Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Lower Goulburn River

OCTOBER 2011 V1.0

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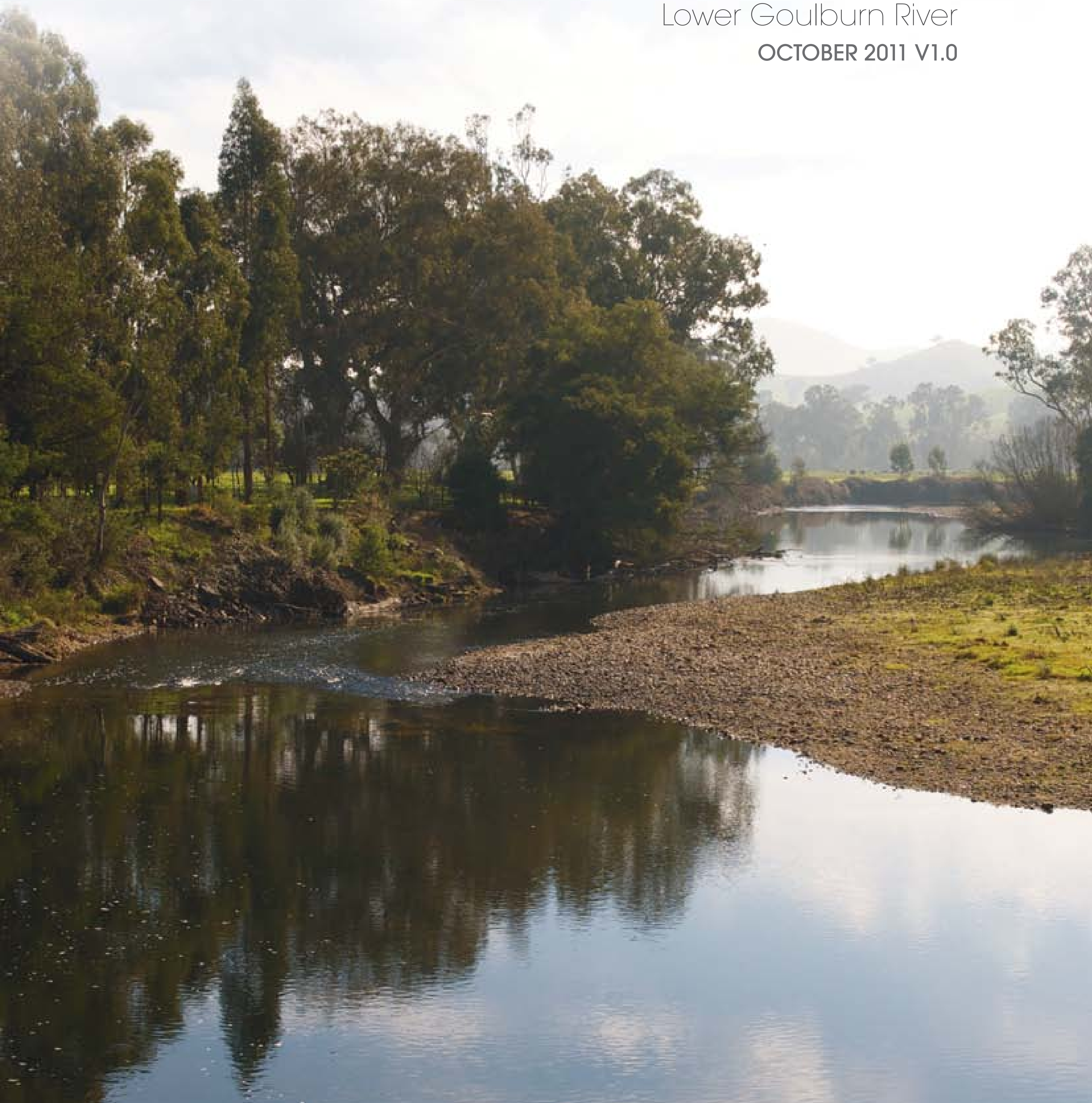

Environmental Water Delivery: Lower Goulburn River

Increased volumes of environmental water are now becoming available in the Murray Darling Basin and this will allow a larger and broader program of environmental watering. It is particularly important that managers of environmental water seek regular input and suggestions from the community as to how we can achieve the best possible approach. As part of the consultation process for Commonwealth environmental water we will be seeking information on:

- community views on environmental assets and the health of these assets
- views on the prioritisation of environmental water use
- potential partnership arrangements for the management of environmental water
- possible arrangements for the monitoring, evaluation and reporting (MER) of environmental water use.

This document has been prepared to provide information on the environmental assets and potential environmental water use in the Lower Goulburn River.

The Lower Goulburn River supports a number of important ecological values which have been recognised at national, regional and local scales. Ecological values include the presence of a number of threatened species of flora and fauna, intact native fish populations and areas of healthy riparian vegetation. Potential water use options for the Lower Goulburn River include the provision of baseflows for Reaches 4 and 5 as well as the provision of flow freshes in winter-spring and summer-autumn. This is expected to enable growth, reproduction and small-scale recruitment for a range of flora and fauna, including native fish.

A key aim in undertaking this work was to prepare scalable water use strategies that maximise the efficiency of water use and anticipate different climatic circumstances. Operational opportunities and constraints have been identified and delivery options prepared. This has been done in a manner that will assist the community and environmental water managers in considering the issues and developing multi-year water use plans.

The work has been undertaken by consultants on behalf of the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon and discussions have occurred with organisations such as the Victorian Department of Sustainability and Environment, Goulburn-Murray Water, Goulburn Broken Catchment Management Authority and the Murray-Darling Basin Authority.

Management of environmental water will be an adaptive process. There will always be areas of potential improvement. Comments and suggestions including on possible partnership arrangements are very welcome and can be provided directly to: ewater@environment.gov.au. Further information about Commonwealth environmental water can be found at: www.environment.gov.au/ewater.

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Acronyms

ACRONYM	MEANING
ARI	Average recurrence interval
BE	Bulk Entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EVC	Ecological vegetation classes
eWater CRC	eWater Cooperative Research Centre
FSL	Full Supply Level
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
G-MW	Goulburn-Murray Water
GSM	Goulburn Simulation Model
ISC	In Stream Condition
MDBA	Murray-Darling Basin Authority
NERWMP	North East Regional Water Monitoring Partnership
NRSWS	Northern Region Sustainable Water Strategy
NVIRP	Northern Victorian Irrigation Renewal Project
QOR	Qualification of Rights
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SKM	Sinclair Knight Merz
SRA	Sustainable Rivers Audit
TLM	The Living Murray program
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWQMN	Victorian Water Quality Monitoring Network

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided in this document is intended to help establish an operational framework that provides scalable strategies for environmental water use based on the watering needs of selected assets. This document outlines the processes and mechanisms that will enable water use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. It specifically targets large scale water use options for the application of large volumes of environmental water.

To maximise the system's benefit, three scales of watering objectives are expressed:

1. Water management area (individual wetland features/sites within an asset).
2. Asset objectives (related to different water resource scenarios).
3. Broader river system objectives across and between assets.

Information provided focuses on the environmental watering objectives and water use strategy for the Lower Goulburn River in northern Victoria, including options for the use of water held in Goulburn storages.

As part of this project, assets and potential watering options have been identified for regions across the Basin. This work has been undertaken in three steps:

1. Existing information for selected environmental assets has been collated to establish asset profiles, which include information on hydrological requirements and the management arrangements necessary to deliver water to meet ecological objectives for individual assets.
2. Water use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) that are either currently in operation at each asset or methodologies that could be applied for accurate accounting of inflow, return flows and water 'consumption'
   - decision triggers for selecting any combination of water use options
   - approvals and legal mechanisms for delivery and indicative costs for implementation.

1.2 Catchment and river system overview

The Goulburn River extends from the northern slopes of the Great Dividing Range north to the Murray River near Echuca. It has a mean annual discharge for the catchment of approximately 3,200,000 ML (CSIRO 2008), 50 per cent of which on average is diverted for use. The two major water regulation structures on the river are Lake Eildon and Goulburn Weir. The mid sections of the Goulburn River between Lake Eildon and Shepparton have a confined floodplain (up to four kilometres wide). Constructed levees confine the floodplain along the Lower Goulburn River below Shepparton. Flood water leaving the channel of the Lower Goulburn River downstream of Shepparton either returns to the channel (where blocked by levees), or flows north via the Deep Creek system that discharges to the Murray River downstream of Barmah. The Broken River is a major tributary of the Goulburn River, discharging at Shepparton.

Lake Eildon has a capacity of approximately 3,334,000 ML, and provides water to the majority of the Shepparton, Central Goulburn, Rochester and Pyramid/Boort irrigation areas (some volumes are also contributed by the Loddon and Campaspe Rivers). Water is diverted at Goulburn Weir (located eight kilometres north of Nagambie) into the East Goulburn Main Channel and is harvested into Waranga Basin (capacity 432,000 ML) via the Stuart Murray Canal and Cattanach Canal.

