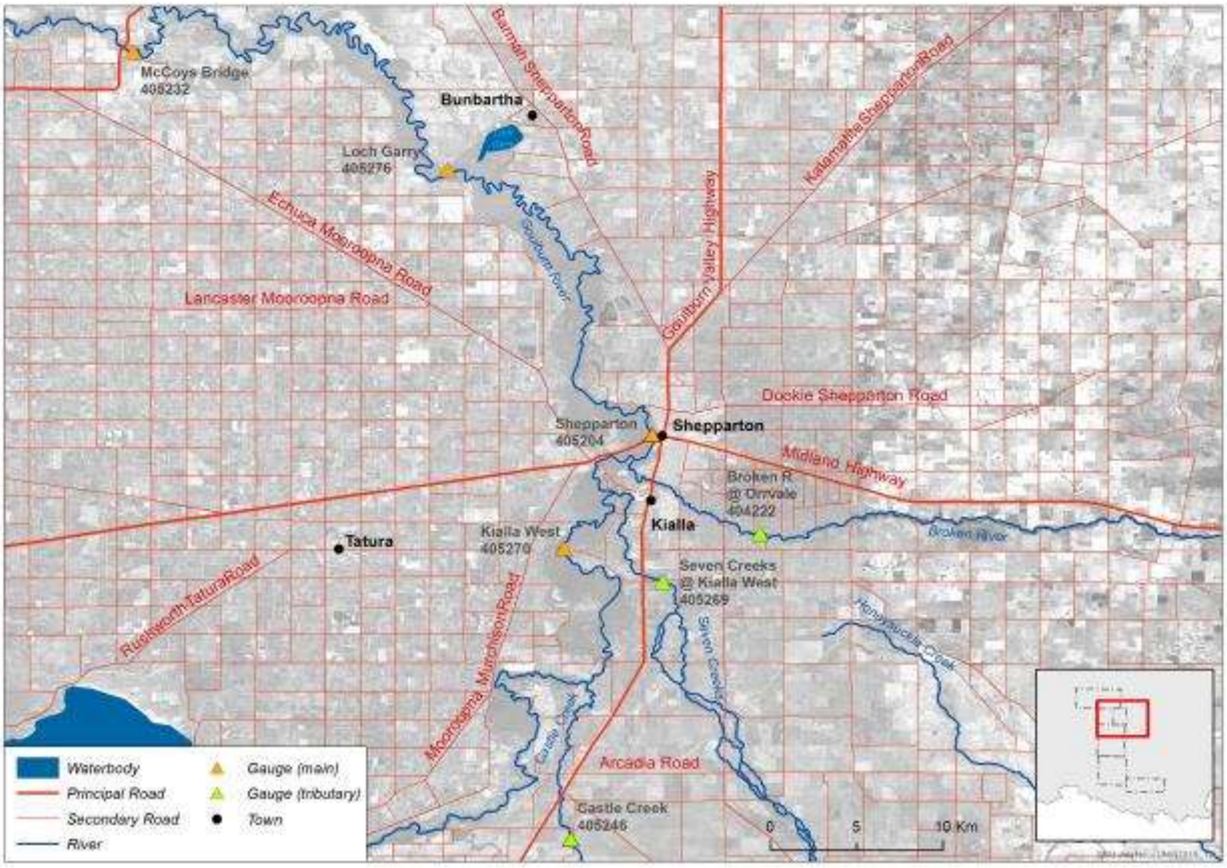
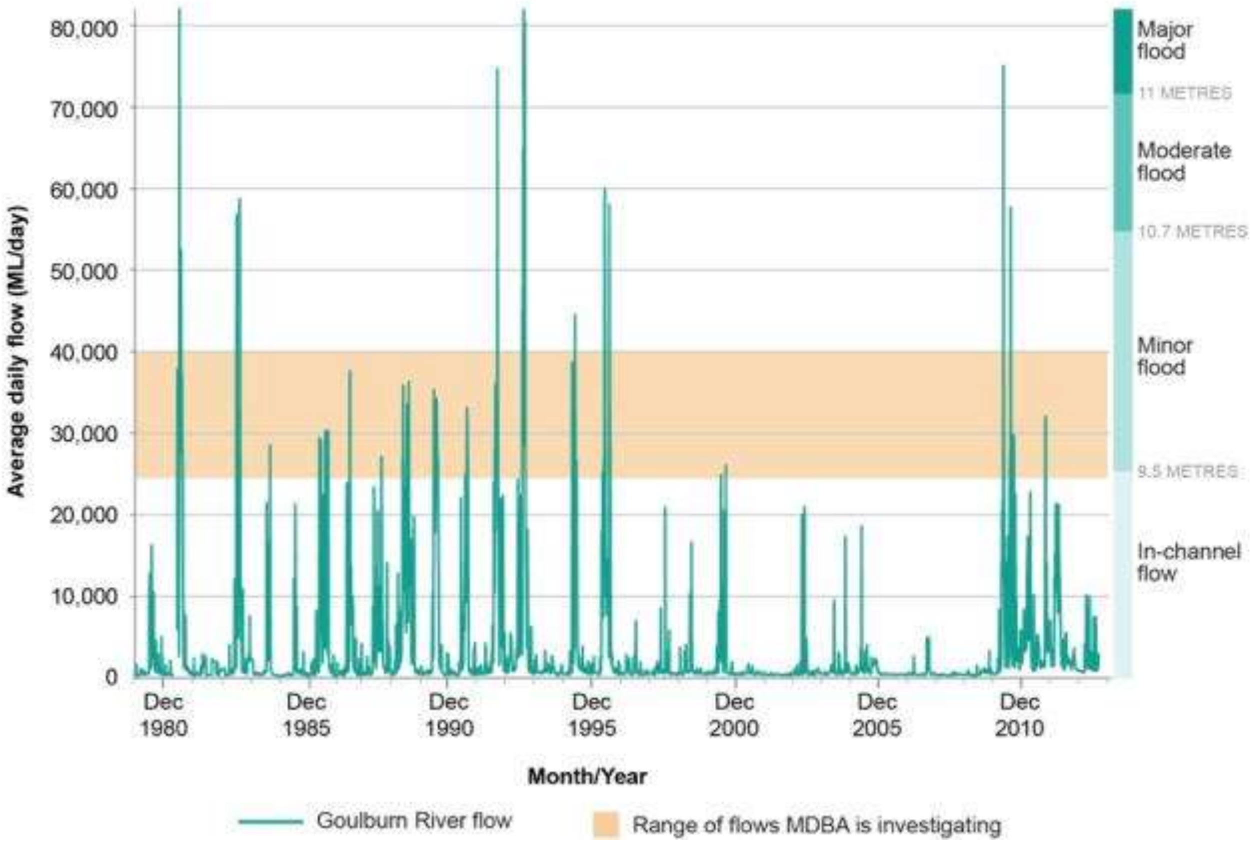


Figure 39 Kialla to Loch Garry subreach

There is one flood gauge situated on the Goulburn River in this subreach (at Shepparton) that is used by the Bureau of Meteorology for flood forecasting purposes. The river flows recorded at the Goulburn River gauge at Shepparton between 1979 and 2013 can be seen in Figure 40.



MDBA = Murray–Darling Basin Authority; ML = megalitre

Note: The shaded box outlines the range of flows that MDBA is investigating (25–40,000 ML/day).

The flood categories (minor, moderate and major floods) are as defined by the Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 40 Flows in the Goulburn River at Shepparton gauge, 1979–2013

Since the completion of Big Eildon Dam in 1955, major flooding has occurred around the Shepparton–Mooroopna area in 1956, 1958, 1974, 1975, 1981, 1992, 1993 and 2010. These major floods have highlighted that the relative contribution from the Goulburn and Broken rivers, and Seven Creeks can vary significantly, and that the relative contribution from the three catchments can markedly influence flood behaviour in Shepparton–Mooroopna.

The 1974 flood was dominated by the Goulburn River and by the Broken River in 1993. The 2010 flood saw gauges on the Goulburn and Broken Rivers, and Seven Creeks all peak at major flood level.

> *Floods with different volumes of water behind them have very different behaviours — the 1974 flood took 18 hours to get from Shepparton to McCoy Bridge, whereas the*

1993 flood was much slower.
Resident near McCoy Bridge

Historical data are presented in Table 12, together with other examples of moderate and minor flood events. A range of flows has been provided as background context for the river levels that people have experienced first-hand. Many are far larger and more damaging than the flows constraints work is investigating; they are not the aim of this Strategy. Some of the smaller historical events are also included in Table 12 that are in the range of the managed overbank flows being investigated. This is so people can think about the types of effects that have occurred at flows of these sizes.

Table 12 Example recorded flows for the Goulburn River at Shepparton (gauging station 405204)

Flood class	Date	Gauge height (m)	Flow (megalitres/day)	Is constraints work considering these sorts of flows?
Major	17 May 1974	12.08	191,166	No
Major	20 September 1975	11.21	89,632	No
Major	25 July 1981	11.19	87,200	No
Major	23 September 1993	11.18	86,140	No
Major	20 October 1992	11.13	82,433	No
Major	8 September 2010	11.09	78,550	No
Moderate	12 December 2010	10.80	59,617	No
Moderate	5 October 1996	10.77	57,807	No
Minor	6 March 2012	9.96	32,335	Yes
Minor	19 January 2011	9.81	30,097	Yes
Minor	15 November 2000	9.52	26,340	Yes

What flows are being considered

Constraints work is investigating flow rates of between 25,000 and 40,000 ML/d (e.g. 9.4–10.3 m at the Shepparton gauge, station 405204) (Table 13 and as indicated by the shaded box on Figure 40).

These would be overbank flows up to around the minor flood level range. At below minor flood level, river levels are not high enough to trigger emergency management or flood warnings from the Bureau of Meteorology. At minor flood level, there is some inconvenience. Low-lying areas next to rivers and creeks start to get wet, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged (see also 'What is the Constraints Management Strategy?').

Constraints work is **not** considering flows at moderate or major flood levels. Flows significantly higher than the minor flood level are damaging and disruptive, and outside the bounds of active river management. Constraints work is collecting information about what effects river flows have at different places along the Goulburn River, but only up to the minor flood level range.

Table 13 Comparison of flows footprints for the Kialla to Loch Garry subreach and flood categories at the Shepparton gauge

Measure	Flow footprints being looked at for the Kialla to Loch Garry subreach (that include the flow contribution of tributaries)			Shepparton gauge, Minor flood level[1]	Shepparton gauge, Moderate flood level[1]	Shepparton gauge, Major flood level[1]
Flow rate (megalitres/day)	**25,000**	**30,000**	**40,000**	26,000	54,000	72,000
e.g. Gauge height (m) at Shepparton	**9.4**	**9.8**	**10.3**	9.5	10.7	11.0

[1] Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

The flows that constraints work is looking at have occurred in the past. The hydrographic record shows that flows around the minor flood level (staying inside the levees) have happened more than 15 times since 1979. They are therefore not an unusual type of flow. Outside of drought periods, people in the region are already managing through flow events of this size at least every few years.

> *From my memory, there were only a couple of years where floodwaters did not come up to the levee on the floodplain (they were 1968 and 1982). Otherwise, up until 1997 floodwaters came up to the levee every year. Then from 1997 we hit approximately 12 years of drought and it stopped happening.*
> *Long-term resident at Kotupna*

What these flows look like

Linking a gauge reading at Shepparton with the actual flow downstream is not always accurate, because of the effect of tributaries inflows and localised rainfall run-off. To assist MDBA to understand how landholders and community assets could be affected by different flows, flow footprint maps were developed to help visualise the flows.

Flow footprint maps were created using hydraulic models to show how flows of different sizes move down the river and spread across the landscape. Flow footprint maps let you look at what is likely to get wet for different-sized river flows.

When interpreting the maps, it is important to bear in mind that they are from a model of a generalised event, not a real event. Therefore, some caution should be used when interpreting the ‘typical flow’ footprints presented in this report. They are not intended to mimic real flow events, but be an initial representation of what could get wet for a flow of a particular size.

Figure 41 shows a flow footprint map for flows of 25,000, 30,000 and 40,000 ML/d between Kialla and Bunbartha (Loch Garry).

The map shows the wetlands and near-floodplain getting wet around Shepparton and downstream, but largely staying within the protective levee network. This land is mainly river reserves and national park.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although the maps probably overestimate the Shepparton flow footprint at 40,000 ML/d. The maps show the lake near the CMA and Princess Park oval as being wet. However, even in September 2010, the football oval itself didn't connect with the river and that flow was much bigger (up near 90,000 ML/d). In general, the flow footprints look a little overstated.

The accuracy of the maps is currently limited by the amount of data available to calibrate the hydraulic model. The maps should therefore be viewed as a first estimate, with more accurate mapping required.

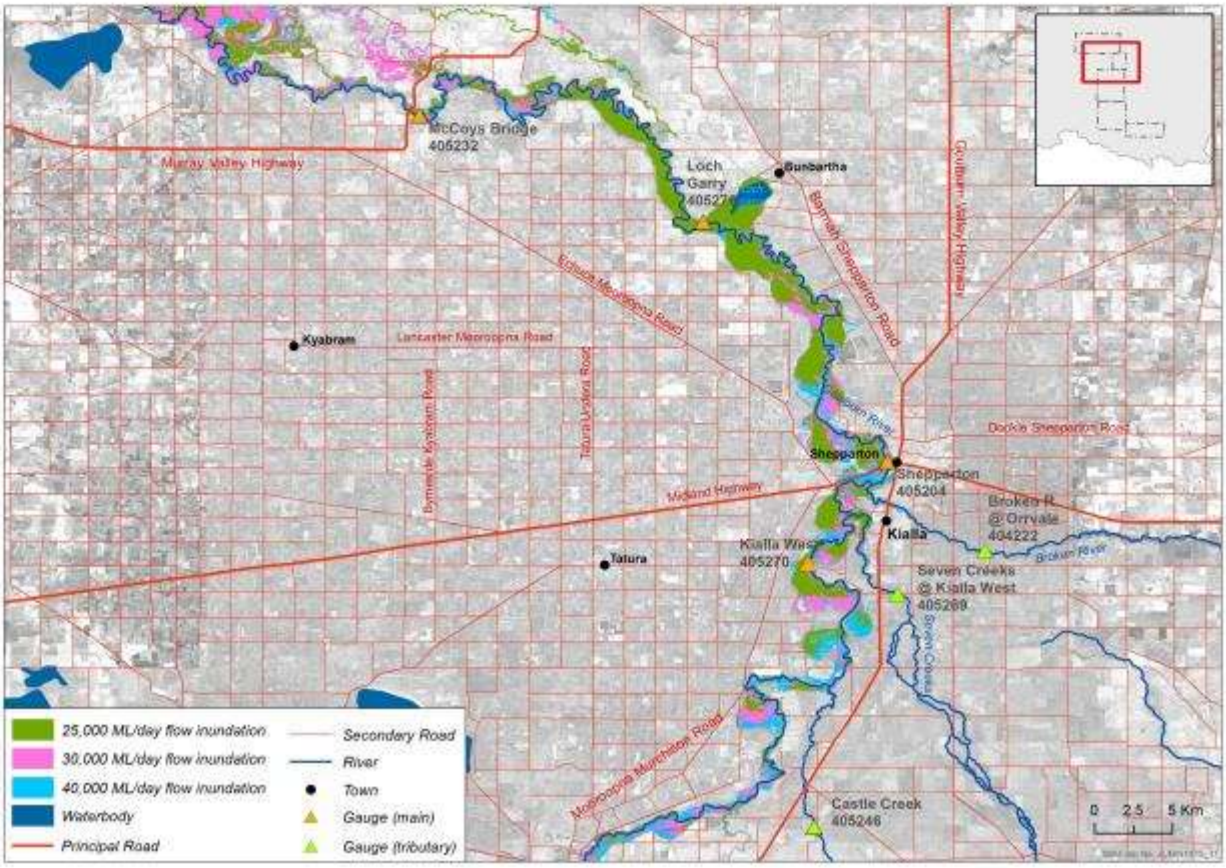


Figure 41 Flow footprints for flows of 25,000, 30,000 and 40,000 megalitres (ML)/day between Kialla and Loch Garry

Tributaries

The tributaries in the Goulburn have different characteristics and therefore different effects on the flow of the main Goulburn stem. Water Technology analysed historical flow data in the Goulburn River and its tributaries to provide a general, though incomplete, understanding of the tributaries in the Goulburn catchment. This information is summarised for each tributary below.