The storage and release of water in Lake Eildon has significantly altered the hydrology of the Goulburn River. Filling in winter to spring and releases to meet irrigation and consumptive demand mean that high flows in the mid Goulburn River channel now occur in summer to autumn, while low flows occur in winter to spring due to harvesting in Lake Eildon. Below Lake Eildon flows increase progressively due to tributary inflows. The natural seasonal flow pattern is retained below Goulburn Weir (where water is diverted to meet irrigation and consumptive demand), but is substantially reduced in volume from natural conditions. The recent decommissioning (2009-10) of Lake Mokoan means that additional water is likely to enter the Goulburn River from the Broken River during winter to spring. This is expected to bolster the natural pattern of higher flows in winter to spring and lower flows in summer to autumn in the Lower Goulburn River.

The Lower Goulburn River is a high value wetland system. The floodplain consists of a large area of habitat for fauna such as waterbirds and fish. It has a wide variety of wetland types and vegetation types, and is an excellent example of a major floodplain system.

Environmental flow recommendations have been developed for the Goulburn River (Cottingham et al. 2003, 2007), based on five representative reaches of the river (Figure 1). The information and recommendations contained in this document are based on the environmental watering needs of the Lower Goulburn River, being Reach 4 (Goulburn Weir to Shepparton) and Reach 5 (Shepparton to the Murray River) (Cottingham et al. 2003, 2007).

1.3 Overview of river operating environment

Regulation of flows along the Goulburn River downstream of Lake Eildon is managed by Goulburn-Murray Water (G-MW). Water sources for the regulated section of the Goulburn River comprise releases from Lake Eildon and tributary inflows. Flows reaching Goulburn Weir are diverted to the East Goulburn Main Channel and to Waranga Basin (via the Stuart Murray Canal and the Cattanach Canal) to meet irrigation, stock and domestic, and urban demand. Water is also released from Goulburn Weir to the Lower Goulburn River. Downstream of Goulburn Weir, the river collects tributary inflows (including the Broken River) and irrigation drain inflows prior to discharging to the Murray River near Echuca.

The region's regulated surface water resources are covered by bulk entitlements for water allocation from the Broken River and the Goulburn River and its tributaries for all urban water use. There are private diverter licences in unregulated parts of the catchment.

In 2005-06 there was 1,958,600 ML of bulk entitlement and 28,900 ML of licensed private diversion (CSIRO 2008). The Murray-Darling Basin cap on surface water diversions is set at 2,034,000 ML for the combined Goulburn, Broken and Loddon systems (CSIRO 2008). The environmental water reserve for the Goulburn Basin includes 124,600 ML held by the Victorian Environmental Water Holder (VEWH), and passing flows released as a condition of consumptive bulk entitlements held by G-MW. However, most of the environmental entitlement volume is not for the Goulburn River but for the Murray and Snowy Rivers.

Goulburn Valley Water and North East Water are responsible for the urban water supply in the Goulburn-Broken region. Coliban Water also diverts water from the Waranga Western Channel for urban water supply. G-MW is responsible for the supply of bulk raw water in the regulated river systems to these urban water corporations and manages the delivery of the raw water through the channel system. G-MW is also responsible for managing groundwater and unregulated surface water licensed diversions from the Goulburn-Broken catchment. G-MW operates Lake Eildon, Goulburn Weir, Waranga Basin and Greens Lake as part of the Goulburn River system and Lake Nillahcootie on the Broken River.

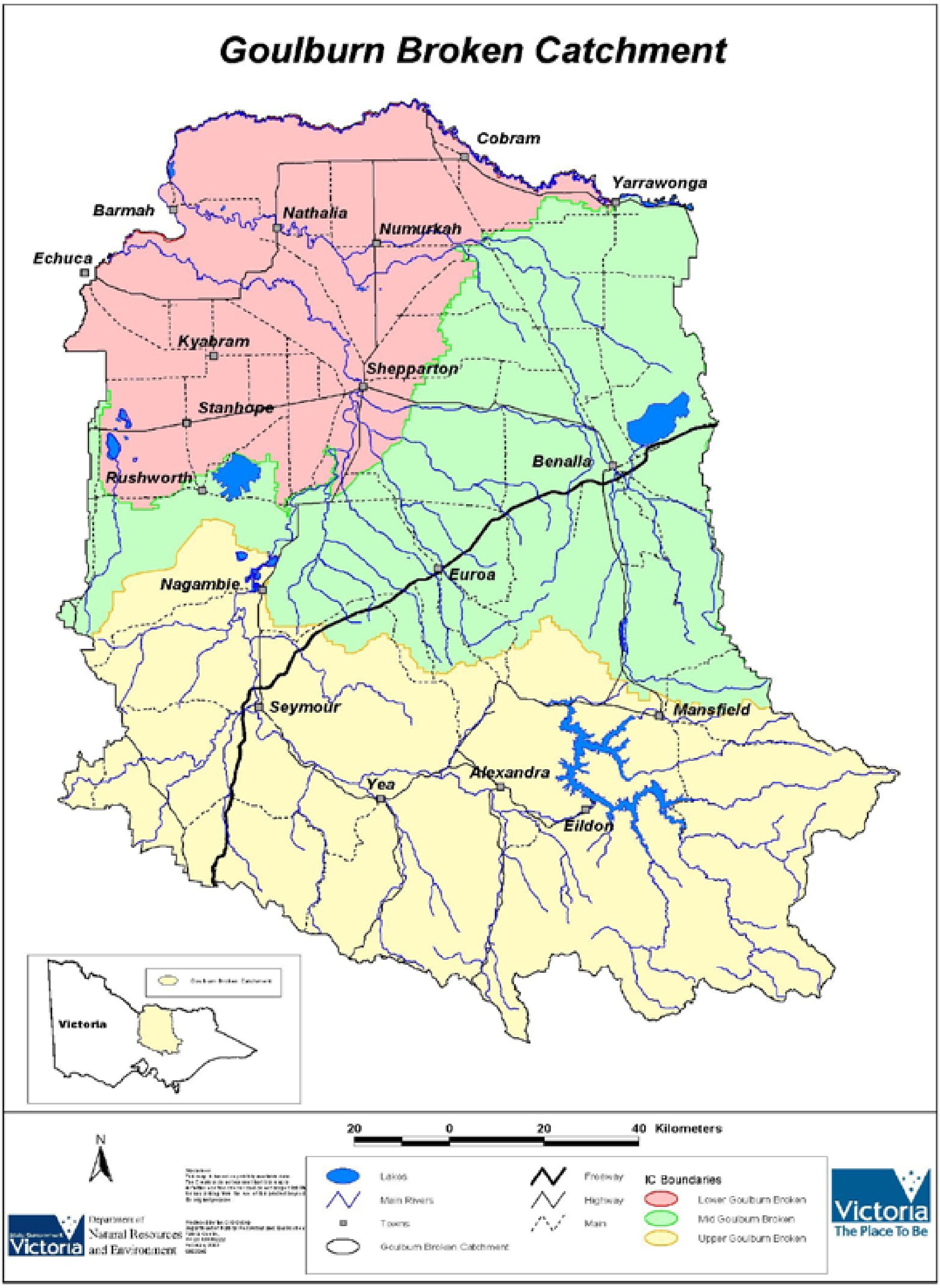

Figure 1: Map of the Goulburn catchment including the 5 reaches of the Goulburn River below Lake Eildon (courtesy DSE).

Environmental water is managed by the Goulburn Broken Catchment Management Authority (GB CMA), in cooperation with G-MW, the Victorian Department of Sustainability and Environment (DSE) and the VEWH. The Goulburn water quality reserve is managed by G-MW.

Environmental flow recommendations have been developed for the five river reaches below Lake Eildon (Cottingham et al. 2003, 2007). This document focuses on the two reaches below Goulburn Weir (Reach 4 and Reach 5), considered in previous environmental flow projects:

- Reach 4: Goulburn River from Goulburn Weir to Shepparton.
- Reach 5: Goulburn River from Shepparton to the Murray River.

Reaches 1-3, which include the Goulburn River from Lake Eildon to Goulburn Weir, were not considered in this project as there is limited scope for the use of environmental water. This is due to irrigation demand, which has resulted in an altered seasonality of flows, rather than a reduction in overall flow volume.

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values for Reach 4 and Reach 5

Ecosystem values associated with the Lower Goulburn River include:

- The presence of intact native fish populations, including species such as Murray cod and golden perch.
- The intact and generally healthy riparian and floodplain areas, including river red gum communities and other ecological vegetation classes and complexes.
- The presence of threatened flora and fauna species (see Appendix 1).
- Its connection with other important rivers and floodplain systems along the Murray River, providing habitat diversity and connection at landscape scales.
- The presence of a number of Ecological Vegetation Classes (EVCs) in the Murray Fans bioregion, including Riverine Grassy Woodland, Sedgy Riverine Forest and Floodplain Riparian Woodland, as well as protecting areas of endangered Plains Woodland and Riverine Chenopod Woodland along the Murray River.
- The presence of a diversity of habitats including permanent and temporary wetlands found within the floodplain (including billabongs, sloughs, marginal swamps, potholes, scroll swales, anabranches and cut-off loops), and key wetlands such as the Gemmills Swamp nature conservation reserve and Reedy Swamp state wildlife reserve and Loch Garry Wildlife Management Cooperative Area.

Ecological values associated with the Lower Goulburn River are recognised by:

- Its listing under the Directory of Important Wetlands in Australia as an wetland of national importance.
- Its status as a National Park (forests between Echuca and Shepparton).
- Its declaration as a Heritage River.

In addition to its own intrinsic values, the Lower Goulburn River is important at a regional scale, complementing the ecosystem values recognised at nearby assets such as the Barmah-Millewa Forest and Gunbower Forest. Water from the Goulburn River discharges to the Murray River upstream of Gunbower Forest and contributes to the watering of this important Ramsar-listed site. The Lower Goulburn River also meets a number of criteria applied by the Murray-Darling Basin

Authority (MDBA 2010) in selecting hydrologic indicator sites (Table 1), which are recognised as key environmental assets across the Murray-Darling Basin.

Table 1: MDBA key environmental asset criteria met by the Lower Goulburn River floodplain (MDBA 2010).

Criterion	Description	Values
1	The asset is recognised in and/or is capable of supporting species listed in, international agreements.	The Lower Goulburn River floodplain is formally recognised in, or is capable of supporting species listed in the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) or the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). For a full list of species listed under Commonwealth legislation that have been recorded at the Lower Goulburn River Floodplain refer to Appendix 3.
3	The asset provides vital habitat.	The Lower Goulburn River Floodplain's ecological features make it a high-value wetland system. The floodplain consists of a large area of habitat for fauna such as waterbirds and fish (Department of the Environment, Water, Heritage and the Arts 2009h).
4	The asset supports Commonwealth-, state-, or territory-listed threatened species and/or ecological communities.	The Lower Goulburn River Floodplain meets this criterion because it supports species listed as threatened under Commonwealth or state legislation. For a full list of species that have been recorded refer to Appendix 3.

2.2 Broad-scale ecosystem objectives

The *Goulburn Broken Regional River Health Strategy 2005-2015* (GB CMA 2005) aims to achieve four main objectives:

1. Enhance and protect the rivers that are of highest community value from any decline in condition.
2. Maintain the condition of ecologically healthy rivers (as defined in the Victorian River Health Strategy).
3. Achieve an 'overall improvement' in the environmental condition of the remainder of rivers.
4. Prevent damage from inappropriate development and activities.

Additional ecosystem objectives have also been proposed by the MDBA (2010), and are outlined in Table 2.

Table 2: Proposed objectives and targets for the Lower Goulburn River Floodplain hydrologic indicator site (MDBA 2010).

Objectives	Justification of targets	Target
1. To protect and restore water-dependent ecosystems that support migratory birds listed in international agreements. (Criteria 1). 2. To protect and restore water-dependent ecosystems that provide vital habitat. (Criteria 3). 3. To protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and/or ecological communities.	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any decrease in the current area of wetlands would signal a change in ecological character.	Maintain 100% of current extent of wetlands in good condition.
Objectives 1 to 3	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any change in the current area or health of vegetation communities would signal a change in ecological character.	Maintain 100% of current extent of red gum forest in good condition. Maintain 100% of current extent of red gum woodland in good condition.
Objectives 1 to 3	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any reduction in the recorded frequency and abundance of bird breeding or number of bird species would signal a change in ecological character. Interim ecological objective under The Living Murray program.	Provide conditions conducive to successful breeding of waterbirds.

More specific ecosystem objectives for the Lower Goulburn River, consistent with the general objectives stated for the *Goulburn Broken Regional River Health Strategy 2005-2015* (GB CMA 2005) and those proposed by the MDBA (2010), have been used when developing environmental flow recommendations (Cottingham et al. 2003) to meet the needs of vegetation, macroinvertebrates and native fish.

Objectives relating to aquatic and riparian vegetation are to:

- enhance the extent and diversity of aquatic vegetation (in-channel and wetlands)
- contribute to processes such as river productivity
- maintain diversity of river bank vegetation
- reduce the extent and impact of weeds
- maintain continuity and cover of river bank vegetation
- enhance the extent and diversity of aquatic vegetation.

Objectives relating to macroinvertebrates are to:

- maintain or restore a trophic structure and diversity with a balanced representation of all functional groups
- achieve an Ausrivas O/E scores = Band A
- maintain or restore biomass to equivalent level of rivers elsewhere (e.g. Ovens)
- maintain dynamic, diverse food webs that support higher organisms and contribute to river health.

Objectives relating to native fish are to provide:

- suitable in-channel habitat for all life stages
- suitable off-channel habitat for all life stages
- passage for all life stages
- cues for adult migration during spawning season
- access to floodplain and off-channel habitats for spawning and/or larval rearing
- low flows for recruitment and survival
- floodplain and bench inundation for the exchange of food and organic material between the floodplain and channel.

Cottingham et al. (2007) also identified the following ecosystem objectives for geomorphology processes and in-channel primary production (phytoplankton, periphytic algae and macrophytes):

- maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity
- support dynamic, diverse food webs for phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition which more closely resembles un-impacted sites.

The full list of flow-related ecosystem objectives proposed by Cottingham et al. (2007) is presented in Appendix 2.

Cottingham et al. (2003 and 2007) used the FLOWS method to assist in the identification of critical flow components, as part of the total flow regime, to protect, sustain or restore specific flow dependent assets or values. The key elements of the FLOWS process include (DNRE 2002):

- an objective setting process that links environmental objectives to flow objectives and recommendations
- the use of an environmental flows scientific panel
- the use of hydrologic and hydraulic analysis tools in the interpretation and development of recommendations.

3. Watering objectives

The 2003 study by Cottingham et al. examined how water that might be released from Lake Eildon to the Murray River as part of The Living Murray initiative could be used to protect or enhance the ecological condition of the Goulburn River. At that time, the study could only make limited assessments of future water delivery scenarios, as there was no information on the volume and timing of water that might be required for the Murray River. There was also only very limited information from which to develop recommendations for watering floodplain areas, and these were limited to recommendations for the reach immediately below Lake Eildon.

After 2003, the expansion of water markets led to increased inter-valley transfers (IVTs) and the possibility of significant use of IVTs in the Lower Goulburn River, particularly between January and March (Cottingham et al. 2007). The scientific panel that developed environmental flow recommendations in 2003 was reconvened in 2007 to consider the implications of summer IVTs for the Lower Goulburn River. This subsequent study was somewhat restricted in scope as it focused on in-channel IVTs and did not include specific flow-related ecosystem objectives for the floodplain and wetlands. However, some overbank flows were recommended based on in-channel and riparian process objectives.

Overall, the overbank recommendations in 2003 and 2007 were developed on a hydrological basis, rather than to specifically meet defined floodplain ecosystem objectives and the riverine objectives influenced by floodplain ecosystems and hydraulics. To fill this gap, DSE completed a study that specifically examined the water requirements of the Lower Goulburn River floodplain (DSE 2011). The study was based on floodplain assets, such as ecological vegetation classes (EVCs) and wetlands, along Reaches 4 and 5 of the Goulburn River. The study concluded that flow events of between 25,000 – 40,000 ML/d (7 years in 10) would maintain or improve the condition of floodplain assets.

3.1 Asset watering objectives

A detailed assessment of ecosystem objectives and their flow requirements was provided by Cottingham et al. (2007) when considering summer inter-valley transfers along the Lower Goulburn River. This study identified a range of flows that would be required to meet objectives and also accounted for inter-annual variability that would be expected under different climatic conditions. A suite of watering options for Reaches 4 and 5 of the Goulburn River are presented in Appendix 2. The 10th percentile, 30th percentile, 50th percentile and 70th percentile years can be considered representative of extreme dry, dry, median and wet years, respectively. This work, along with the floodplain recommendations of DSE (2011), provides the basis for the potential watering options in Table 3, which might be pursued under a range of climatic scenarios.

Table 3 is based on the watering needs of Reach 4 (Goulburn Weir to Shepparton), as this reach has a greater diversity of features and habitats than Reach 5. Releases from Goulburn Weir to meet the watering needs of Reach 4, along with tributary inflows, will also often meet the watering needs of Reach 5. In addition, supplementary releases over and above that required for Reach 4 can be made to meet the needs of Reach 5 based on information in Appendix 2.

It should be noted that the scenarios for extreme dry, dry, median and wet years are only indicative of what might occur during a watering year. Such categorisations infer that a particular year remains constant (i.e. a dry year remains dry) and independent from other scenarios. In reality, climatic and flow conditions can vary seasonally and annually. In addition, climatic conditions are not always indicative of flow conditions and vice versa. For example, a dry spring may be followed by a wet summer, with water availability being that of a median year overall. Climatically, conditions may be dry or very dry, but because of water demand and delivery, flow conditions in a river may be that of a median or wet year.