Seven Creeks

Seven Creeks has a catchment area of 1,505 km^2. The creek has one gauge at Kialla West. This gauge has 10 years of instantaneous data, classified as poor, with missing data during high flow periods (due to backwater effects from Goulburn River). The mean daily flow for July–November is 219 ML/d (Figure 42).. The 'peakiness' ratio value of the catchment is 4.90.

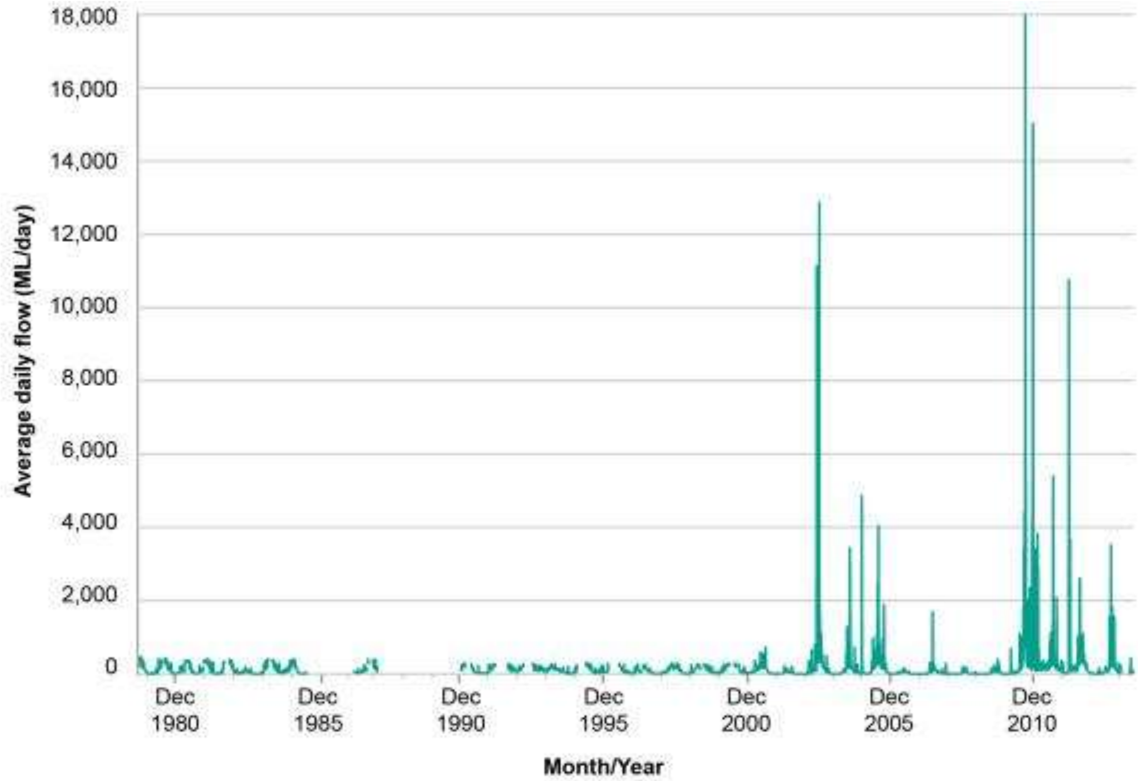


Figure 42 Average daily water flow in Seven Creeks Kialla West (gauging station 405269), December 1980 – December 2013

Broken River

The Broken has a catchment area of 2,508 km^2. The Broken has one gauge at Orrvale which has 25 years of instantaneous data, classified as 'good'. The mean daily flow for July–November is 362 ML/d. The 'peakiness' ratio value of the catchment is 28.32 (Figure 43). Historically flows were affected by large upstream diversions into Lake Mokoan and Broken Creek Systems — Lake Mokoan was decommissioned and returned to natural wetland system as of 2009.

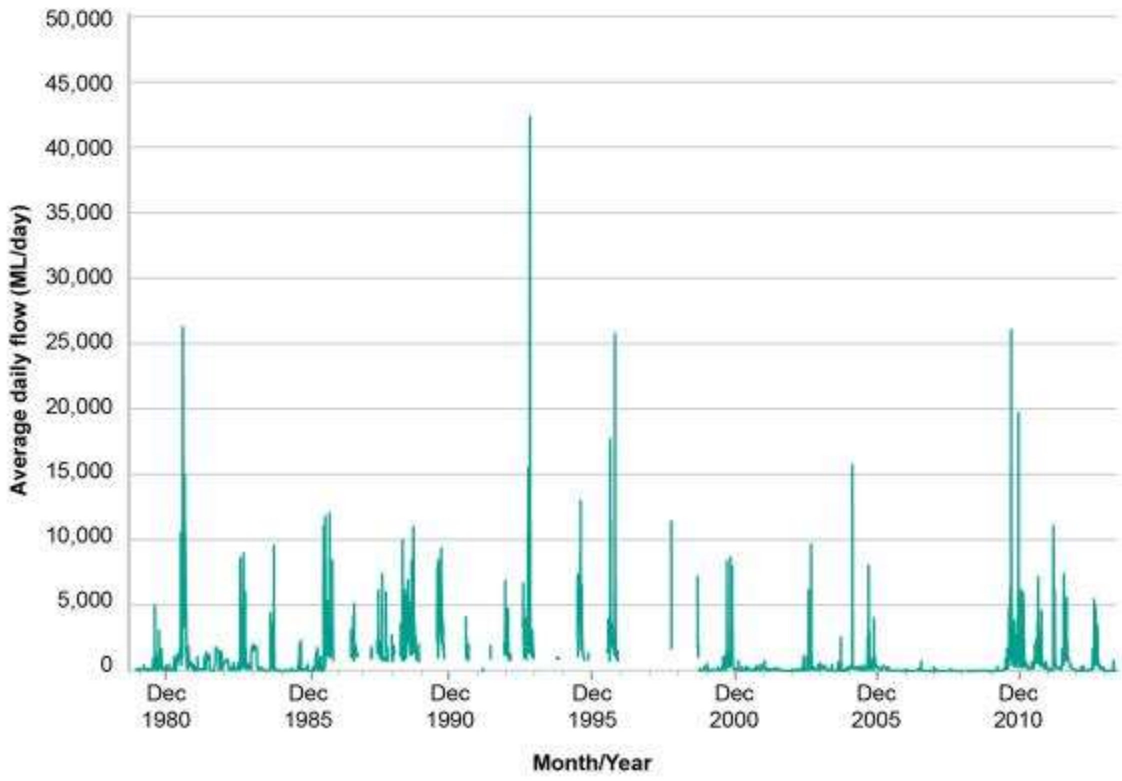


Figure 43 Average daily water flow in Broken River at Orrvale (gauging station 404222), December 1980 – December 2013

What could be affected by these flows

The following information about what might happen at different river levels is a guide only. Information has been sourced from community feedback, local flood guides and council reports, where available.

Below minor flood level — examples of areas affected by overbank flows below minor flood level include:

- localised flooding in some low-lying rural paddocks
- Raftery Road and Watts Road (back road between Shepparton and Mooroopna) is closed when flows are about 18,000 ML/d
- first penstocks closed (at Princess Park north and south, Macguire Road, and Hassett Street)
- Welsford Street pump is turned on when the gauge height reaches 9.15 m.

Minor flood level — examples of areas affected by overbank flows around minor flood level include:

- localised flooding in rural paddocks
- penstock closure or pump operation (Creek St, Kialla Park, the Boulevard, Newton Street)
- Tom Collins Drive at Fitzjohn Road closed and Aquamoves car park affected at around 10.3 m.

What the community thinks about the suggested flows

Initial feedback from landholders suggests that flows up to **30,000 ML/d** may be a tolerable level of inconvenience flooding. This is subject to suitable mitigation measures being in place, such as improving the stormwater drainage system and addressing road access issues.

The flows between 25,000 and 30,000 ML/day, around minor flood level, could be created by releases from Eildon in combination with tributary flows. Tributary flows passing down the river could also be topped up by temporarily stopping the transfer of water into Waranga Basin and allowing it to continue to move downstream of Goulburn Weir (noting that this would be outside of the irrigation season and that environmental water entitlements held in Eildon Dam would still be debited for any water used this way).

Local councils and landholders in this region provided a number of other key points in relation to considering any change to regulated river flows.

Effects

> *The size of flows being considered is well within what the area naturally would have experienced.*

> *Late season (September onwards) and extended duration flows (greater than a week) will increase effects on crops, levees and bank erosion Raised by several residents*

> *There is a risk of more frequent watering leading to an increase in vegetation and bushfire risk — especially now that the national park is no longer grazed.*

> *If an environmental flow came through and it was high enough to trigger pulling the Loch Garry bars, people would be very angry — not only because they would be being flooded and suffering damages and losses, but also because the Loch Garry landholders would be paying for the bars to get pulled.*
> *Several Loch Garry landholders*

> *Duration of water against the levees and river banks is a concern — the longer the levees are wet, the more bank slumping and riverbank slips that you see. If water stays up against the levees for a long time, there are also issues of water seepage through the levees. One farmer has experience of extended 'topping up' of a flow in New South Wales for 21 days — high flows for this long resulted in levee slumping*

and collapse. Sharp and short is okay, but long duration leads to levee weakening, seepage and possible collapse.

Level of general community interest will change at different flows. (i.e. people at Shepparton will be interested as water appears in the floodways), but levels of community concern will increase as water levels increase, especially if water becomes very visible over large areas.

Access

Every flood is different. For example, the difference between the floods of 1973 and 1993 was huge. In 1973, it was very quick to travel between Shepparton and McCoy Bridge, but in 1993 it was much slower.

In a 'normal' year, winter rain prewets the country and one big rain in spring will bring floods.

As soon as the river goes overbank at Shepparton it can be hard for people to access boat ramps. And once the river level drops, they cannot access the foreshore areas for a while due to the wet boggy ground.

During picking season, there are often backpackers camping near the causeway bridge. Riverbank camping is very popular in and around the foreshore area of Shepparton.

There is a cycle path from Shepparton to Mooroopna that runs alongside the causeway (Midland Highway). Once flows close the cycle path then the cyclists are pushed onto the busy causeway. This can be quite dangerous. Also, when the bush under the causeway goes under, all the kangaroos came up onto the causeway and create a traffic hazard.

At 9.5 m at Shepparton (25,000 ML/d), water starts flowing into the Bunbartha/Deep Creek system and this causes concern for many of the landholders, especially if it water gets into Skeleton and Sheepwash creeks for extended durations. Water in the creek networks significantly affects how landholders can access their paddocks/crops and there are also a number of causeways on the smaller creeks that would become impassable.

Management

Is there enough predictability in the system for river operators to be able to top up unregulated flow pulses from the Broken River and Seven Creeks with sufficient confidence to control the peak and duration, and not cause unintended adverse consequences?

What the operators used to do is cut the flooding off really quick and there was lots of bank slumping. Then they started lowering it slower and now we don't see it as such an issue. After a drought followed by a flood then bank slumping is probably unavoidable. This highlights that we should always be monitoring bank slumping and maintaining levees.

Levees have contained and concentrated Goulburn River flows — making flows deeper and faster with more erosion.

Everyone relies on the levees, yet no-one else will contribute to help fix them, and we can't go out and fix them ourselves as there is so much red tape.
Several landholders regarding levee maintenance

The ownership of the levees is so critical. The amount of debates and anxiety about levee maintenance is huge. This needs to be resolved before the community has confidence that they can withstand higher flows. The levees will need to come under someone's responsibility and preferably not landowners.

A range of protective levee concerns include proximity to the outside of river bends, levees right at the top of the riverbank, riverbank slumping and eroding levees. Levee integrity is also being affected by tree growth, lack of vegetation cover, tracks, animal burrows, etc., which create points of weakness.

Loch Garry to the River Murray

At a glance

The flow footprints constraints work is investigating are 25–40,000 megalitres/day (ML/d) between Loch Garry and the River Murray (e.g. 8.7–9.6 m at McCoy Bridge, gauging station 405232, around the minor flood level). Flow footprints higher than 40,000 ML/d are not being investigated (e.g. flows greater than 9.6 m at McCoy Bridge, gauging station 405232). The overbank flows that constraints work is looking at occurred more frequently in the past.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although perhaps a little overstated at flows of 25–30,000 ML/d.

Initial feedback from landholders suggests that flow footprints up to 30,000 ML/d may be a tolerable level of inconvenience flooding. This is subject to suitable mitigation measures being in place (e.g. regulators on levee outlets to control nuisance flooding outside the levee network, reliable level of rural levee protection, and improved roads and drainage). The flow footprint of flows 25–30,000 ML/d, around minor flood level, could be created by releases from Eildon and/or Goulburn Weir in combination with tributary flows.

Reach characteristics

This subreach flows from Loch Garry near Bunbartha to meet the River Murray (Figure 44). There are no tributaries along this stretch of the Goulburn (that contribute flows to the river), but there are a number of effluent creeks (that take flows away from the river) and significant wetlands. Effluent creeks include the Bunbartha–Deep–Sheepwash–Skeleton Creek complex and Wakiti Creek.

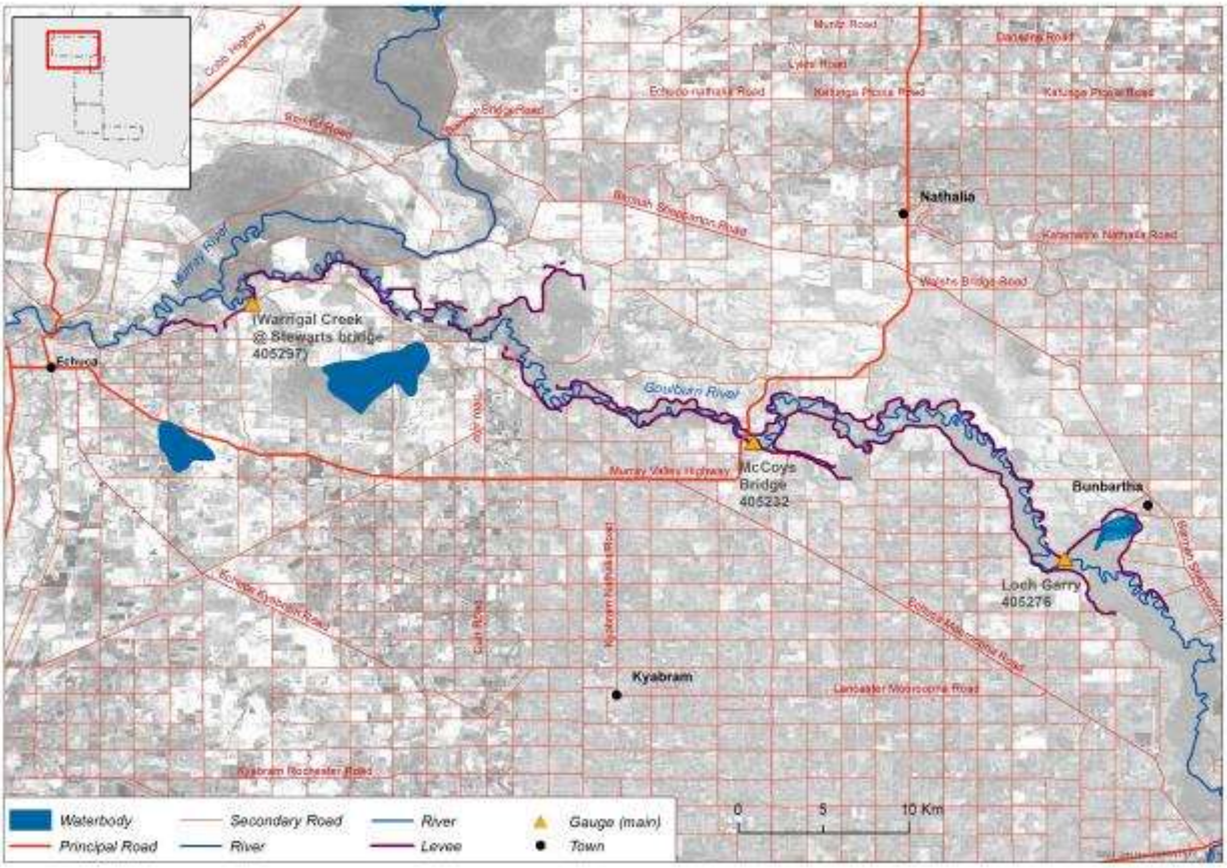
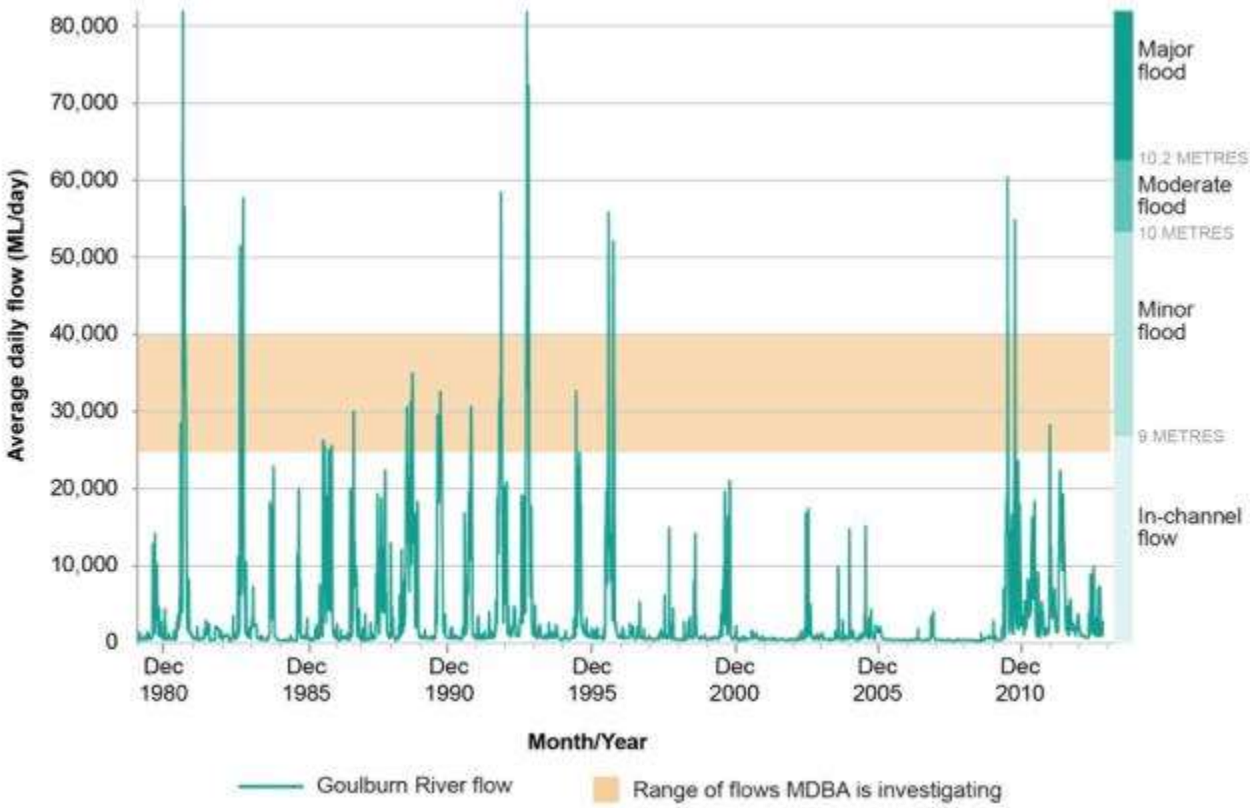


Figure 44 Loch Garry to River Murray subreach

There is one flood gauge in this subreach (at McCoy Bridge) that is used by the Bureau of Meteorology for flood forecasting purposes. The river flows recorded at the Goulburn River gauge at McCoy Bridge between 1979 and 2013 can be seen in Figure 45.



MDBA = Murray–Darling Basin Authority; ML = megalitre

Note: The shaded box outlines the range of flows that MDBA is investigating (25–40,000 ML/day).

The flood categories (minor, moderate and major floods) are as defined by the Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

Figure 45 Flows in the Goulburn River at the McCoy Bridge gauge, 1979–2013

Previous major floods at McCoy Bridge occurred in 2010, 1993, 1981 and 1974, with flows well above 100,000 ML/d. As can be seen from Figure 45, moderate flooding at McCoy Bridge has occurred six times since 1979, with the most recent event being December 2010. This historical data are presented in Table 14, together with other examples of moderate and minor flood events. A range of flows has been provided as background context for the river levels that people have experienced first-hand. Many are far larger and more damaging than the flows constraints work is investigating; they are not the aim of this Strategy. Some of the smaller historical events are also included in Table 14 that are in the range of the managed overbank flows being investigated. This is so people can think about the types of effects that have occurred at flows of these sizes.

Table 14 Example recorded flows for Goulburn River at McCoy Bridge (gauging station 405232)

Flood class	Date	Gauge height (m)	Flow (megalitres/day)	Is constraints work considering these sorts of flows?
Major	19 May 1974	>11.10	167,523	No
Major	27 July 1981	11.02	113,620	No
Major	8 October 1993	11.01	112,929	No
Major	10 September 2010	10.23	63,051	No
Moderate	22 October 1992	10.19	61,206	No
Moderate	14 December 2010	10.09	56,461	No
Minor	6 October1989	9.42	35,205	Yes
Minor	17 June 1995	9.30	32,977	Yes
Minor	29 August 1990	9.29	32,871	Yes

What flows are being considered

Constraints work is investigating flow rates of between 25,000 and 40,000 ML/d (e.g. 8.7–9.6 m at the McCoy Bridge gauge station 405232) (Table 15 and as indicated by the shaded box on Figure 45).

These would be overbank flows up to around the minor flood level range. At below minor flood level, river levels are not high enough to trigger emergency management or flood warnings from the Bureau of Meteorology. At minor flood level, there is some inconvenience. Low-lying areas next to rivers and creeks start to get wet, requiring the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged (see also 'What is the Constraints Management Strategy?').

Constraints work is **not** considering flows at moderate or major flood levels. Flows significantly higher than the minor flood level are damaging and disruptive, and outside the bounds of active river management. Constraints work is collecting information about what effects river flows have at different places along the Goulburn River, but only around the minor flood level category.

Table 15 Comparison of flows footprints for the Loch Garry to River Murray subreach and flood categories at the McCoy Bridge gauge

Measure	Flow footprints being looked at for the Loch Garry to River Murray subreach (that include the flow contribution of tributaries)			McCoy Bridge, Minor flood level[1]	McCoy Bridge, Moderate flood level[1]	McCoy Bridge, Major flood level[1]
Flow rate (megalitres/day)	**25,000**	**30,000**	**40,000**	28,333	52,115	61,743
e.g. Gauge height (m) at McCoy Bridge	**8.7**	**9.1**	**9.6**	9.0	10.0	10.2

[1] Bureau of Meteorology, noting that flood categories are linked to specific gauges. As you move away from the gauge, the river situation can be quite different from what is being recorded at the gauge.

The flows that constraints work is looking at have occurred in the past. The hydrographic record shows that flows around the minor flood level have happened more than 10 times since 1979. They are therefore not an unusual type of flow. People in the region are already managing through flow events of this size at least every few years when not in drought.

What these flows look like

Linking a gauge reading at McCoy Bridge with the actual flow downstream is not always accurate, because of the effect of tributaries inflows and localised rainfall run-off. To assist MDBA to understand how landholders and community assets could be affected by different flows, flow footprint maps were developed to help visualise the flows.

Flow footprint maps were created using hydraulic models to show how flows of different sizes move down the river and spread across the landscape. Flow footprint maps let you look at what is likely to get wet for different-sized river flows.

When interpreting the maps, it is important to bear in mind that they are from a model of a generalised event, not a real event. Therefore, some caution should be used when interpreting the 'typical flow' footprints presented in this report. They are not intended to mimic real flow events, but be an initial representation of what could get wet for a flow of a particular size.

Figure 46 shows a flow footprint map for 25,000, 30,000 and 40,000 ML/d flows between Bunbartha (Loch Garry) and the River Murray and the protective rural levee network.

The map shows wetlands and floodplain within the protective levee network, but also water flowing down a number of effluent creek systems. This includes public lands (national park around Stuarts Bridge) and some private land, especially around Yambuna forest and downstream. Many landholders in this region already have levees in place to protect their land from nuisance flows, but protective levees may not have been picked up at the scale the modelling was undertaken. There would also be some inundation of land in New South Wales near the Goulburn–Murray confluence, but not much.

Feedback from local councils and landholders was that the flow footprint maps looked about right, although perhaps a little overstated. In particular, local council engineers were surprised at the number of roads that would be affected at the 25,000 ML/d flow. It was questioned whether so many roads would really be inundated, as the number of roads affected appears too extensive for a relatively small flow that already occurs quite often. Further validation and calibration is needed.

The accuracy of the maps is currently limited by the amount of data available to calibrate the hydraulic model. The maps should therefore be viewed as a first estimate, with more accurate mapping required if constraints work is to proceed further.

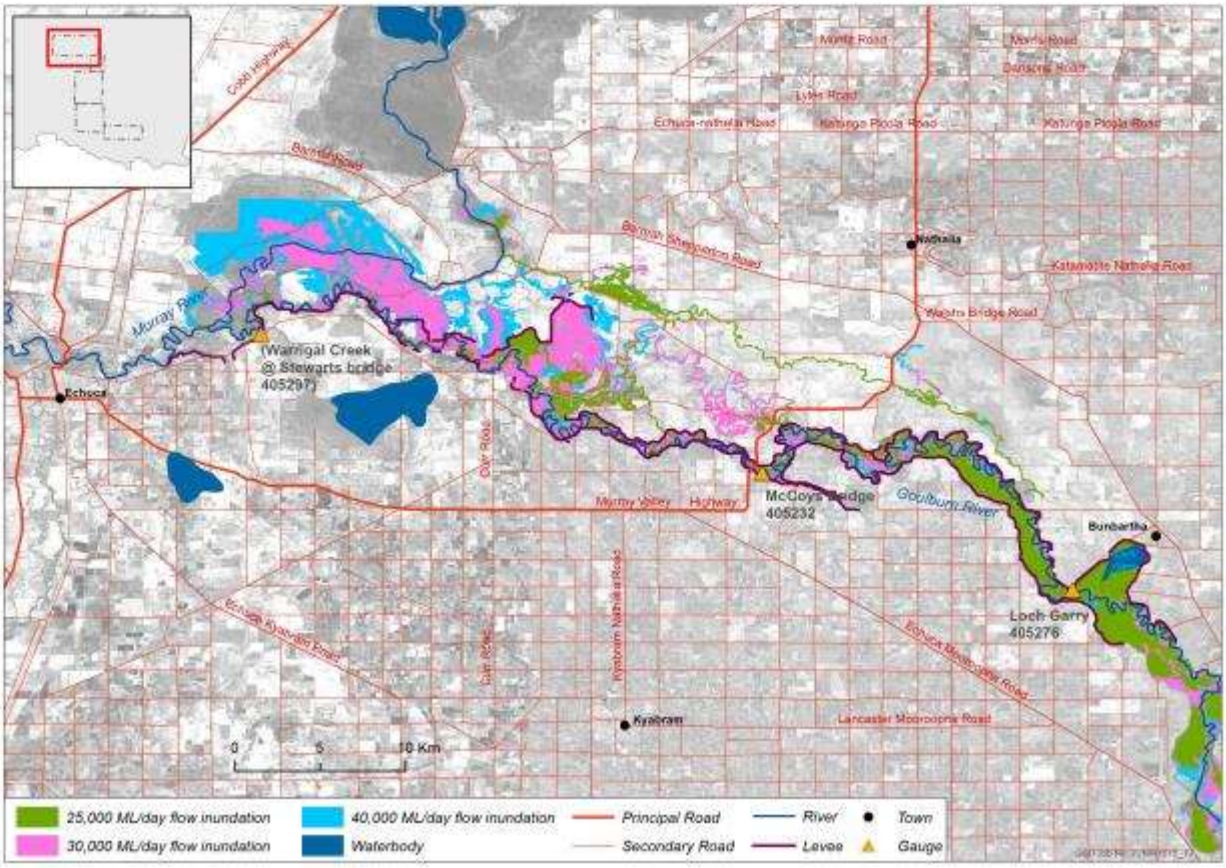


Figure 46 **Flow footprints for flows of 25,000, 30,000 and 40,000 megalitres (ML)/day between Loch Garry and the River Murray, including the levee network alongside the river**

What could be affected by these flows

The following information about what might happen at different river levels is a guide only. Information has been sourced from community feedback, local flood guides and council reports, where available.

Below minor flood level — examples of areas affected by overbank flows below minor flood level include:

- localised flooding in some low-lying rural paddocks
- Yambuna Bridge Road closed due to flooding along a 3 to 4-km stretch
- Stewarts Bridge Road closed in parts due to flooding.

Minor flood level — examples of areas affected by overbank flows around minor flood level include:

- localised flooding in rural paddocks
- Yambuna Bridge Road, Stewarts Bridge Road and a number of other floodplain roads closed, especially tracks through the Lower Goulburn National Park
- access roads and stock crossings through the Deep-Sheepwash-Skeleton Creek complex outside the levee network could be affected.

What the community thinks about the suggested flows

Initial feedback from landholders suggests that flows up to **30,000 ML/d** may be a tolerable level of inconvenience flooding. This is subject to suitable mitigation measures being in place (e.g. regulators on levee outlets to control nuisance flooding, easement payments, improved roads and drainage).

Flows of 30,000 ML/d, nearing minor flood level, could be created by releases from Eildon in combination with tributary flows. Tributary flows passing down the river could also be topped up by temporarily stopping the transfer of water into Waranga Basin and allowing it to continue to move downstream of Goulburn Weir (noting that this would be outside of the irrigation season and that environmental water entitlements held in Eildon Dam would still be debited for any water used this way).

Local councils and landholders in this region provided a number of other key points in relation to considering any change to regulated river flows.