While the Cottingham et al. (2007) work was instigated to advise on upper flow limits over the summer to autumn period of IVT releases, both it and the work of Cottingham et al. (2003) included floodplain inundation recommendations, suggesting events of between 20,000-60,000 ML/d. Subsequent investigation by the Department of Sustainability and Environment (DSE 2011) found that most of the floodplain features such as EVCs and wetlands were inundated at discharges between 25,000 - 40,000 ML/d. The feasibility of delivering such flood events, including how best to deliver or supplement flows whilst avoiding damage to private property and infrastructure, is an issue requiring further investigation.

Recent flooding (events in 2010 and early 2011) along the Goulburn River following prolonged drought has also removed the chronic need for flood events for the next two to three years, although there are ecosystem benefits with high flow events in consecutive years (e.g. establishment of floodplain and wetland seedlings set the previous year, consecutive bird breeding events). Opportunities to augment tributary inflows and deliver small flood events should be considered as they arise. Blackwater events that have occurred after inundation of the floodplain (e.g. December 2010) serve as a reminder that 'managed' flood events may be more beneficial in winter and spring, when temperatures are lower.

Recent management of the Goulburn River (2007-2010) has been adjusted according to a Qualification of Rights (QoR) (Cottingham et al. 2010). While it is unlikely that such conditions will be imposed again, they can be considered to represent an 'extreme dry' climatic scenario. The QoR specifies a minimum flow of 150 ML/d from Goulburn Weir, down from 250 ML/d under normal conditions as prescribed by the Bulk Entitlement (BE). The QoR also changes the passing flows at the McCoys Bridge gauging station, which is the most downstream gauging site on the Goulburn River, and is located slightly upstream of its confluence with the Murray River:

- For the months of November to June inclusive, a minimum average monthly flow of 250 ML/d at a daily rate of no less than 200 ML/d (previously 350 ML/d and 300 ML/d).
- For the months of July to October inclusive, a minimum average monthly flow of 150 ML/d at a daily rate of no less than 100 ML/d (previously 400 ML/d and 350 ML/d under the BE).

Flow objectives under these and similar circumstances include:

- avoid critical loss of threatened species and communities (Murray cod, golden perch)
- maintain key refuges (deep and shallow water habitat, connection between in-channel habitats)
- avoid irretrievable damage or catastrophic events (minimise low dissolved oxygen (DO) events, fish kills)
- maintain minimum base flows and water quality.

Table 3: Proposed water management objectives for Reaches 4 and 5 under specific water availability scenarios.

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	10^{th} percentile year	30^{th} percentile year	50^{th} percentile year	70^{th} percentile year
Objectives for Reaches 4 and 5	Flow objectives include: • Avoid critical loss of threatened species and communities (Murray cod, golden perch). • Maintain key refuges (deep and shallow water habitat, connection between in-channel habitats). • Avoid irretrievable damage or catastrophic events (minimise low DO events, fish kills). • Maintain minimum baseflow and water quality, opportunistically increasing baseflow where possible.	Flow objectives under these circumstances include: • Maintain water quality. • Increase variability in baseflow. • Increase baseflow to those recommended in environmental flow studies (310-860 ML/d). • Allow winter/spring freshes derived from tributary inflows to pass along the river. • Supplement the number of winter-spring freshes (no upper limit). • Deliver a flow fresh in summer-autumn (up to 6,600 ML/d*). These flows will: • Support the survival and growth of threatened species and communities, including limited small-scale recruitment (Murray cod, golden perch). • Maintain a diversity of in-channel habitats (pools, runs, snags). • Maintain low-flow river functional processes such as planktonic and macrophyte production. • Provide some fluctuation in low flows to vary habitat availability and refresh habitat quality.	Under this scenario, there would be sufficient water available to meet BE requirements. There is also likely to be sufficient water to deliver one or more flow freshes, although this will usually depend on the frequency and magnitude of rainfall-rejection flows (i.e. cancelled irrigation orders). There will be sufficient water available to: • Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna in the low-flow channel (e.g. native fish such as Murray cod, trout cod, golden perch). • Promote connectivity between the river channel and low-lying features such as bars and benches. • Inundate vegetation on the lower levels of the river bank. • Promote watering of riparian vegetation higher up the river bank and onto the floodplain. • Achieve bankfull discharge required to sustain geomorphological processes. • Achieve connection between the river channel and the wider floodplain support high-flow river and floodplain functional processes.	Under this scenario, objectives (over and above those for a median year) will be to: • Enable growth, reproduction and large-scale recruitment for a diverse range of riverine and floodplain/wetland flora and fauna. • Increase habitat availability by increasing winter-spring base flows, and increasing the frequency and/ or magnitude of flow freshes. • Promote watering of riparian vegetation higher up the river bank and onto the floodplain. • Achieve bankfull discharge required to sustain geomorphological processes. • Achieve connection between the river channel and the wider floodplain to support high-flow river and floodplain functional processes.

<table>
<tr><th></th><th colspan="4">Management objectives for specific water availability scenarios</th></tr>
<tr><th></th><th>Extreme dry</th><th>Dry</th><th>Median</th><th>Wet</th></tr>
<tr><th></th><th>Goal: Avoid damage to key ecological assets</th><th>Goal: Ensure ecological capacity for recovery</th><th>Goal:Maintain and improve ecological health and resilience</th><th>Goal: Improve and extend healthy aquatic ecosystems</th></tr>
<tr><th>Water availability</th><th>10th percentile year</th><th>30th percentile year</th><th>50th percentile year</th><th>70th percentile year</th></tr>
<tr><td>Potential use of environmental water</td>
<td>Environmental water can be used to supplement base flows to increase variability in habitat availability, ensure connection between habitats, and help to maintain water quality. Environmental water could also be used to meet the following objectives (Cottingham et al. 2003, 2007), with priority given to supplementing flows from spring as far as possible into summer-autumn:

• 310 ML/d (>80% of the time) Achieves two macroinvertebrate objectives:
1. Provision of conditions suitable for aquatic vegetation, which provides habitat for macroinvertebrates.
2. Provision of slackwater habitat favourable for planktonic production (food source) and habitat for macroinvertebrates.
• 400 ML/d (>93% of the time) Achieves one macroinvertebrate and one native fish objective:
1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates.
2. Suitable in-channel habitat for all small bodied fish life stages.</td>
<td>Environmental water can be used to supplement base flows to increase variability in habitat availability in keeping with the objectives above (Cottingham et al. 2003, 2007), beyond those provided by the BE:

• 500 ML/d (>99% of the time) Achieves one native fish objective:
1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages.
• 540 ML/d (>90% of the time) Achieves two macroinvertebrate objectives:
1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates.
2. Maintenance of water quality suitable for macroinvertebrates.
• 610 ML/d (>90% of the time) Achieves one native fish objective:
1. Provide deep water habitat for large-bodied native fish.
• 830 ML/d (>95% of the time) Achieves one macroinvertebrate objective:
1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates.</td>
<td>Environmental water can be used to supplement winter-spring flows and deliver bankfull and overbank flows to meet various ecosystem objectives (Cottingham et al. 2003, 2007). The difference between this and the dry scenario is that baseflow can be maintained for longer durations, and that freshes (both in winter-spring and summer) can be more frequent or of larger magnitude. However, it should be noted that recent investigations suggest that it will be very difficult to use environmental water to supplement bankfull and overbank flows.

• 500 ML/d (>98% of the time) Achieves one native fish objective:
1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages.
• 540 ML/d (>99% of the time) Achieves two macroinvertebrate objectives:
1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates.
2. Maintenance of water quality suitable for macroinvertebrates.</td>
<td>Environmental water can be used to supplement winter-spring flows and deliver bankfull and overbank flows to meet various ecosystem objectives (Cottingham et al. 2003, 2007). The difference between this and the median year scenario is that baseflow can be maintained for longer durations, and that freshes (both in winter-spring and summer) can be more frequent or of larger magnitude and duration:

• 500 ML/d (>98% of the time) Achieves one native fish objective:
1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages.
• 540 ML/d (>99% of the time) Achieves two macroinvertebrate objectives:
1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates.
2. Maintenance of water quality suitable for macroinvertebrates.
• 610 ML/d (>98% of the time) Achieves one native fish objective:
1. Provide deep water habitat for large-bodied native fish.</td></tr>
</table>