Effects

> *Gauge heights were provided (at Shepparton) of when the Wakiti Creek starts to flow due to water coming through Hancocks pipes (6.5–7.1 m), when the Yambuna Bridge Road first gets cut (7.3–7.5 m) and when access is completely restricted (9.5 m).*

> *It takes flows about two days to get from Hancocks pipes to Yambuna forest. However when Wakiti Lagoon is dry it can take longer as the lagoon has to fill up. Once Wakiti Lagoon is full it doesn't take much to go up onto the Yambuna Bridge Road.*

Local farmers and residents are concerned about insufficient 'risk buffer' associated with a 40,000 ML/d flow — unexpected rainfall or additional unregulated tributary flow could turn these kinds of flows into a damaging flood.

All flows coming down the Goulburn River need to pass through gaps in the Bama sandhills. There are only a few routes that water can take.

High Goulburn River flows and Murray flows interact and can cause backing-up issues along the Goulburn and the Deep Creek system. This can affect access for some landholders (e.g. closing the Deep Creek alternative access route). Generally, this occurs whenever the water level in Shepparton is 10–11 m.

The Goulburn can stop the Murray back to Barmah if high flows clash.

September to November is critical for crops as well as a popular time for visitors to the region taking spring breaks.

Some residents raised possible health concerns about the potential for an increase in mosquitoes and mosquito-borne diseases (Ross River, etc.).

Access

High river flows close the Yambuna Bridge Road due to flows coming through Hancocks pipes (which means a 60-km detour to get around to Echuca). 'Hancocks pipes' are 3 or 4 large open pipe drains through the levee bank, which are often blocked by branches.

There are 3 or 4 places where the Yambuna Bridge Road is regularly cut and would require re-engineering — improving drainage and road surface.

Access to the forest for visitors is important for several regionally important tourism businesses in the lower Goulburn.

Management

Hancocks pipes is an inadequate levee outlet structure that has been recommended for upgrade in a number of studies dating back to at least the mid-1980s. A regulator was suggested to control heights at when and for how long water flows into the Wakiti Creek, so that high flows at Shepparton don't cut Yambuna Bridge Road for extended periods of time.

Better communication during flows is needed — not enough at the moment. Communities need to be able to get information in real time as the event unfolds.

Every time a levee bank gets wet, it potentially weakens. Levee maintenance is very important.

Heavy vegetation loads in creeks and distributor channels can affect how flows spread across the landscape.

Appendix 1 Constraints of the Goulburn River

Waterways in the Goulburn region have been substantially modified to convey water for irrigation and consumptive purposes, drain excess water and protect properties from flooding.

The CSIRO Murray–Darling Basin Sustainable Yields Project reported that flooding in the lower Goulburn River has significantly reduced, largely because of water resource development in the Goulburn River (CSIRO 2008). Under without-development conditions, flows that inundated the lower Goulburn River floodplain were relatively common, occurring every 2.5 years on average, with never more than about a decade between events (CSIRO 2008).

River flow along the Goulburn River has mainly been modified by two major features — Eildon Dam in the upper catchment and the Goulburn Weir in the mid-catchment — that regulate river flow and supply water for irrigation, urban and environmental purposes. Floodplain development and levees along the lower Goulburn River have also altered the characteristics of the floodplain.

Eildon Dam

Eildon Dam was built between 1915 and 1929, expanded in 1935, and expanded again between 1951 and 1955. The dam is the second-largest water storage in Victoria, with a capacity of 3,334,000 ML. Eildon Dam is operated in accordance with rules about target-filling curves and flood mitigation requirements, which are linked to the current bulk entitlement.

On average, 91% of water released from Eildon Dam is diverted for irrigation in the Goulburn, Loddon and Campaspe valleys, and the lake supplies about 60% of water used in the Goulburn–Murray Irrigation District. With such a large storage capacity, operation of the lake fully captures flows from the upstream catchments in all but the wettest years.

Flow conditions in the mid-Goulburn River (downstream of Eildon Dam to Lake Nagambie) have been reversed. Lower flows now occur in winter and spring because of harvesting of tributary flows into storage at Eildon Dam, and higher flows now occur in summer and autumn because of water releases from Eildon Dam to meet demand for irrigation and consumption. When little additional water is flowing from the downstream tributaries, typical releases from Eildon Dam during the irrigation season are up to 9,500 ML/day.

Although Eildon Dam storage and releases typically dominate the flow regime in the mid-Goulburn, to some extent this is lessened by the number of tributaries between Eildon Dam and Goulburn Weir. Together, the unregulated tributaries contribute as much volume as the upper Goulburn tributaries above Eildon Dam, and they retain a natural flow pattern. Tributaries include the Acheron, Rubicon and Yea rivers, and Spring, Whiteheads, King Parrot, Hughes, Sugarloaf, Sunday and Major creeks.

The flow regime at gauging stations along the Goulburn River is determined by a combination of these upstream influences. At Trawool, there are two high-flow seasons: during late winter to spring (from high tributary inflows), and in summer to early autumn (from Eildon Dam releases during the irrigation season). At Shepparton, the flow regime is mostly influenced by tributary inflows (Broken River and Seven Creeks), as most of the Eildon releases and mid-Goulburn tributary flows are diverted at Goulburn Weir across to Waranga Basin and irrigation areas.

Goulburn Weir

Goulburn Weir is an important mid-river regulating structure approximately 235 km downstream of Eildon Dam. Water stored in Eildon Dam is sent to Goulburn Weir, where it is diverted for irrigation and stock and domestic purposes. Goulburn Weir supplies the large off-stream storage Waranga Basin (capacity 432,000 ML), which supplies an extensive irrigation area. Waranga Basin harvests and stores flows from unregulated tributaries downstream of Eildon Dam and water released from Eildon Dam.

Goulburn Weir has very little active storage (regulating capacity) because it is usually held close to full so that water can be diverted via gravity along three irrigation canals: the Stuart Murray Canal, Cattanach Canal and the East Goulburn main channel. Diversions to the East Goulburn main channel supply the Shepparton Irrigation Area. The Stuart Murray Canal supplies part of the Central Goulburn Irrigation Area and Waranga Basin, and the Cattanach Canal diverts water into Waranga Basin. Waranga Basin supplies irrigation water for the Loddon, Campaspe and Goulburn valleys. Goulburn Weir also forms Lake Nagambie, which supplies local farming and residential needs and is a significant recreation site.

The Goulburn Weir and its harvesting operation have reduced the average annual downstream flow in the Goulburn River to less than half of the estimated pre-regulated flow. Large flow diversions have reduced the size, frequency and duration of ecologically important flows. Despite this, the Goulburn River below Goulburn Weir still retains much of the natural seasonal flow pattern. This is partly because of the influence of natural flow patterns from the mostly unregulated Broken River and the Seven Creeks that join the Goulburn River below Goulburn Weir, and partly because of the large diversion of irrigation water at the Goulburn Weir, which keeps flows low during summer and autumn.

Floodplain development and levees

Numerous levees (embankments) have been built alongside the Goulburn River to protect properties from floodwater.

Along the riverine plain downstream of Shepparton, artificial levees and other structures obstruct flood flows and have significantly changed where water spreads across the landscape. The meandering 156-km stretch of river between Shepparton and Wyuna is closely flanked by a system of levees built in the 1800s that closely confines the floodplain.

A report written by the Snowy Mountain Engineering Corporation for the Goulburn Broken Catchment Management Authority (SMEC 1998) says:

> *The lower Goulburn has been extensively modified. The floodplains have been cleared for agriculture and grazing. The south side includes established irrigation and drainage infrastructure with its network of roads. Dryland agriculture and grazing occupy the floodplain to the north with a small proportion of irrigation.*
>
> *Following several flooding episodes a committee was set up on the 'eastern side'. A petition to government was prepared requesting assistance to construct a levee scheme. When landholders on the 'western side' awoke to the fact that levees were being considered they had the government veto the scheme.*

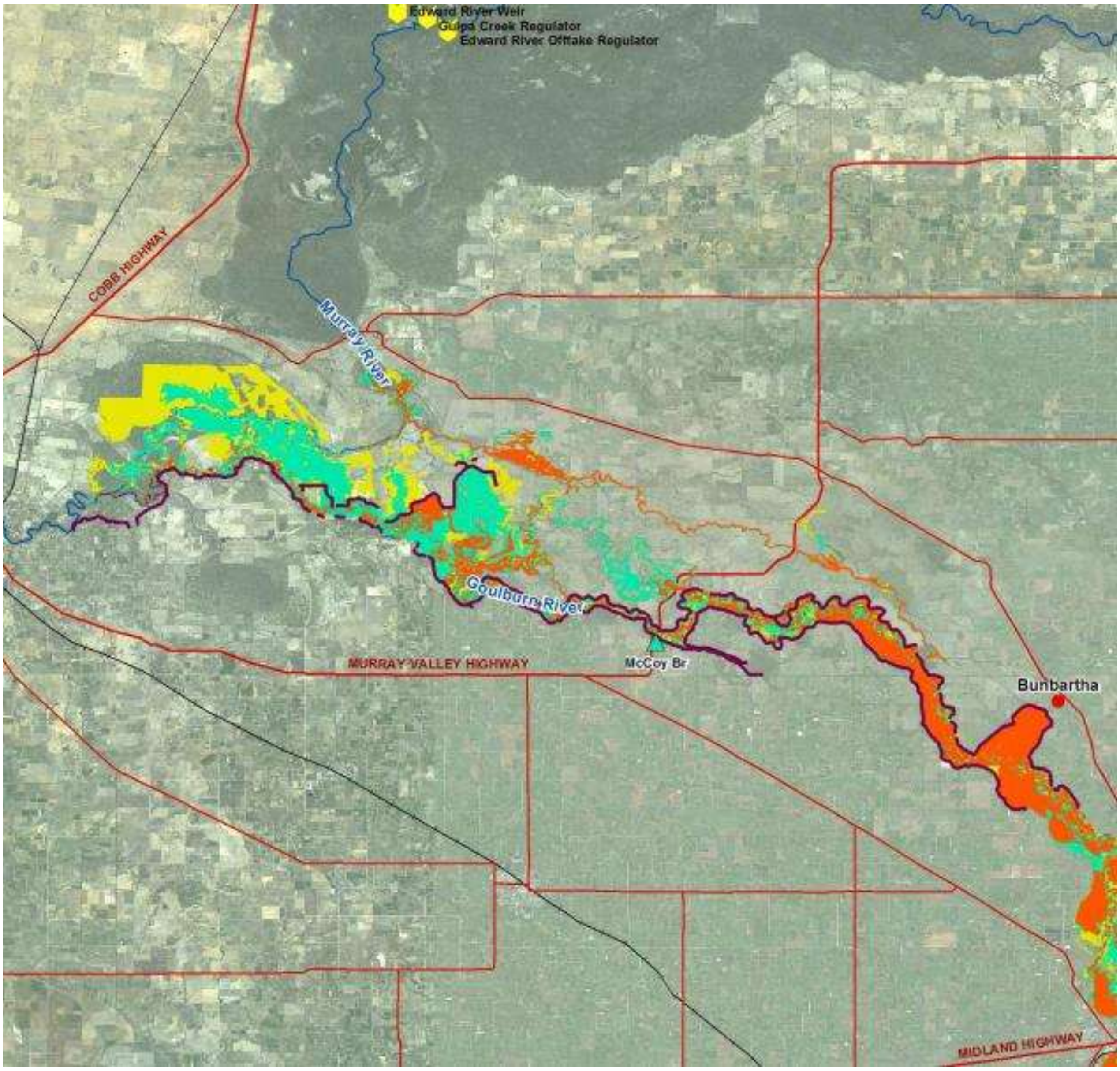
Several years followed where a local dispute over a levee in Yambuna occurred. A Mr George Stickels saw this to be an opportunity to call for a conference of the interested shires of 'Deakin, Rodney, Shepparton and Numurkah'. Within a few days of a deputation asking that the unemployed be set to work to construct levees, 'men with barrows and tools' were at work constructing levees.

According to the 1936 Nathalia Herald news article, the engineers were instructed to save all the land they could. The engineers Messrs Muntz and Bage set out the levee scheme whereby no levees were to be nearer than seven chains (approximately 140 m) from the river and in no case were the river bends to be followed. The levees constructed, as they exist today clearly do not conform to the engineers' criteria.

Levees can reduce the frequency of flooding, but no levee is guaranteed to be flood-proof, as they are designed to control only a certain amount of floodwater. Large floods either overtop or damage the levees, allowing floodwaters to flow through an opening or break. Although levees can have significant benefits in reducing flood extent and damage, they can have adverse effects such as (GB CMA 2002):

- reducing river and floodplain habitats and isolating wetlands
- increasing flow concentration and stream power, leading to increased flow rates, increased flood levels downstream and bank erosion
- intensifying land use in the protected areas of the floodplain, with a resulting increase in social disruption and flood damage if the levee fails or overtops
- reducing the frequency of deposition of silt and fertile material across the floodplain
- reducing floodplain soil moisture
- giving a false sense of security that the levee-protected areas are immune to floods that are larger than the levees are designed to contain
- needing ongoing maintenance and repair to maintain structural integrity, because levees are only as strong as their weakest point. However, lack of clarity around levee ownership and maintenance are perennial issues in rural areas.

The alignment of the lower Goulburn levees has been mapped to identify the area of floodplain contained within the levees, because floodplain development (significant private and community assets) has occurred right up to the levees (Figure A1).



Note: Levees are marked as purple lines and the flow footprints being investigated are marked in orange (25,000ML/d), green (30,000ML/d), and yellow (40,000ML/d).

Figure A1 Levee alignment downstream of Loch Garry

Levees provide some flood protection, but even during moderate events, the levees cannot contain the amount of water flowing down the lower Goulburn River. The levees have been breached and repaired at least 10 times over the past 100 years. Despite controlled releases at Loch Garry and several other levee bank outlets (Hancocks, Wakiti, Deep Creek), water spills over and through the levees onto the surrounding floodplains to both the north and south of the river. Anecdotal information from several community sources is that whenever the river gets above 55,000 ML/d at Shepparton, the rural levee network will breach somewhere, often in areas of weakness where it has breached previously. Levee breaches and spills cause substantial damage to agriculture and infrastructure outside the levees.

A number of different levee outlet structures allow water to leave the levee system into floodplain creeks, but the style and age of these structure can cause problems. For example:

> *In the big 1916 flood, the levees burst in the vicinity of Hancocks Creek and were not rebuilt. About one-third of the river flow used to go out through the gap in the levees near Hancocks.*
> *After the 1974 flood, there was money to rebuild levees that had blown in the flood, but the money was not supposed to be used on levees that were damaged by earlier floods. However, there was a councillor at the time who put forward fixing up the levees at Hancocks.*
> *State Rivers held a meeting at Kotupna where the issue was discussed — a range of folks there had wanted a spillway put in. Instead of a spillway in 1982 we got pipes that clogged with debris and can hardly handle any of the flow that the area used to. It went from around a 250-m gap in the levees to where water could only squeeze through three 6-ft pipes. State Rivers went against district knowledge and recommendations.*
> *The structure has been terrible ever since — the pipes are always getting clogged. State Rivers put a steel grille across the top, but it still gets blocked and we have to keep contacting people to get it cleared.*
> *Even worse, the power of high flows that used to dissipate and spread through the wide gap is now concentrated and has caused a lot of erosion. The river is now at least 25 m wider compared to when the pipes were first put in. For a number of years you couldn't swim in the river as it was so muddy with lots of sludge on the bottom after all the erosion from near Hancocks.*
> *You can't get near Hancocks pipes when the river is flowing strongly; it is a dangerous whirlpool full of debris.*
> *Long-time residents near McCoy Bridge and Yambuna*

Hancocks pipes through the levee bank, almost completely clogged with debris (the arrow indicates the position of the pipe). ***Photo: Morris Brown***

Hancocks pipes through the levee bank after debris has been removed. ***Photo: Geoff Earl, GB CMA***

Understanding the implications of other past waterway management practices

There used to be a creek outlet on the south bank — Dunnamores Creek -— but it no longer exists. The original brickworks outlet at Dunnamores Creek caused problems in the major flood of 1974, after which a containing bank was constructed. The outlet was damaged in the flood of September 1993, and was blocked off by bulldozing and joining the levee across the gap (SKM 1998).

The south side has long sections of levee with reduced crest levels designed to operate as spillways for flood relief — these are the only remaining ‘outlets’ on the south side of the river. These include Keoghs and Cooks (upstream of the Wells Creek confluence), which were altered after the major floods in 1993. The crests and land sides of the levees were not reinforced, however, and the Keoghs outlet was damaged during a moderate flood in 1996 (SKM 1998).

Other outlets reportedly existed in the original levee construction, but no longer occur. There may have been an outlet structure to Yambuna Creek and a small pipe outlet downstream of McCoy Bridge near Verings Lane in Kotupna (SKM 1998). The ‘loss’ of a number of levee outlets over time has concentrated the flow speed and depth within the leveed floodway and also unequally distributed floodwaters onto the northern bank of the floodplain (although based on the geomorphology, this is the direction that the river generally moves).

Cutting off meanders (i.e. straightening the river course) has previously been used in the lower Goulburn floodplain to improve the flood conveyance capacity; 22 meander cuts were constructed on the Goulburn River between Loch Garry and the Murray between 1914 and 1939 (SKM 1998). Cutting off meanders shortens the flow path and increases the gradient; however, it also increases velocities and erosion, and transfers high flood levels downstream.

Meander cuts were originally excavated to a depth that allowed them to carry flood flows only at high river stages; however, their design was not robust enough to withstand the force of large floods. Some of the cuts eroded to a depth where they captured the entire river flow at low flow (SKM 1998). By 1993, six of the cuts had fully captured the low flow of the river, and the river downstream of Loch Gary is now 9% shorter than it was in 1914.

Two low-level weirs have been constructed to stabilise the (new) riverbed in two of the largest meander cuts: Connollys Cut upstream of McCoy Bridge near the Wakiti Creek outlet and Pells Cut downstream of Hancocks Creek outlet (SKM 1998).

Inequity in levels of flood protection in the lower Goulburn

The standard of flood protection differs along the lower Goulburn River, creating perceptions of inequity for different landholders and dispute about the relative contribution of different management interventions over the past 100 years. Some parts of the floodplain are inundated more frequently than others, but this would largely have been the case before the levees were constructed.

Those areas of the lower Goulburn floodplain that currently have a higher standard of protection were generally less susceptible to the impacts of flooding before the levee system was introduced (i.e. higher ground localities, e.g. Wyuna, Kanyapella and Kotupna). Areas with less protection tend to be lower floodplain areas that are harder to protect. Before the levees, Deep Creek and its tributaries would have carried flood flows to the north whenever river flows exceeded the capacity of the river channel, because that is the way the land slopes. Before the levees and the Loch Garry regulator, these flows would have been even more frequent and sustained.

Nevertheless, all downstream landholders are affected by any floodplain interventions caused by the actions of upstream landholders that change the distribution of flood flows.

It is not possible or desirable to change current flow distribution to any notion of pre-development or mid-20th century development, because significant land development has accompanied the varying levels of flood protection provided by the levee system. Current levels of flood protection should be maintained. If operated well, the levee system is capable of managing floods and their distribution in 92% of years, which is a good standard for a rural levee system (SKM 1998).

Appendix 2 Environmental water management in Victoria

The term 'environmental water' is often used quite loosely, but, essentially, it is water that is used to maintain the environmental values and health of water-dependent ecosystems. Importantly, environmental water is not 'all of the water' or 'all of the water that the environment needs', but is a flow regime that considers trade-offs between environmental, consumptive and other beneficial-use outcomes that may fully or partly meet the ecological water requirements. The following definition incorporates this concept and provides a common basis for consistent reporting across jurisdictions (NWC 2010):

> *Environmental water is the water regime that is deliberately managed to achieve ecological objectives.*

Environmental water can also provide other public benefits such as mitigating pollution and supporting public health, Indigenous, cultural, recreation, fisheries, tourism, navigation and amenity values. There is general recognition that good waterway condition supports social and economic values and regional growth.

Environmental water is generally linked to achieving specific environmental objectives, which are often informed by ecological values. Objectives may relate to how much of an environmental asset is to be maintained (e.g. providing overbank flows of a specific size to inundate a specific area of floodplain). Values may relate to specific endangered species, or ecological functions that can be linked to particular components of the natural hydrological regime (e.g. flows during spring to trigger fish spawning, or base flows to maintain drought refuges).

Once environmental objectives are defined, the environmental water requirements of the system can be determined. These requirements underpin the ongoing sustainable use of the water resource. Environmental water requirements are a description of the water regime needed to maintain ecological values of water-dependent ecosystems at a low level of risk.

Sources of water

In the Goulburn catchment, sources of water for overbank flows include unregulated flows, environmental entitlements, minimum passing flows and a water quality allowance established in the bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995 and subsequent amendments. Goulburn–Murray Water (GMW) is the principal water storage and irrigation area manager in northern Victoria (Goulburn–Broken, Campaspe, Loddon and Ovens catchments). GMW is also the major bulk entitlement holder in northern Victoria and is responsible for the day-to-day delivery of water (including environmental water) throughout its river systems.

Environmental water entitlements can be called out of storage when needed and delivered to streams or wetlands to protect or improve their environmental values and health in either the Goulburn River or downstream in the River Murray. Environmental entitlements in the Goulburn catchment are held by the Victorian Environmental Water Holder (VEWH), the Commonwealth Environmental Water Holder (CEWH), and joint Basin government under The Living Murray Initiative:

- VEWH is the independent statewide coordinator of environmental watering activities in Victoria and liaises with other environmental water holders to coordinate delivery of their water with the delivery of Victorian Water Holdings (see the Victorian Environmental Water Holder website[8]). The Goulburn–Broken Catchment Management Authority engages communities to identify regional priorities and develop watering proposals. It works with GMW to order and deliver environmental water on behalf of the VEWH and the CEWH.

- The CEWH is responsible for managing the Commonwealth's environmental water holdings to protect the environmental assets of the Murray–Darling Basin (see the CEWH website[9]).
- The Living Murray program of the joint Basin governments is responsible for managing water holdings to deliver water to icon sites along the River Murray, with Gunbower–Koondrook–Perricoota Forest being of particular relevance for sourcing water from the Goulburn River (see the MDBA website on River Murray environmental water[10]).

To give an idea of the size of environmental entitlements, as at 31 May 2014, environmental water holdings in the Goulburn catchment have grown to 494,865 ML.

With purchases of water entitlements by the Commonwealth over the past few years, potentially 322,090 ML of high-reliability entitlement is available for environmental use (VEWH and GMW: 57,660 ML; The Living Murray: 45,184 ML; CEWH 219,246 ML) and a further 172,775 ML of low-reliability entitlements (The Living Murray: 156,980 ML; CEWH 15,795 ML) (Table A1). Goulburn catchment entitlements make up around 13.5% of the full portfolio of Commonwealth environmental water holdings across the Murray–Darling Basin (1,729,834 ML of registered entitlements of varying security).

Table A1 Environmental water available for use in the Goulburn River

Water source	Environmental water type	Responsible agency	Description	Conditions
Bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Minimum flow	GMW	Minimum flow of 120 ML/d at Eildon Pondage Weir	None[a]
Bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Minimum flow	GMW	Minimum average weekly flow of 250 ML/d at Goulburn Weir	The daily rate is to be no less than 200 ML/d[a]
Bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Minimum flow	GMW	Minimum average monthly flow of 350 ML/d from November to June inclusive at McCoy Bridge gauging station	The daily rate is to be no less than 300 ML/d[a]
Bulk entitlement (Eildon – Goulburn Weir)	Minimum flow	GMW	Minimum average monthly flow of 400 ML/d from July to October inclusive at	The daily rate is to be no less than 350 ML/d[a]

8 www.vewh.vic.gov.au

9 www.environment.gov.au/water/cewo

10 www.mdba.gov.au/what-we-do/environmental-water/river-murray

Water source	Environmental water type	Responsible agency	Description	Conditions
Conversion Order 1995			McCoy Bridge gauging station	
Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Goulburn water quality allowance	GMW	30,000 ML per year	Maintenance of water quality
Bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Additional passing flow below Eildon Pondage Weir	GMW	Minimum passing flows at Eildon Pondage Weir increased to 250 ML/d	Inflows to Eildon Dam for previous 24 months must reach a specified volume[a]
Bulk entitlement (Eildon – Goulburn Weir) Conversion Order 1995	Additional passing flow below Eildon Pondage Weir	VEWH	Up to 80 GL to provide up to 16,000 ML/d peak flow for 1 day	Inflows to Eildon Dam from previous 12 and 24 months must reach specified volumes and the Secretary of DSE confirms the need for a release[a]
Environmental water entitlements	Victorian River Murray flora and fauna entitlement	VEWH	27,600 ML high-reliability entitlement	An environmental water entitlement for the River Murray. To be used for Hird and Johnson swamps, with the balance to be released in a manner that maximises benefits to flora and fauna of other wetlands along or with access to the Murray River system
Environmental water entitlements	Goulburn Environmental Water Savings Supply Deed	VEWH	One-third of water savings created in the Goulburn System as a result of modernisation works completed as part of Stage 1 of the Northern Victorian Irrigation Renewal Project	Volume based on works implemented and water losses saved in previous year’s climate
Environmental water entitlements	Environmental entitlement (Goulburn System – Living Murray) 2007	MDBA	45,184 ML high-reliability entitlement and 156,980 ML low-reliability entitlement, as at 31 July 2013	Water allocated to this entitlement must be used for The Living Murray icon sites. However, this water can provide environmental benefits in the Goulburn River en route to the River Murray

Water source	Environmental water type	Responsible agency	Description	Conditions
Environmental water entitlements	Commonwealth environmental water holdings	CEWH	219,246 ML Goulburn high-reliability water share and 15,795 ML Goulburn low-reliability water share as at 31 May 2014	Water use is subject to agreement with the CEWH

CEWH = Commonwealth Environmental Water Holder; DSE = Victorian Department of Sustainability and Environment; GMW = Goulburn–Murray Water; MDBA = Murray–Darling Basin Authority; ML = megalitre; VEWH = Victorian Environmental Water Holder

a Minimum flows in the Goulburn Bulk Entitlement can be reduced under drought conditions and banked for later use.

Source: Updated from GB CMA (2013b)

Environmental water planning

The Victorian Government has a clear framework for making decisions about water allocation and entitlements. This includes a share of water for the environment called the Environmental Water Reserve. The framework for making decisions on water allocation and entitlements has been strengthened in Victoria with the development of the Northern Region Sustainable Water Strategy (SWS) to plan for long-term water security (DSE 2009).

In 2010, the Victorian Parliament passed an amendment to the Victorian *Water Act 1989* to establish the independent VEWH. On 1 July 2011, the VEWH took over responsibility for holding Victoria's environmental water entitlements and is the statewide coordinator of environmental watering activities.

The Goulburn–Broken Catchment Management Authority is responsible for determining the environmental water requirements of streams and wetlands in the Goulburn region, developing and submitting seasonal watering proposals to the VEWH for consideration, and managing the delivery of environmental water in accordance with the VEWH's Seasonal Watering Plan. Seasonal watering proposals take a 'seasonally adaptive approach' to help guide the environmental objectives prioritised under scenarios ranging from drought to a very wet catchment (Table A2).

The VEWH prepares seasonal watering plans, based on each of the Victorian catchment management authorities' seasonal watering proposals. The plans describe the desired environmental water use for rivers and wetlands across Victoria in the coming year. To help facilitate the desired environmental water use outlined in the plans, the VEWH negotiates access to environmental water managed by the CEWH and MDBA. The VEWH then prepares seasonal watering statements that authorise catchment management authorities to undertake the agreed watering activities, including the use of CEWH and MDBA water. As more environmental water becomes available during the season, the VEWH may prepare additional seasonal watering statements. Where possible, the VEWH, CEWH and MDBA seek to coordinate the delivery and management of environmental water to maximise ecological benefits. Commonwealth environmental water that is allocated to Victorian sites is delivered by waterway managers (Goulburn–Murray Water) through the VEWH processes under Victoria's water entitlement framework.

Each government funds the delivery, monitoring and management of its own environmental water. The key task for all environmental water holders is to ensure that environmental water is coordinated and used as efficiently and effectively as possible.

Table A2 The 'seasonally adaptive' approach to river and wetland management

	Drought	Dry	Average	Wet to very wet
Long-term ecological objectives	Long-term objectives to move towards ecologically healthy rivers - set through regional river health strategies and sustainable water strategies and reviewed through the 15-year resource review			
Short-term ecological objectives	• Priority sites have avoided irreversible losses and have capacity for recovery	• Priority river reaches and wetlands have maintained their basic functions	• The ecological health of priority river reaches and wetlands has been maintained or improved	• The health and resilience of priority river reaches and wetlands has been improved
Annual management objectives	• Avoid critical loss • Maintain key refuges • Avoid catastrophic events	• Maintain river functioning with reduced reproductive capacity • Maintain key functions of high priority wetlands • Manage within dry-spell tolerances	• Improve ecological health and resilience	• Maximise recruitment opportunities for key river and wetland species • Minimise impacts of flooding on human communities • Restore key floodplain linkages
Environmental water reserve	• Water critical refuges • Undertake emergency watering to avoid catastrophic events • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• In priority river reaches provide summer and winter baseflows • Water high priority wetlands • Provide river flushes where required to break critical dry spells • Provide carryover (for critical environmental needs the following year) • If necessary, use the market to sell or purchase water	• Provide all aspects of the flow regime • Provide sufficient flows to promote breeding and recovery • Provide carryover to accrue water for large watering events • If necessary, use the market to sell or purchase water	• Provide overbank flows • Provide flows needed to promote breeding and recovery • If necessary, use the market to sell or purchase water
River and wetland catchment activities	• Protect refuges (including stock exclusion) • Increase awareness of the importance of refuges • Enhanced monitoring of high risk areas and contingency plans in place • Investigate feasibility of translocations • Environmental emergency management plans in place • Protect high priority river reaches and wetlands through fencing; pest, plant and animal management; and water quality improvement works • Implement post-bushfire river recovery plans	• Protect refuges • Protect high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Environmental emergency management plans in place • Improve connectivity • Implement post-bushfire river recovery plans	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands	• Protect and restore high priority river reaches and wetlands through fencing, revegetation, pest plant and animal management, water quality improvement and in-stream habitat works • Monitor and survey river and wetland condition • Improve connectivity between rivers and floodplain wetlands • Emergency flood management plans in place • Implementation of post-flood river restoration programs

Source: DSE (2009)

Environmental water delivery

A minimum of one to two days notice (preferably four days) is required for environmental water orders from Goulburn system storages. If constraints in making environmental water available are foreseen by Goulburn–Murray Water, it will advise the Environmental Water Manager accordingly and the order will be adjusted, postponed or cancelled.