<table>
<tr><th></th><th colspan="4">Management objectives for specific water availability scenarios</th></tr>
<tr><th></th><th>Extreme dry</th><th>Dry</th><th>Median</th><th>Wet</th></tr>
<tr><th></th><th>Goal: Avoid damage to key ecological assets</th><th>Goal: Ensure ecological capacity for recovery</th><th>Goal:Maintain and improve ecological health and resilience</th><th>Goal: Improve and extend healthy aquatic ecosystems</th></tr>
<tr><th>Water availability</th><th>10th percentile year</th><th>30th percentile year</th><th>50th percentile year</th><th>70th percentile year</th></tr>
<tr><td></td>
<td>• 500 ML/d (>98% of the time) Achieves one native fish objective:
1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages.
• 540 ML/d (>80% of the time) Achieves two macroinvertebrate objectives:
1. Entrainment of litter packs available as food/habitat source for macroinvertebrates.
2. Maintenance of water quality suitable for macroinvertebrates.
• 610 ML/d (>80% of the time) Achieves one native fish objective:
1. Provide deep water habitat for large-bodied native fish.
• Bank any excess water for subsequent years.</td>
<td>• 860 ML/d (>94% of the time) Achieves one geomorphology objective:
1. Maintain pool depth.
• Up to 6,600 ML/d (up to 7 days)*
Deliver a flow fresh in summer-autumn that would increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine sediment deposits.
• Up to bankfull**
Deliver a winter-spring flow fresh that would achieve the following objectives:
1. Improvement of macroinvertebrate and native fish habitat quality (e.g. disruption of biofilms, flushing of fine sediments).
2. Entrainment of litter packs available as food/habitat sources for macroinvertebrates.
3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs.
4. Pre-spawning and movement cues for some native fish species (e.g. golden perch).
5. Maintain natural rates of sediment mobilisation and deposition.</td>
<td>• 610 ML/d (>99% of the time) Achieves one native fish objective:
1. Provide deep water habitat for large-bodied native fish.
• 830 ML/d (98% of the time) Achieves one macroinvertebrate objective:
1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates.
• 860 ML/d (100% of the time) Achieves one geomorphology objective:
1. Maintain pool depth.
• Up to 6,600 ML/d (up to 7 days)* Deliver a flow fresh in summer-autumn that would increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine sediment deposits.
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</tr>
</table>

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	10th percentile year	30th percentile year	50th percentile year	70th percentile year
		• Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Bank any excess water for subsequent years.	1. Improvement of macroinvertebrate and native fish habitat quality (e.g. disruption of biofilms, flushing of fine sediments). 2. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates. 3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs. 4. Pre-spawning and movement cues for some native fish species (e.g. golden perch). 5. Maintain natural rates of sediment mobilisation and deposition. • Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Banking of water to supplement catchment inflows for bankfull and overbank events in subsequent years.	2. Entrainment of litter packs available as food/habitat source for macroinvertebrates. 3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs. 4. Pre-spawning and movement cues for some native fish species (e.g. golden perch). 5. Maintain natural rates of sediment mobilisation and deposition. • Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Bank any excess water for subsequent years.

*An upper limit is applied to summer freshes to avoid increased rates of sediment deposition in pools. See Cottingham et al. (2007) for further explanation.

**Information on the frequency, magnitude and duration of freshes is contained in Cottingham et al. (2003).

***For further details, see DSE (2011).

PART 2:
Water Use Strategy

4. Environmental Water Requirements

4.1 Baseline flow characteristics

Current flow is less than natural flow over the non-irrigation season for all reaches of the Goulburn River downstream of Lake Eildon, because of the water being harvested in Lake Eildon during these months. In contrast, summer releases from Lake Eildon for irrigation supply mean that flows are kept unnaturally high between Lake Eildon and Goulburn Weir.

Historically, releases from Lake Eildon during the irrigation season typically peaked at around 10,000 ML/d. In recent years, drought combined with improved farming practices have reduced peak irrigation season releases, which are now in the order of 6,000 ML/d.

Prior to the introduction of inter-valley trading, most of the water released from Lake Eildon for supplying irrigation demands was diverted at Goulburn Weir. Reach 4 and Reach 5 of the Goulburn River are downstream of Goulburn Weir. Consequently, flows through Reach 4 were generally regulated to a minimum of 250 ML/d prior to 2005-06 (72 per cent of the time in the non-irrigation season and 79 per cent of the time in summer). Reach 5 was less regulated, because of the contribution of tributary inflows, such as the Broken River. The difference between the natural and current flow duration curves for Reach 4 and Reach 5 (as modelled in 2006) is shown in Figure 2 to Figure 5.

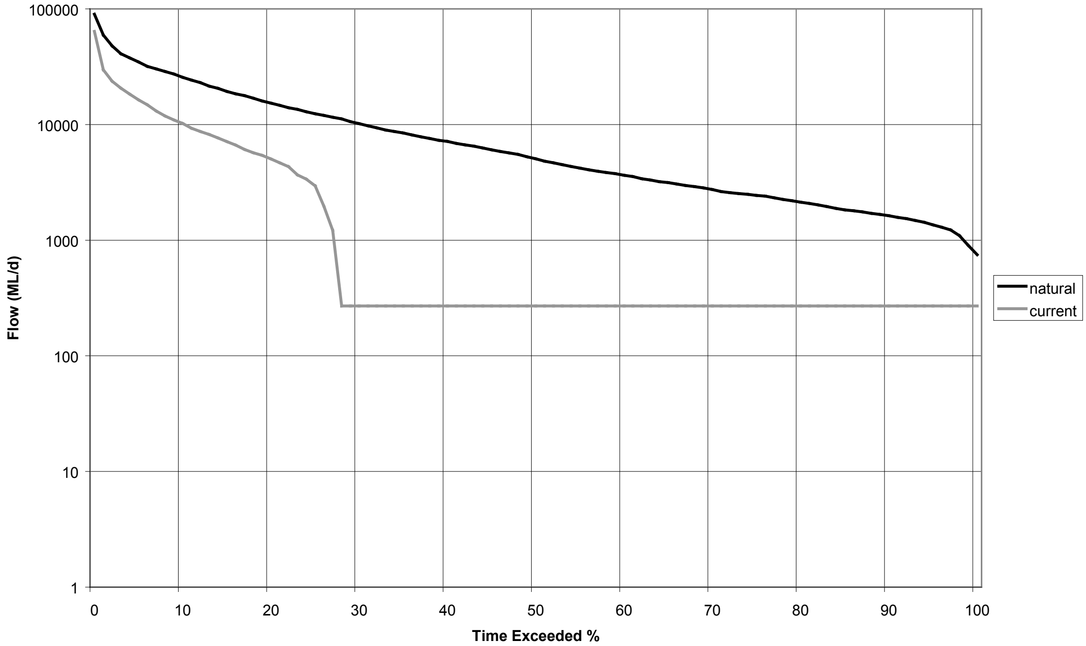

Figure 2: Flow duration curve for the non-irrigation season in the Goulburn River Reach 4, downstream of Goulburn Weir prior to 2006 (SKM 2006).

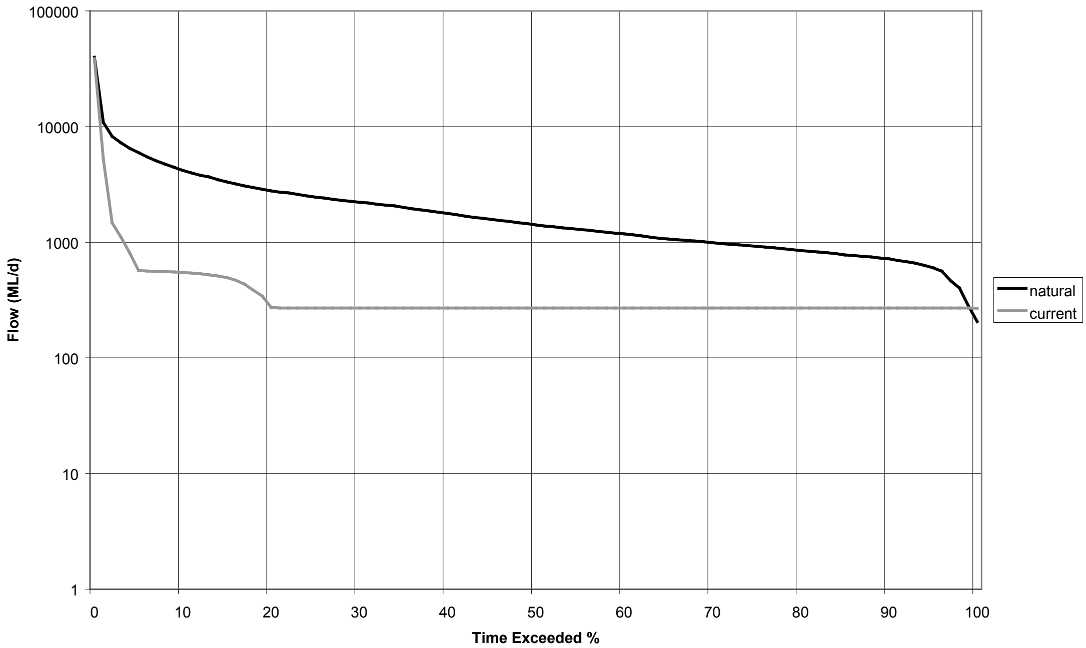

Figure 3: Flow duration curve for summer (Dec-May) in the Goulburn River Reach 4, downstream of Goulburn Weir prior to 2006 (SKM 2006).

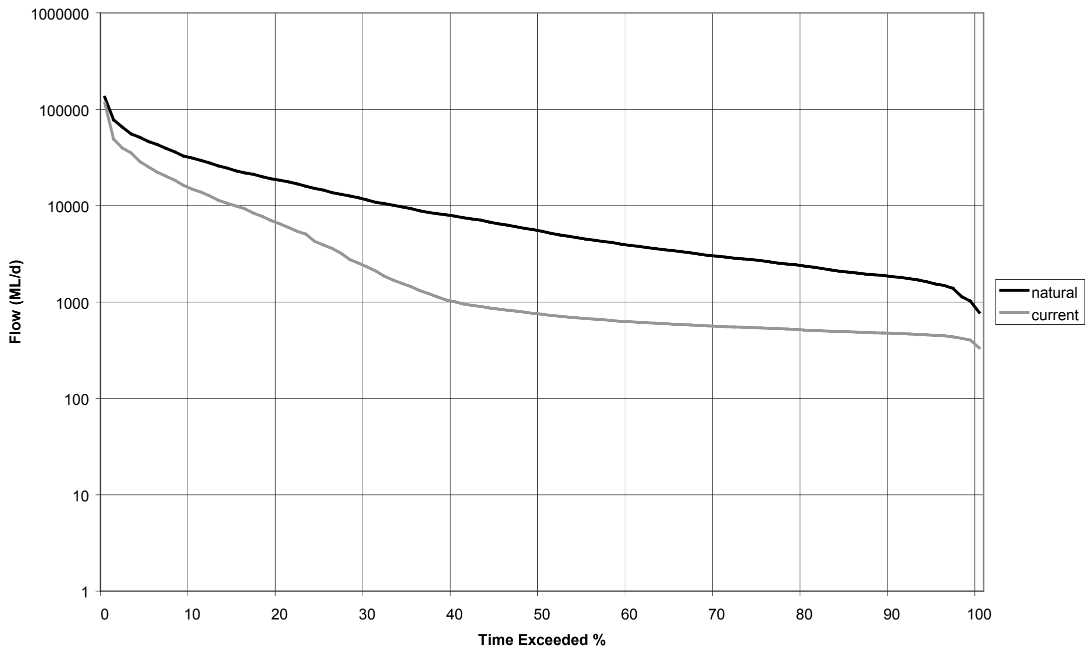

Figure 4: Flow duration curve for non-irrigation season in the Goulburn River Reach 5, Shepparton to the Murray River prior to 2006 (SKM 2006).

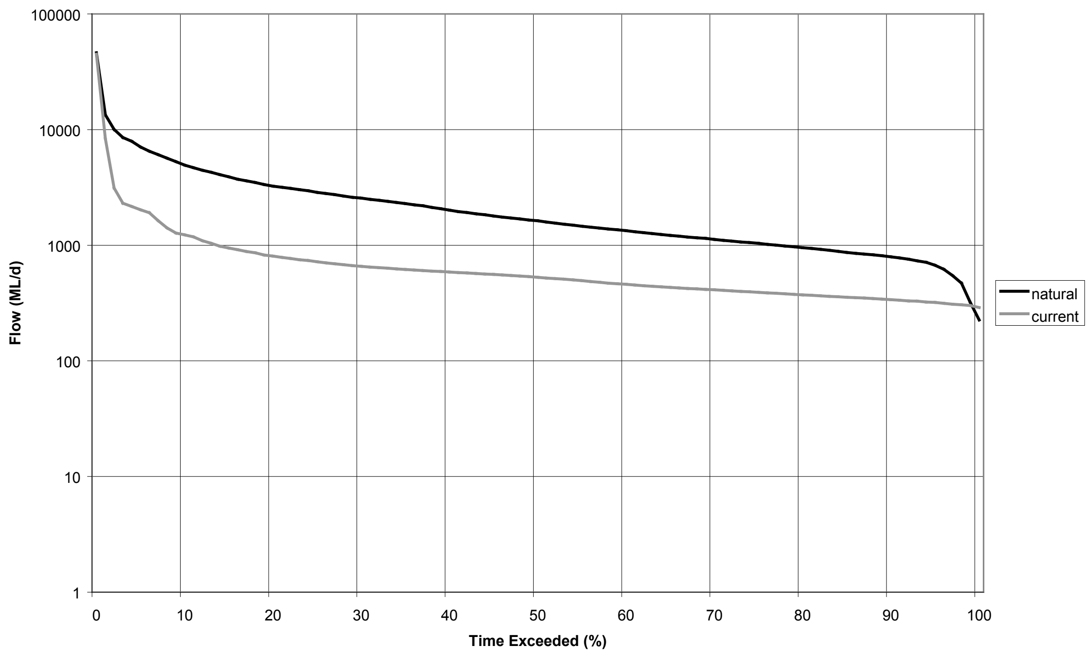

Figure 5: Flow duration curve for summer (Dec-May) in the Goulburn River Reach 5, Shepparton to the Murray River prior to 2006 (SKM 2006).

In more recent times, flows in Reach 4 and Reach 5 during the irrigation season have been increased by inter-valley transfers from Lake Eildon to the Murray River. In 2005-06, inter-valley transfers were delivered in a single period from January to March (Figure 6), but delivery in several shorter duration periods is also possible in any one year. Expectations are that water trades will result in typical inter-valley transfers of 1,000 – 2,000 ML/d, with peaks of up to 4,000 ML/d. However, short duration peaks of up to 8,000 ML/d are considered possible (Cottingham et al. 2007). Note that such transfers could only occur outside periods of significant irrigation demand (at Goulburn Weir) as there is insufficient channel capacity in the mid-Goulburn to pass 8,000 ML/d over Goulburn Weir in addition to supplying high irrigation demands.

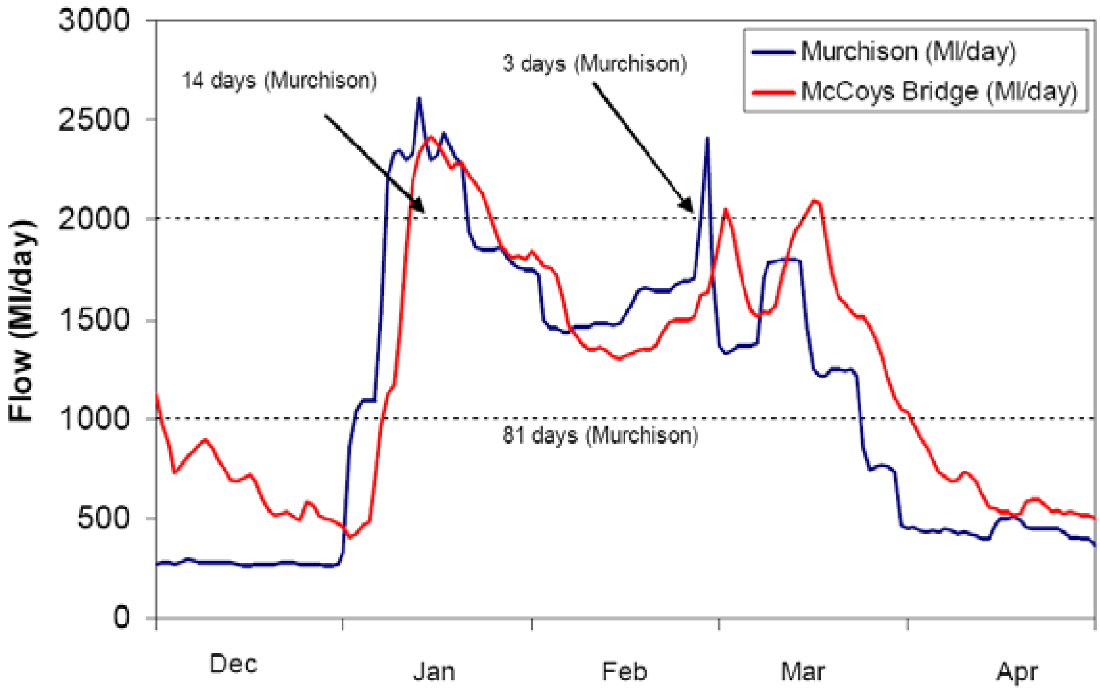

Figure 6: Pattern of flow at Murchison and McCoys Bridge during the summer and autumn of 2005-06. The duration of events above 1,000 ML/d and 2,000 ML/d are shown (Cottingham et al. 2007).

The daily flow model of the Lower Goulburn River is known as the Goulburn-Broken-Campaspe-Loddon REALM model. At the time of preparing this document, the model had not been updated for several years and many of the assumptions in the model were out of date. Hence gauged flow data has been used in the information presented below.

The period of data assessed (Table 4 and Table 5) is from 1974 to 2010. This period of record includes a range of climatic conditions, including the recent drought conditions and the wetter conditions during the 1970s. In these tables, the 30th percentile flow is the flow that is not exceeded on 30 per cent of all days in that month over the historical period (i.e. 30 per cent of July days had a flow at Shepparton below 513 ML/d over the historical period). These tables show that a minimum flow of 150-300 ML/d has historically been maintained in the Lower Goulburn River and that, in median and wet years, the streamflow in these reaches peaks in winter to spring. Note that the values in Table 4 and Table 5 are derived independently for each month. The seasonal pattern of average daily flows through Reach 4 and Reach 5 of the Goulburn River (Figure 7) are similar to the seasonal pattern of percentile flows.