Releases from Eildon Dam take approximately 2.5 days to reach Goulburn Weir. Releases from Goulburn Weir take one day to reach Murchison, four days to reach Shepparton and seven to eight days to reach McCoy Bridge (near the River Murray). However, this can be influenced by existing conditions in the river channel and seasonal conditions. If flows are being harvested at Goulburn Weir into Waranga Basin, environmental releases can be made from Goulburn Weir by reducing harvesting into Waranga Basin, hence saving travel time from Eildon Dam (GB CMA 2012).

Table A3 shows a summary of the volume of environmental water delivered in the Goulburn catchment between 2009 and May 2014, and the different amounts of water contributed to these watering actions by the Commonwealth and delivery partners (The Living Murray program and VEWH). This table clearly illustrates that cumulative environmental watering in the Goulburn catchment since 2009 has been significant; however, no managed floodplain watering of the lower Goulburn River has yet been undertaken.

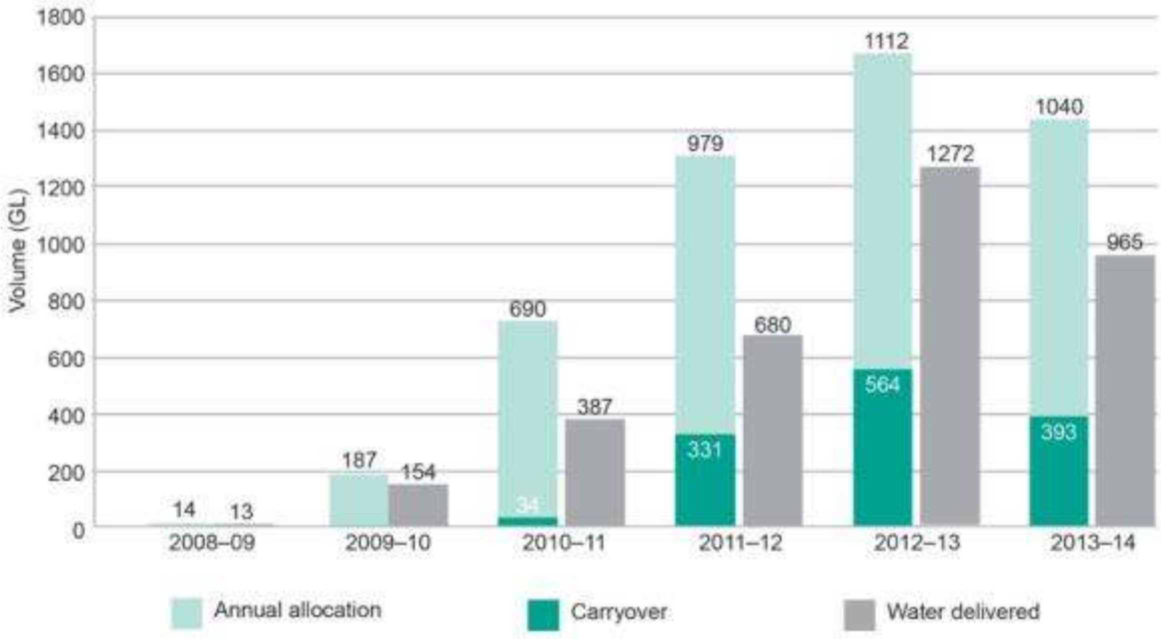
Table A3 Environmental water delivered in the Goulburn region between 2009 and May 2014

Catchment complex	Commonwealth contribution (ML) 2009–14	Partner contribution (ML) 2009–14	Total delivered (ML) 2009–14
Lower Goulburn River floodplain	0	0	0
Goulburn–Broken catchment river flows	690,644	111,344	801,988
Other Goulburn–Broken catchment sites	75	0	75

Source: CEWH Environmental water use website[11]

Importantly, although there are several entitlement holders involved, most of the available environmental water allocations in the Goulburn catchment are used every year. This is because the water is needed for a range of environmental objectives in the river and downstream every year. A proportion of the environment's water is carried over, as is the same entitlement for other irrigation users, but the majority of holdings are used each year (Figure A2).

11 www.environment.gov.au/topics/water/commonwealth-environmental-water-office/about-commonwealth-environmental-water/how-mu-0



Source: CEWH About Commonwealth environmental water website[12]

Figure A2 Availability and use of Commonwealth water, 2008–09 to 2013–14

Every year, the outcomes from environmental watering activities are assessed and key learnings are captured by each of the environmental water holders. For the Goulburn River, monitoring and outcome reports can be found at the following locations:

- Goulburn–Broken Catchment Management Authority's seasonal watering proposals[13] include the ecological objectives for watering, and the proposed monitoring programs are in the VEWH seasonal watering plan[14] for each year
- Commonwealth Environmental Water monitoring website[15]
- The Living Murray, MDBA monitoring website.[16]

12 www.environment.gov.au/topics/water/commonwealth-environmental-water-office/about-commonwealth-environmental-water

13 www.gbcma.vic.gov.au/default.asp?ID=waterway_and_floodplain

14 www.vewh.vic.gov.au/news-and-resources/resource-library/seasonal-watering-plan

15 www.environment.gov.au/topics/water/commonwealth-environmental-water-office/monitoring-and-evaluation

16 www.mdba.gov.au/what-we-do/mon-eval-reporting/TLM-environmental-monitoring

Appendix 3 Constraints-related studies relevant for the Goulburn River

A number of studies have contributed to our current understanding of constraints in the Goulburn River. These include technical reports and analyses that have been produced over the past three years through the early phases of the Constraints Management Strategy (Table A4).

There are also reports and analyses that pre-date the Strategy but which have helped inform its development and our current understanding of the issues (Table A5).

Table A4 Constraints studies completed as part of the Constraints Management Strategy relevant to the Goulburn River (2013–15)

Phase/year	Tasks	Output/report
2013 Preliminary	Identify areas of the Murray–Darling Basin likely to get the best environmental outcomes from relaxation of physical constraints	*Preliminary overview of constraints to environmental water delivery in the Murray–Darling Basin – technical support document*, MDBA
2013 Preliminary	Constraints Management Strategy: - establish principles, timelines, roles and responsibilities - early identification of regional benefits, impacts and risks	*Constraints Management Strategy 2013 to 2024*, MDBA
2014 Prefeasibility	Rationale for flow rates along the Goulburn River — what is the new flow rate range we are looking to achieve and why?	*Overbank flow recommendations for the lower Goulburn floodplain* (2011), Victorian Department of Sustainability and Environment *Goulburn River reach report*, MDBA
2014 Prefeasibility	Develop flow inundation maps and assess map accuracy	*Flow inundation mapping and impact analysis,* CMS Prefeasibility technical report, MDBA *Goulburn River reach report,* MDBA
2014 Prefeasibility	Quantify who and what would be affected by flow inundation maps Estimate mitigation costs	*Constraints Management Strategy annual progress report to ministers 2013–14*, MDBA *Cost estimates report,* CMS prefeasibility, MDBA Subsidiary consultants reports that informed the cost estimates report: - *Goulburn draft report: estimate of the cost to establish easements,* GHD - *Constraints Management Strategy costing project — easement costing methodology*, GHD for MDBA

Phase/year	Tasks	Output/report
		- *Regional infrastructure costing report*, URS - *Analysis of Goulburn River constraints modelling,* Water Technology for MDBA
2014 Prefeasibility	Describe current understanding of benefits, impacts and risks	*Constraints Management Strategy annual progress report to ministers 2013–14*, MDBA *Priority constraints analysis — methods and results,* MDBA *Goulburn River reach report*, MDBA
2015–16 Feasibility	Improve accuracy of flow inundation maps	*CMS business case (Victoria),* in development
2015–16 Feasibility	Refine mitigation cost estimates and test assumptions	*CMS business case (Victoria),* in development
2015–16 Feasibility	Increase understanding of benefits, impacts and risks	*CMS business case (Victoria),* in development *Updated Goulburn River reach report*, MDBA
2016–24 Planning and Implementation	Dependent on June 2016 decision by Basin Ministers on whether to proceed	

Table A5 Studies of relevance to constraints investigations in the Goulburn River, 2003–14

Year	Relevant tasks	Output/report
2003	Develop environmental flow recommendations for the Goulburn River below Lake Eildon	*Environmental flow recommendations for the Goulburn River below Eildon Dam,* Cooperative Research Centre (CRC) Freshwater Ecology and CRC Catchment Hydrology
2006	Scope current broad-scale extent of physical and river operational constraints along the Goulburn River and provide options for operational/structural changes	*Goulburn, Campaspe, Loddon environmental flow delivery constraints study*, Sinclair Knight Merz (SKM) for GBCMA
2007	Broaden 2003 Goulburn River environmental flows study to include consideration of implications of summer inter-valley transfers	*Evaluation of summer inter-valley transfers from the Goulburn River,* Cottingham et al.

Year	Relevant tasks	Output/report
2008–10	Develop a hydraulic model for the Goulburn River (flow footprints) Understand what is affected by different flow rates in different parts of the Goulburn River downstream of Lake Eildon (asset mapping and potential damage assessment) Early assessment of tributary behaviour and gauging data quality	*Goulburn River environmental flows hydraulics study*, Water Technology for GBCMA: - executive summary, environmental flow scenarios - topographic data review - hydraulic model construction and calibration - asset mapping – data collation and review - hydraulic model application and affected asset assessment — environmental flow scenarios - real-time flow management — framework scoping - streamflow data assessment and tributary inflow analysis - potential flood damage assessment (URS Australia)
2011	Refinement of hydraulic model created by Water Technology (2010) including mapping the location of levees, assets inside and outside of levees, and a further assessment of what environmental assets are inundated at different flow rates	*Hydraulic modelling analysis for the lower Goulburn River,* Water Technology for GBCMA
2011	Provides information on the environmental assets of the Goulburn River and potential environmental water use in the lower Goulburn River	*Environmental water delivery — lower Goulburn River,* Commonwealth Environmental Water Holder
2011	A trial to learn how environmental water can best be delivered between Eildon and Killingworth to inundate floodplain wetlands without impacting on private and public assets. Photo points and gauging results along the mid-Goulburn when November 2011 releases from Lake Eildon were approximately 5,000, 7,000 and 9,000 ML/day	*Goulburn River environmental flow monitoring, Thiess Services* *Mid-Goulburn River elevation analysis — final report,* Water Technology for GBCMA
2011	Determine how much water can be sustainably used from rivers and creeks across the Murray–Darling Basin	*The proposed 'environmentally sustainable level of take' for surface water of the Murray–Darling Basin: method and outcomes,* MDBA

Year	Relevant tasks	Output/report
2012	Summarises work to date on environmental water requirements for lower Goulburn to inform the development of the Basin Plan A number of site-specific flow indicators (e.g. timing, frequency, duration and size of event) developed to achieve ecological objectives	*Assessment of environmental water requirements for the Lower Goulburn,* MDBA
2012	Explore potential environmental benefits that would result if some major existing river operating constraints in the southern connected Basin were relaxed	*Hydrologic modelling of the relaxation of operational constraints in the southern connected system: methods and results*, MDBA
2013	Improve knowledge, data and information of the levees along the Goulburn River including levee surveys, condition assessments and cost estimates for priority works	*Rural levees assessment — final report of lower Goulburn River levees,* Water Technology for GBCMA
2013	Explore ways to change river management arrangements to coordinate the delivery of environmental water across catchments to achieve multiple ecological outcomes	*Summary of analysis undertaken to support the experienced river operators workshop (April 19, 2012)*, MDBA
2014	Identifying opportunities for flows between Lake Eildon and Nagambie to benefit the Goulburn River's environmental, social and economic values	*Mid-Goulburn River flows study — final report: flow recommendations,* Cottingham et al. for GBCMA

Appendix 4 Changes to the Shepparton ratings table

A change to the Shepparton ratings table was first detected during MDBA consultation in mid-2013. This understandably caused concern for Deep Creek landholders, as the rules that trigger the opening and closing of the Loch Garry regulator are based on river heights at the Goulburn River gauge at Shepparton.

However, there have been no changes to the height or time-based rules at Shepparton that trigger the pulling of Loch Garry bars. There has also been no change to the physical location or height of the Goulburn River gauge at Shepparton.

Ratings tables use a mathematical relationship to convert gauged river heights to flow rates. The relationship is calibrated using field measurements of flow rates at different river heights, wherever these are available.

Significantly, ratings tables can change. Over time, as more field information is collected, ratings tables have different amounts of data available with which to define the mathematical relationship between river height and flow rate. Changes to the mathematical relationship can change the calculation of flow rate for a given river height.

Between 2004 and 2010, 34 feet (10.36 m) at Shepparton was estimated to correspond to a flow rate of around 50,600 ML/day.

After 2010, there seems to be a change in the mathematical relationship that converts river height to flow at Shepparton. From recent Thiess ratings tables (version 12, July 2013), 34 feet (10.36 m) at Shepparton now corresponds to 41,454 ML/day. This is around 9,000 ML/day less than previously estimated. To put this change into context, Table A6 shows the estimated flow rates for a 10.36 m river level at Shepparton using different versions of the Thiess ratings tables since 2004.

There is no obvious hydraulic driver for a change of this size (Geoff Earl, Goulburn Broken Catchment Management Authority, and Mark Bailey, Goulburn–Murray Water, pers. comm.). The only hydraulic change that could have affected the Shepparton gauge, albeit minimally, was in 2009 when a rock ramp fishway was installed at Shepparton town Weir. However, this will not have contributed to or caused the change in the flow – river height relationship at the 25,000–40,000 ML/d flow rates being considered (Geoff Earl, Goulburn Broken Catchment Management Authority, and Mark Bailey, Goulburn–Murray Water, pers. comm.).

This change is relevant to the Constraints Management Strategy because the upper flow rate that constraints work is investigating is 40,000 ML/day at Shepparton. This is now very close to the river height that triggers the opening of the Loch Garry regulator. This is not something environmental water holders want to do, and it is not something that Deep Creek landholders want to happen.

Table A6 Estimated flow rates for a 10.36-m river level at Shepparton using different versions of the Thiess ratings tables since 2004

Date of different versions of the Shepparton ratings table	Rating (ML/day) for a 10.36-m river level at Shepparton
July 2013	41,454
Feb 2013	41,454
Mar 2012	41,454
Aug 2010	50,120R
Jan 2008	50,600R
Feb 2005	50,642R
July 2005	50,642R
Dec 2004	50,642R
Nov 2004	50,642R
July 2004	50,642R

R = data extrapolated

The issue is that MDBA has been unable to confirm what exactly has caused the change in the Shepparton ratings table, although we have a working hypothesis.

The only possible explanation that we have found is that flow readings before September 2010 all had an 'R' data tag against them. This is important because the Thiess ratings tables state that 'All rated data has been coded as reliable except where the following tags are used ... R ... Rating table extrapolated'. This means that the earlier flow rates for these river heights at Shepparton were estimated by extrapolation. Rates with an 'R' data tag therefore used a flow–height relationship that was estimated from much lower gauged flows, rather than from flows of this size that were actually measured in the field.

The recent ratings tables (versions after August 2010) no longer have the 'R' data tag. Presumably this is because field measurements of flow rate for different river heights were undertaken during the 2010–11 floods. MDBA is currently awaiting additional advice from Thiess to help confirm this potential reason for the ratings table change. Ratings tables can and do change through time, but it is important to understand exactly why.

Appendix 5 Examples of flow events along the Goulburn River

Constraints work in the Goulburn is investigating flows in the range of 25,000–40,000 ML/day at Shepparton. To help people understand the range of overbank flows that constraints work is investigating, several examples of flow events have been selected from the hydrological record.

Three events have been chosen to show what was happening along the Goulburn River and its tributaries downstream of Lake Eildon, resulting in a particular sized flow at Shepparton. These are:

- an overbank flow event approaching 40,000 ML/day at Shepparton that happened without the addition of managed water (June 1995, reached 39,735 ML/day at Shepparton)
- a flow event that fell just short of reaching the lower Goulburn floodplain that may be the type of event managers could add water to in the future (July 2003, 20,846 ML/day)
- a large flood event much bigger that the overbank flows constraints work is looking at, but for comparison and reference purposes (September 2010, 78,500 ML/day, nearly double the upper flow rate constraints work is investigating).

It is important to note that there is no magic recipe. As there are lots of tributaries, there are many different potential flow contributions that can make up a flow at Shepparton. The following examples are illustrative, but not definitive. These examples also do not prescribe or describe the types of events that environmental water may be added to in the future. In particular, the 2003 example has not been assessed for its operational feasibility if similar conditions were to occur again in the future.

The Goulburn longitudinal profile shows how the elevation of the landscape changes as you move from Lake Eildon to the River Murray, highlighting towns and gauge locations as well as where various tributaries join the Goulburn River (Figure A3).

In some cases tributaries have good gauging data records through time (e.g. Rubicon River, Acheron River). In other cases tributaries are only partially gauged (e.g. Yea River up to 50% of catchment ungauged), and therefore gauge readings do not completely reflect the flows entering the Goulburn main stem or conditions experienced in the tributary. There are also some smaller creeks without gauging stations and even for some that do, there can be periods for which tributary gauging data is poor quality or unavailable (e.g. Snobs Creek).

Figure A4 shows snapshots of the peak flows from each of the tributary and main-stem gauges for an overbank flow of 40,000 ML/d at Shepparton (June 1995), a flow that fell short of reaching the lower Goulburn floodplain (July 2003), and a overbank flow much larger than the flows constraints work is investigating (September 2010). This is to allow people to compare the peak flows in different parts of the catchment during these different-sized events.

Naturally the peak flow is not the full story of how an event unfolds, but Figure A4 provides some comparison information for just how high river flows got in different parts of the catchment for different events.

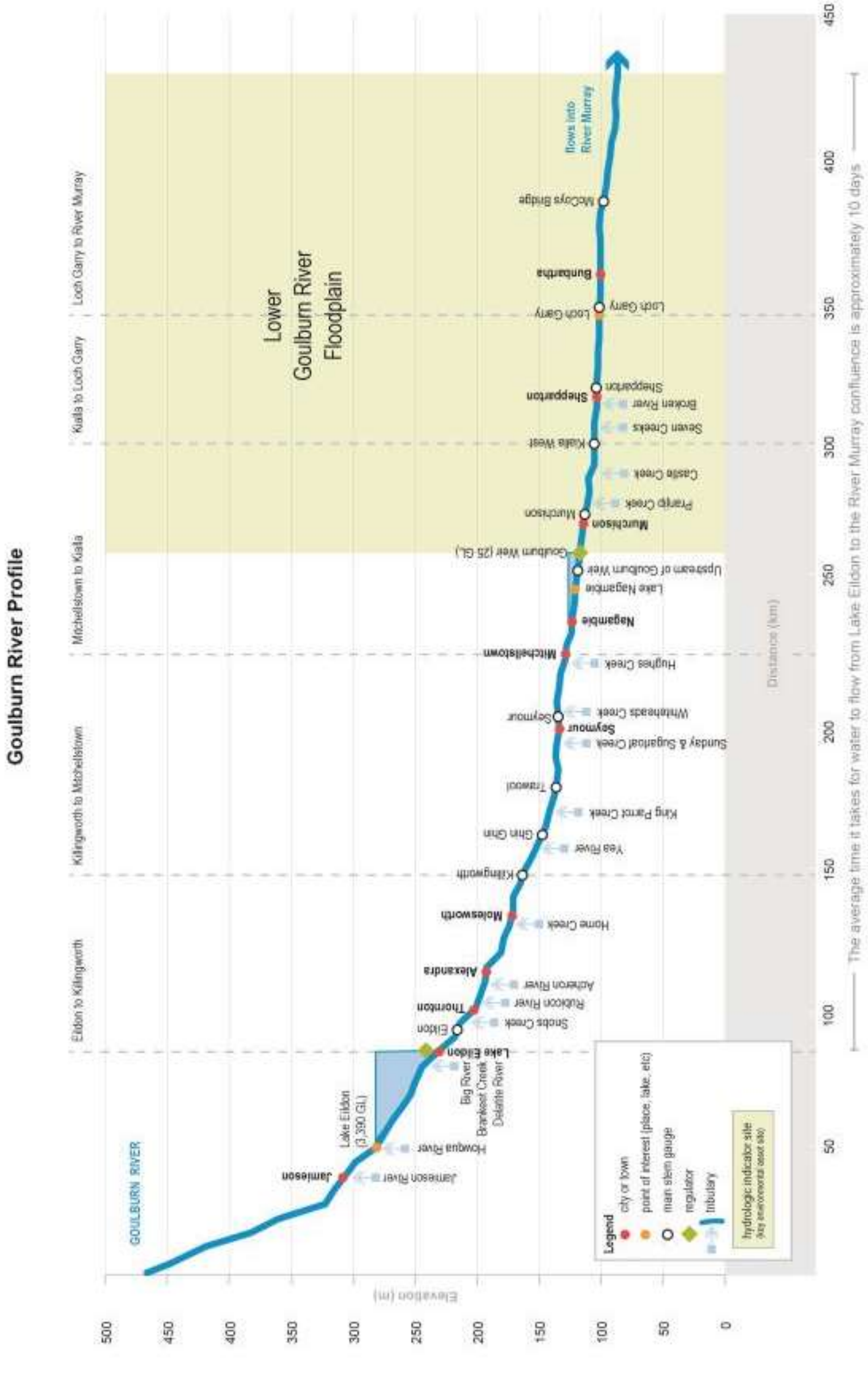
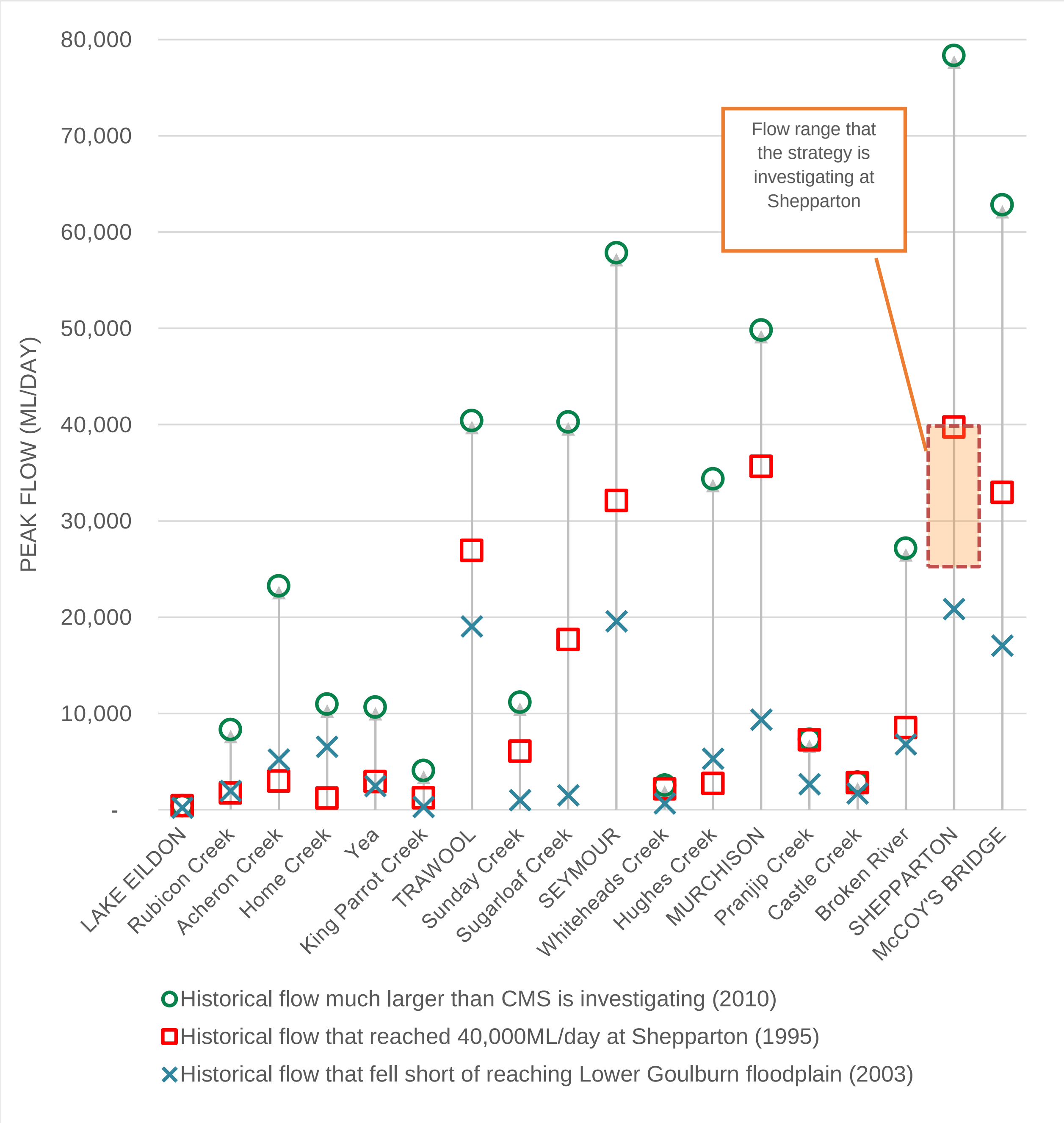


Figure A3 Goulburn River profile



Main-stem gauges are in uppercase, tributary data are in lowercase.

Figure A4 Peak flow in different parts of the catchment for three different-sized events at Shepparton (1995, 2003, 2010)

Appendix 6 Easements

Higher managed flows are needed in some areas of the Basin for water to reach important wetlands, billabongs and creeks. However, higher managed flows could result in water flowing over private land.

Currently, river operators cannot deliver water orders that would result in water flowing onto private land unless they have landholder approval to do so. Easements are one option to negotiate permission between landholders and river authorities. Landholders are paid in advance for impacts now and into the future that a change in managed flows would cause.

Landholders can still use their land freely, but are paid up front for potential impacts.

What is an easement?

An easement is a legal agreement that allows someone other than the landowner to conduct an activity on private land. For example, a utilities company may have an easement on private land to allow access to power lines. An easement is recorded on the land title and applies to a defined area of land. The easement sets out the limits of use and the rights and responsibilities of both groups involved. The landowner is still free to use the land and the landholder is paid in advance for negative impacts as part of establishing the easement.

Easements in the context of water on private land

It is well recognised that water that leaves the river channel can have a number of impacts on private land. Sometimes overbank flows can be beneficial to farm productivity (improved pasture growth, watering of vegetation used as stock shelter, etc), depending on when, how often and for how long the flows are delivered. At other times, overbank flows have negative impacts for landholders.

Impacts of water on agricultural land include damage to pastures and fences, interrupted access to land, reduced hay/silage production, the need to relocate stock, and the number of days that stock have to be kept off a wet area. There can also be things that landholders have to do after the water has retreated, including fixing up fences, cleaning up river debris, or managing weeds.

With easements, payment is made to the landholder in recognition of the fact that overbank flows can change the production and use of agricultural land. The payment is granted for managed overbank flows only, not flows that would have happened without management intervention (e.g. as a result of high rainfall). The payment is made once, but importantly it is calculated to include the cumulative impacts of managed events into the future.

The frequency, timing and duration of proposed managed flows is included in figuring out what an easement should cost. It is recognised that these three things can change the degree to which agricultural land is affected by managed overbank flows.

An easement arrangement provides certainty to both landholder and river manager. This includes defining boundaries around how high managed river flows for environmental purposes are allowed to go at an individual property scale.

Where has this been done before?

Basin governments have yet to make a decision about whether to proceed with planning and implementing constraints projects (June 2016). The following information is provided as an example of an easements process that has been conducted downstream of Hume Dam.

IMPORTANT NOTE: The following information is not intended to describe or prescribe a future easements process if constraints projects do move ahead to planning and implementation.

River Murray, Hume to Yarrawonga – establishing the right for river operators to release 25,000 ML/day downstream of Hume Dam

Easements have been established along the River Murray downstream of Hume Dam. Through the 1990s and 2000s, the Murray–Darling Basin Commission (MDBC, now MDBA) worked with landholders to obtain the right to release 25,000 ML/day from Hume Dam. This flow of water was required to meet peak irrigation demand in the River Murray. It was recognised that flows of this volume inundated private land and had adverse impacts for landholders along the Murray River to Yarrawonga.

In recognition of these impacts, easements were purchased to enable flows of this volume to pass. The water authorities also upgraded some low-lying infrastructure (e.g. private roads and bridges) and implemented a number of programs to protect against adverse changes to the river channel (e.g. riverbank erosion, bank slumping etc.)

The easement process

A reference group was established to consider a number of ways water authorities could negotiate permission to put water onto private land. The reference group consisted of floodplain landholders, professional land valuers, agriculturalists, MDBC staff and downstream water users. The reference group considered covenant, property purchase and easement processes and concluded that establishing easements were the preferred process to obtain permission.

The guidelines for establishing an agreement were set by MDBC, and included the need to establish lasting, voluntary landholder agreements; recognise erosion issues; and be forward looking.

The process was delivered according to a set of agreed principles that were transparent and robust, and a consistent approach was used for development of all landholder easements based on disaggregated land worth, and the type and degree of impact compared with pre-managed flow conditions.

Easement values – what was considered?

The reference group, governments and water authorities worked closely with riverbank landholders over a number of years to investigate how easement values should be calculated (Figure A5). This involved:

- individual property visits
- verifying where water flowed at certain volumes
- aerial surveys
- community feedback
- scientific advice.

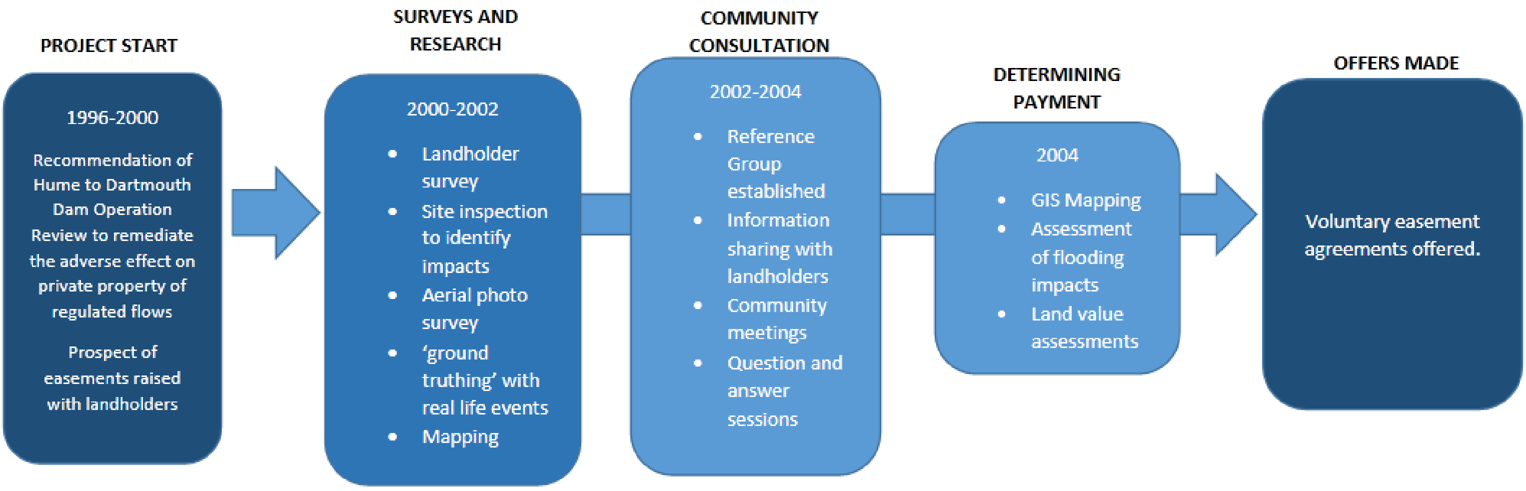


Figure A5 The process of determining easements for the River Murray downstream of Hume Dam

This all helped to build a picture of what direct and indirect impacts are caused by overbank flows. Some of the impacts considered in the Hume to Yarrawonga process included soil water logging, damage to pastures and crops, damage to fences, erosion, spread of red gum saplings and limited access to areas of land.