A daily Source-Rivers model of the Goulburn River is currently being developed by SKM for the GB CMA and the eWater Cooperative Research Centre (eWater CRC). This model currently only includes the main stem of the river to model possible flow management during unregulated winter and spring flows, and does not include many of the complex operating rules associated with irrigation water delivery. Further development of this daily time step model will assist with the modelling of environmental flows on the Goulburn River in the future.

Table 4: Streamflow (ML/d) for the Goulburn River at Shepparton (1974-2010); Reach 4.

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	190.3	513.3	747.4	3,221.9
Aug	204.3	699.5	2,433.0	8,463.2
Sep	214.9	812.0	2,661.2	9,024.6
Oct	185.1	579.6	943.0	2,165.4
Nov	282.0	491.2	665.5	1,150.8
Dec	235.4	419.5	516.1	692.4
Jan	151.9	423.0	522.2	756.6
Feb	167.5	403.0	483.0	664.0
Mar	176.1	422.6	501.9	645.5
Apr	198.4	427.8	499.8	592.2
May	214.7	410.8	492.9	698.8
Jun	274.2	493.0	670.1	1,272.5

Table 5: Streamflow (ML/d) for the Goulburn River at McCoys Bridge (1976-2010); Reach 5.

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	203.5	538.0	782.2	3,454.1
Aug	195.9	726.5	2,568.0	9,639.7
Sep	186.2	921.0	3,329.0	9,444.5
Oct	232.5	675.3	1,178.5	2,558.8
Nov	304.8	570.4	807.6	1,299.9
Dec	204.0	493.0	618.7	754.1
Jan	202.8	481.8	595.0	794.9
Feb	257.9	455.0	566.9	781.0
Mar	245.2	439.0	535.0	716.9
Apr	272.0	460.6	565.8	688.0
May	327.5	483.4	607.2	825.4
Jun	291.7	475.5	659.8	1,378.0

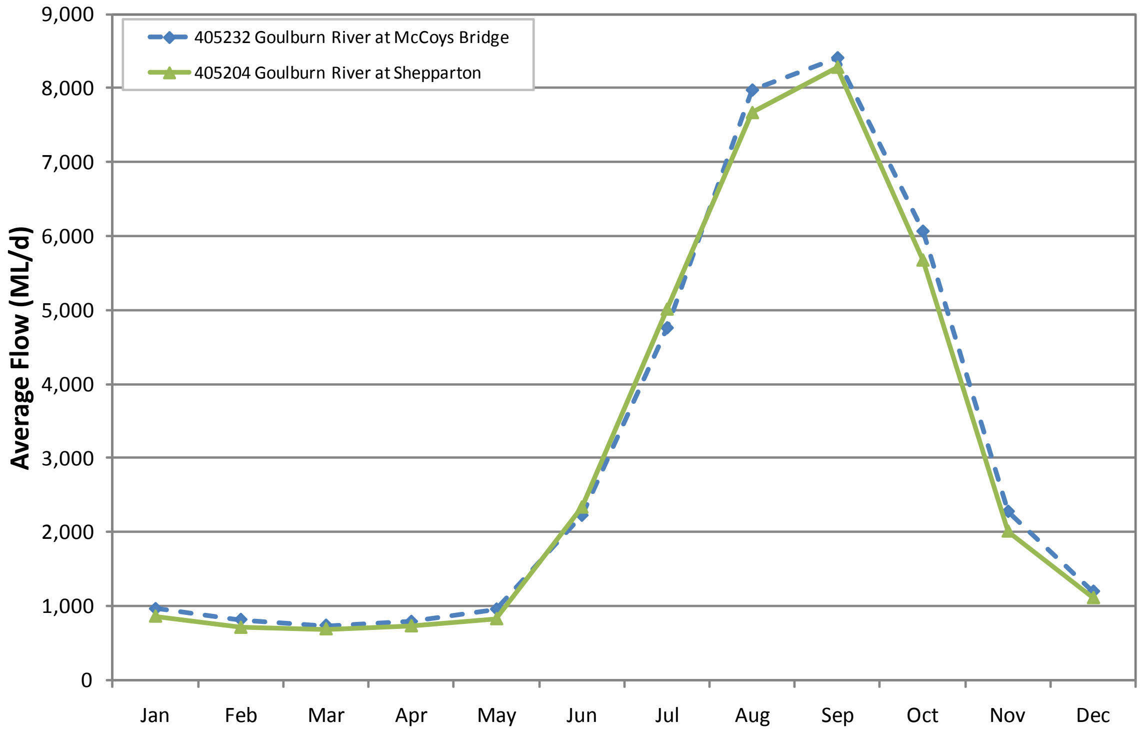

Figure 7: Average daily flow recorded at streamflow gauges at McCoys Bridge (405232) and Shepparton (405204) between 1977 and 2010.

4.2 Environmental water demands

Environmental water can be used to supplement flows to deliver the proposed flow components or events identified earlier in this document (Table 3, Section 3). Delivering these flows can increase habitat availability, ensure connection between habitats and support water quality. The actual volumes of water required will vary depending on antecedent conditions that affect inflows. The volumes identified in Table 6 and Table 7 are examples based on meeting the shortfall between a limited number of flow targets (310 ML/d, 400 ML/d, 500 ML/d, 540 ML/d, 610 ML/d, 830 ML/d or 860 ML/d) and modelled flow in Reach 4 and Reach 5 for extreme dry, dry, median and wet years.

Flows were modelled in the monthly Goulburn Simulation Model (GSM). To calculate shortfalls in meeting daily recommendations, it was assumed the monthly flow was distributed evenly across the month. The categorisation of extreme dry, dry, median and wet years was based on Goulburn system allocations, as explained further in Section 5.

Based on this information, up to 6,000 ML is required to supplement baseflow in an extreme dry year and up to 110,000 ML could be required to supplement baseflow in a wet year. This indicates that Commonwealth environmental water holdings in the Goulburn system would be sufficient to meet baseflow targets in a very dry year, but water would need to be traded into the system to meet the higher baseflow targets in dry to wet years. The monthly distribution of shortfalls for each flow threshold is contained in Appendix 3.

Historically, based on gauged flows for the Goulburn River at Shepparton (405204) and the Goulburn River at McCoys Bridge (405232), the delivery of a summer to autumn fresh of up to 6,600 ML/d has rarely been met. The only years there have been flows greater than 6,600 ML/d during summer to autumn in the Lower Goulburn River are 1975, 1984, 1986, 1988, 1989, 1992 and 2005, which were all wet years, with the exception of 2005. The summer fresh recommendation is applicable to dry, median and wet years.

Table 6: Additional annual volumes (GL) required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River.

Baseflow	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting baseflow target year-round (GL)														
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Very Dry	0.0	0.0	2.9	5.8	n/a	n/a	n/a	n/a	34.2	54.3	n/a	n/a	n/a	n/a
Dry	n/a	n/a	n/a	n/a	0.0	15.8	0.0	20.6	0.0	30.9	1.2	65.1	2.0	70.5
Median	n/a	n/a	n/a	n/a	0.0	19.2	0.0	25.3	0.0	38.7	0.0	85.1	0.0	91.5
Wet	n/a	n/a	n/a	n/a	0.0	21.0	0.0	28.8	0.0	43.6	0.0	102.6	0.0	110.8

Table 7: Additional annual volumes (GL) required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River.

Baseflow	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting baseflow target year-round (GL)														
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Very Dry	0.0	0.0	0.8	3.1	n/a	n/a	n/a	n/a	28.3	40.3	n/a	n/a	n/a	n/a
Dry	n/a	n/a	n/a	n/a	0.0	9.2	0.0	14.0	0.0	22.4	0.0	59.5	0.0	64.9
Median	n/a	n/a	n/a	n/a	0.0	9.4	0.0	13.2	0.0	22.1	0.0	68.2	0.0	74.5
Wet	n/a	n/a	n/a	n/a	0.0	16.6	0.0	25.0	0.0	41.9	0.0	98.5	0.0	106.7

Table 8 shows that if a fresh is delivered solely from environmental water releases (i.e. without any natural inflow contributions downstream of Lake Eildon), the volume of water required above baseflow to deliver a peak flow of up to 6,600 ML/d ranges from 38,000 ML to 46,000 ML.

Table 8: The additional volume of water required to deliver a fresh of 6,600 ML/d to the Lower Goulburn River above varying baseflows.

Baseflow	Additional water required to deliver fresh of 6,600 ML/d above baseflow volume* (GL)
500 ML/d	45.9
540 ML/d	44.9
610 ML/d	43.3
830 ML/d	38.7
860 ML/d	38.1

Note: Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from recorded baseflow either side of the event.

Table 9 shows the volume of water required above the hydrographs recorded at Shepparton (405204) and McCoys Bridge (405232) that would be needed to reach a threshold of 6,600 ML/d in the Lower Goulburn for some select summer to autumn rainfall-runoff events. Required event volumes for similar recorded flood peaks can vary according to the pattern of flow either side of the recorded flood peak.