The outcome

At the end of four-year consultation process, a voluntary easement payment offer was made to riverbank landholders. There was no compulsory acquisition of easements and the offer was left open for over 12 months. The easements agreements set out the limits of the water authority and gave certainty to landowners in knowing what areas were likely to get wet from higher regulated water releases.

A riparian (riverbank) health program was also implemented to mitigate any negative environmental effects of increased managed flows. This included revegetation projects and stabilising banks to reduce erosion. Affected roads and crossings were also upgraded.

Constraints Management Strategy prefeasibility costings for easements

During the prefeasibility stage of the Strategy, easement costings were estimated for each reach in order to prepare initial advice on the potential costs associated with mitigating the negative impacts of higher managed flows on private landholders.

These costings were a broad estimate and made a number of assumptions about the area of land affected and the value of the land. The purpose of the prefeasibility cost estimates was to inform decisions by Basin governments about whether to proceed to the feasibility phase and undertake further studies, not specific investment decisions.

Prefeasibility cost estimates can be found on the MDBA website.[17]

From 2015 to June 2016, the feasibility phase of the Strategy is developing detailed business cases for constraints management, including better refining the assumptions behind the cost estimates of the prefeasibility phase.

Basin governments will decide whether constraints business cases will progress to the planning and implementation phase by June 2016. If this happens, more detailed work would be needed to establish a transparent and fair process in order to move towards negotiating easements to allow managed water onto private land.

[17] www.mdba.gov.au/media-pubs/publications/constraints-management-cost-estimates-report

Appendix 7 Flow interactions between tributaries and the main stem

Constraints work is looking at potential changes to managed flow footprints along the main stem of the Goulburn River. The intent of constraints work is not to change the flow regime of unregulated tributaries.

The Goulburn River is characterised by a large number of unregulated tributaries that add flow into the main stem. There is therefore an obvious connection between what happens in tributaries and main-stem flows. Flow interactions are particularly important in the areas where tributaries meet the river (confluences), but effects can also extend further upstream along tributaries.

When main-stem river levels are high (at or near channel capacity), community members have raised concerns that this can affect the ability of water in tributaries to drain freely. If tributaries are not able to drain freely, the tributary water can start to back up causing flooding issues for tributary landholders.

There are two main factors that affect the ability of tributaries to drain freely:

- size of flow (discharge) coming down the tributary and its duration
- size of flow (discharge) coming down the main stem and its duration.

Big flows down tributaries can lead to a situation where water cannot ‘get away’ into the Goulburn River quickly enough. As many of the tributaries in the Goulburn have headwaters in steep terrain, these rivers quickly collect water from their catchments and can rise very rapidly. If flows are large enough that the water cannot enter the main stem quickly enough, water spreads out onto the river flats of private properties.

Often when tributaries have high flows due to rainfall events, the main stem of the Goulburn can also be relatively high, and the issue of reduced ability to drain freely is made worse. There are also occasions where the main stem of the Goulburn is high due to extended releases from Lake Eildon as part of pre-release flood operations.

Local landholders have described such a situation where in 2012 extended winter pre-releases coincided with large flows in a number of tributaries. This resulted in reports of ‘unusual patterns of flooding’ for some tributary landholders (e.g. along the lower Yea River). The significance of the tributary landholder impact was that it was for extended duration (10 days) rather than short and sharp (one or two days). Extended duration inundation is much more damaging to pastures, particularly hay and silage production and farm productivity.

> *In 2012, the Yea River had floods on 23 June, 3 July, 12 July, 11 August and 18 August. The longest period that we had floodwaters over our property was 10 days, which is abnormal.*
> *In my experience over a lifetime it usually falls completely in two days but can remain up till five days if there is follow-up rainfall, but this was twice as long as normal. Mainly the water will have receded to in-bank flows in 24 hours.*

The photo below, taken 18 August 2012, is flooding on our property along the Yea River, the second-largest upstream tributary to the Goulburn River.
The Bureau of Meteorology, according to flows recorded at the Yea River streamflow gauge, showed a flow level of 1.51 m which does not even reach the minor flood level of 1.8 m and therefore no flood warning was given.

Extended duration floodwaters along the Yea River, 18th August 2012

There has been a suggestion that it was the extended duration pre-releases from Lake Eildon that exacerbated the tributary flooding in 2012, with high Yea River flows meeting high Goulburn River flows and being unable to drain away effectively.

It is important to put main-stem flow rates into context with the size of the tributary flows that were occurring (Figure A6). As part of flood operations to manage a close-to-full storage, in 2011 and 2012 there were extended duration pre-releases from Lake Eildon. In comparison, there were no pre-releases in 2010 as Lake Eildon was in storage mode (filling after the extended drought).

- In 2010, there were flooding impacts for both main-stem and tributary landholders as this was a region-wide large-scale flooding event, but tributary flooding was not influenced by the operation of Lake Eildon as only small releases were being made.
- In 2011, although there were extended pre-releases from Lake Eildon, they didn't coincide with the flow peak coming down the Yea River in mid-August. There were no extended duration flooding impacts reported by Yea River tributary landholders.
- In 2012, with six flow peaks coming down the Yea River of varying sizes between June and August coinciding with extended pre-releases from Lake Eildon there were extended flood duration impacts reported by tributary landholders in August.

There is obviously the potential for significant flow interactions between tributaries and the main stem of the Goulburn River. The exact nature of the relationship remains unclear, except that drainage and flooding issues for tributary landholders seems to arise when high main-stem and tributary flow rates coincide. The relationship between tributary and main-stem flows and the potential for backing up requires further work to better understand the risks, extent and implications for tributary landholders from potential changes to managed releases from Lake Eildon as part of constraints work.

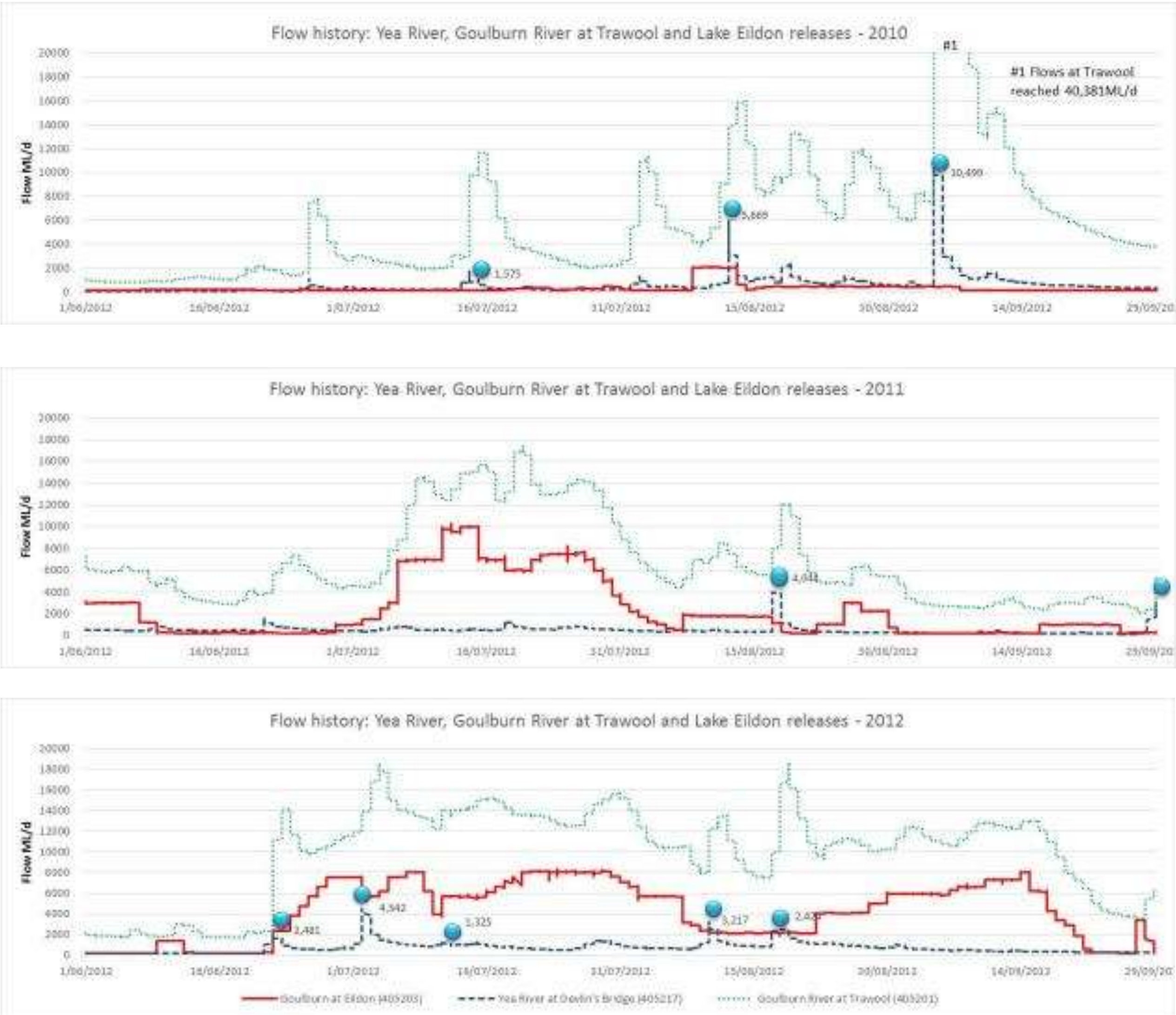


Figure A6 Winter–spring flow history of the Yea River, Goulburn River at Trawool and Lake Eildon, 2010, 2011, 2012

References

Cottingham, P, Stewardson, M, Crook, D, Hillman, T, Oliver, R, Roberts, J & Rutherford, I 2007, *Evaluation of summer inter-valley water transfers from the Goulburn River*, report prepared for the Goulburn Broken Catchment Management Authority, Shepparton.

Cottingham, P, Stewardson, M, Crook, D, Hillman, T, Roberts, J & Rutherford, I 2003, *Environmental flow recommendations for the Goulburn River below Lake Eildon*, Cooperative Research Centre for Freshwater Ecology and Cooperative Research Centre for Catchment Hydrology, Melbourne.

CSIRO (Commonwealth Scientific and Industrial Research Organisation) 2008, *Water availability in the Goulburn–Broken*, report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project, CSIRO, Australia.

Davies, PE, Harris, JH, Hillman, TJ & Walker KF 2008, *SRA report 1: a report on the ecological health of rivers in the Murray–Darling Basin*, *2004–2007*, prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council, Murray–Darling Basin Commission, Canberra.

Davies, PE, Stewardson, M, Hillman, T, Roberts, J & Thoms M 2012, *Sustainable rivers audit 2: the ecological health of rivers in the Murray-Darling Basin at the end of the Millennium Drought (2008–2010)*, prepared by the Independent Sustainable Rivers Audit Group for the Murray–Darling Basin Ministerial Council, MDBA publication 76/12, Murray–Darling Basin Authority, Canberra.

DSE (Department of Sustainability and Environment) 2009, *Northern Region Sustainable Water Strategy*, DSE, Victoria, <www.water.vic.gov.au/initiatives/sws/northern>.

DSE (Department of Sustainability and Environment) 2011, *Overbank flow recommendations for the Lower Goulburn River*, DSE, Victoria.

Feehan, P 2012, 'RCS outline for asset class information', unpublished report, Goulburn–Broken CMA, Shepparton (cited in GB CMA 2013a).

GB CMA (Goulburn Broken Catchment Management Authority) 2002, *Goulburn Broken Regional Floodplain Management Strategy*, GB CMA, Shepparton, viewed August 2014, <www.gbcma.vic.gov.au/downloads/FloodplainManagement/RegionalFPMStrategyFinal-Published.pdf>.

GB CMA (Goulburn Broken Catchment Management Authority) 2012, *Goulburn River Seasonal Watering Proposal 2012–2013,* GB CMA, Shepparton, viewed August 2014, <www.gbcma.vic.gov.au/downloads/Annual_Watering_Plans/2012-04-27_Goulburn_River_Seasonal_Watering_Proposal_2012-13_Final.pdf>.

GB CMA (Goulburn Broken Catchment Management Authority) 2013a, *Goulburn Broken Regional Catchment Strategy 2013–2019,* GB CMA, Shepparton, viewed August 2014, <www.gbcma.vic.gov.au/downloads/RegionalCatchmentStrategy/GBCMA_RCS_2013-19.pdf>.

GB CMA (2013b) *Goulburn River Seasonal Watering Proposal 2013–14,* GB CMA, Shepparton, viewed August 2014, <www.gbcma.vic.gov.au/downloads/Annual_Watering_Plans/Goulburn_River_Seasonal_Watering_Proposal_2013-14_-_Final.pdf>.

Koster, W, Crook, D, Dawson, D & Moloney, P 2012, 'Status of fish populations in the Lower Goulburn River (2003–12)', unpublished report by the Arthur Rylah Institute for Environmental Research for the Goulburn Broken Catchment Management Authority, Department of Sustainability and Environment, Heidelberg, Victoria.

Montecillo, O 2012, 'Analysis of economic data: Goulburn Broken Catchment', unpublished report, Department of Primary Industries, Victoria (cited in GB CMA 2013a).

NWC (National Water Commission) 2010, *Australian environmental water management report 2010*, NWC, Canberra.

SMEC (Snowy Mountain Engineering Corporation) 1998, *lower Goulburn levee audit — modified Findlay Scheme report*, consulting report for Goulburn Broken Catchment Management Authority.

Trueman, W 2012, *True tales of the trout cod: river histories of the Murray-Darling Basin (Goulburn River catchment booklet)*, MDBA publication 02/12, Murray–Darling Basin Authority, Canberra.

Map sources

Australian Government Department of Agriculture, Fisheries and Forestry 2005, © Australian Water Resources Assessment 2000 database.

Geoscience Australia, © GEODATA 250K Series 3 (2008), Topo 1 million data (2001), AusHydro V2.1 (2010), 1 Second DEM V1 (2011).

Goulburn Broken Catchment Management Authority © CMA Strategic Levee Audit.

Murray–Darling Basin Authority 2014, © Flood inundation mapping.

SPOT IMAGE 2010, © SPOT imagery.