Table 9: The additional volume of water required in Reach 4 to deliver a fresh of 6,600 ML/d to the Lower Goulburn River above recorded peaks.

Event	Recorded peak	Additional water required to deliver fresh of 6,600 ML/d*
February 1987	1810 ML/d	45 GL
March 1988	2605 ML/d	29 GL
March 2010	3365 ML/d	32 GL
January 2008	5000 ML/d	18 GL

Note: Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from the recorded baseflow either side of the event.

Proposals have also been made for winter to spring bankfull events of up to 19,000 ML/d and overbank events of 25,000 to 40,000 ML/d (DSE 2011). Based on recorded flow for Shepparton (405204), winter to spring flows above 19,000 ML/d have been recorded in 20 years since 1974 (5.6 years in 10). Over this period, flows greater than 25,000 ML/d have been recorded in 17 years (4.7 years in 10) while flows greater than 40,000 ML/d have been recorded in 8 years (2.2 years in 10). Bankfull events can be considered in all dry, median and wet years. Overbank events are proposed in 7 out of 10 dry, median and wet years. This is greater than the observed frequency of overbank flows recorded historically since 1974.

Table 10 shows the volume required downstream of Goulburn Weir to enhance and extend historical flow peaks to the desired bankfull and overbank peak flow and duration. Up to 140,000 ML would have been required in Reach 4 for the bankfull flow event, whilst up to 420,000 ML would have been required in Reach 4 for the overbank events. Required event volumes for similar recorded flood peaks can vary according to the pattern of flow either side of the recorded flow peak.

Table 10: The additional volume of water required in Reach 4 to deliver a bankfull event of 19,000 ML/d or overbank events of 25-40,000 ML/d to the Lower Goulburn River above recorded peaks.

Event	Recorded peak (ML/d)	Additional water required to deliver event (GL)*		
		Bankfull Flow of 19,000 ML/d	Overbank Flow of 25,000 ML/d	Overbank Flow of 40,000 ML/d
Sep 1998	20,905	141	218	418
Aug 1999	16,632	136	214	413
Sep 2000	24,864	0	74	256
Sep 2005	18,608	141	222	419

Note: Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from the recorded baseflow either side of the event.

5. Operating Regimes

5.1 Introduction

This section presents potential operational triggers for the implementation of environmental flow proposals. These triggers should be used as a guide and refined based on operational experience after watering events. Operational water delivery involves several steps including:

- identifying the target environmental flow recommendations for the coming season
- defining triggers to commence and cease delivering those recommended flows
- identifying any constraints on water delivery, such as available airspace in irrigation channels, the potential for flooding of private land, delivery costs, limits on releases from flow regulating structures and interactions with other environmental assets.

5.2 Identifying target environmental flow recommendations

The selection of target environmental flows in each of the different climate years is triggered by the allocation in July, as shown in Table 11. For example, when the high reliability water share allocation in July is 100 per cent but the low reliability water share allocation is less than 20 per cent, then the suite of recommendations assigned to the dry climate year would be targeted. Allocations have been used as a surrogate for anticipated flow conditions in the Goulburn River, because the differences in within-channel flow in different climate years, previously presented in Section 4.1, are largely influenced by the use of allocations for irrigation supply. If flow conditions change rapidly, such as in a major runoff event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of the suite of target flows should be flexible and in response to conditions in the Goulburn River, because the flow thresholds for achieving the ecological benefits aligned with each threshold, particularly for the higher flow events, are not precisely known at the current time.

Table 11: Identifying seasonal target environmental flow recommendations.

Climate year for selecting flow recommendations	Goulburn high reliability water share allocation in July	Goulburn low reliability water share allocation in July
Extreme dry	≤70%	0%
Dry	71% - 100%	≤20%
Median	100%	21-80%
Wet	100%	>80%

Using these triggers, the frequency of extreme dry years is approximately 1.4 years in 10, dry years occur approximately 2.5 years in 10, median years occur approximately 3.6 years in 10 and wet years occur 2.5 years in 10. This data is based on modelled allocations at the start of July, but allocations from mid-July could be used if a start of July allocation is not announced.

5.3 Delivery triggers

Proposed operational triggers for delivering the suggested environmental flow proposals are presented in Table 12.

The delivery of the baseflow requirements in all years occurs continuously over the season specified in the flow recommendations, and will occur from the nominated start date. These flows are within-channel and can be delivered via releases from Lake Eildon if not already being provided (for example, to meet inter-valley transfer requirements).

The summer to autumn pulse flow of up to 6,600 ML/d has historically (since 1974) been rarely met. If this pulse flow is required as recommended in all but extreme dry years, opportunities to contribute to natural flow peaks is limited. As described in the following section on travel time, releases from Lake Eildon are likely to lag behind natural flow peaks of any runoff events from tributaries downstream of Yea. It is therefore recommended that environmental water managers liaise with the VEWH, GB CMA and G-MW to identify opportunities to deliver flows by piggybacking onto natural floods in the Acheron and Rubicon Rivers. Delivery will need to ensure that flows at Trawool do not exceed the minor flood level of 21,700 ML/d. Estimating the volumes required to meet a target of up to 6,600 ML/d downstream of Goulburn Weir will be difficult because of variability in river losses and attenuation, as well as releases and subsequent diversions at Goulburn Weir for irrigation supply and water users en route. The need for environmental water is likely to be minimised if the summer to autumn pulse can occur at a time when baseflows downstream of Goulburn Weir are higher due to inter-valley transfers for irrigation users in the Murray River. If a natural event in the upper tributaries cannot be piggybacked, environmental water managers should try to time releases with delivery of inter-valley transfers, which will depend on river operation decisions in the Murray. G-MW can provide advice on the likely timing and magnitude of inter-valley transfers in any given season.

The winter to spring bankfull event of up to 19,000 ML/d and overbank event of 25,000 to 40,000 ML/d have historically (since 1974) not been met at the required frequency. Opportunities to trigger or supplement events of this magnitude are limited by upstream flooding constraints. If a peak flow is observed on Acheron and Rubicon Rivers, water released from Lake Eildon will reach Trawool at approximately the same time as the tributary flows, contributing to the peak magnitude of the event. However, minor flooding occurs at Trawool when flows exceed 21,700 ML/d (see Table 14). It would be necessary to ensure releases from Lake Eildon did not cause or contribute to flooding of private land along this reach of the Goulburn River.

Piggybacking on events observed in tributaries downstream of Trawool would provide greater flexibility to release extra water from Lake Eildon while remaining below the Trawool minor flooding threshold. However, due to travel times along the Goulburn River, water released from Lake Eildon will not catch up to events observed on tributaries downstream of Trawool (including the Broken River).

As such, there is limited opportunity to trigger the winter to spring bankfull and overbank events. The occurrence of these events will remain reliant on natural events.

Table 12: Summary of proposed operational regime for achievement of environmental objectives.

Climate year	Flow objective in Goulburn River (Reach 4 and 5)	Season/ timing	Average return period	Trigger for delivery
Extreme dry	310-610 ML/d baseflow	Nov-Jun	All very dry years	Maintain throughout season with releases from Lake Eildon as required.
Dry	500-830 ML/d baseflow	Nov-Jun	All dry years	Maintain throughout season with releases from Lake Eildon as required.
	6,600 ML/d for 7 days	Nov-Jun	All dry years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All dry years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000-40,000 ML/d for 5 days	Jul-Oct	7 years in 10	
Median	500-860 ML/d baseflow	Nov-Jun	All median years	Maintain through season.
	6,600 ML/d for 7 days	Nov-Jun	All median years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All median years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000–40,000 ML/d for 5 days	Jul-Oct	7 years in 10	
Wet	500-860 ML/d baseflow	Nov-Jun	All wet years	Maintain through season.
	6,600 ML/d for 7 days	Nov-Jun	All wet years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All wet years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000–40,000 ML/d for 5 days	Jul-Oct	7 years in 10	

The GB CMA is investigating options to use the volume stored in Goulburn Weir to release flows to coincide with natural flow peaks along the Broken River, thereby providing increasing flows in the Lower Goulburn River downstream of Shepparton. The volume released from Goulburn Weir would then require some supplementing from Lake Eildon releases. This would involve some operational adjustments, such as managing deliveries along the irrigation channels from Goulburn Weir. It may only be practically feasible during winter.

5.4 Travel time

Travel time along the Goulburn River downstream of Lake Eildon has been assessed based on recorded streamflow data and is illustrated in Figure 8. This analysis shows total travel time along the Goulburn River to be in the order of six days when upper system tributaries are not significantly influencing flow. Total travel time along the Goulburn is based on the following reach travel times:

- Lake Eildon to Trawool – one to two days.
- Trawool to Seymour – zero to one day.
- Seymour to Shepparton – one to two days.
- Shepparton to Loch Garry – one day.
- Loch Garry to McCoys Bridge – one day.

Figure 8 shows flow at Lake Eildon, Trawool and Seymour at a time when upper system tributaries (represented by the Acheron and Rubicon Rivers) are not significantly influencing flow.

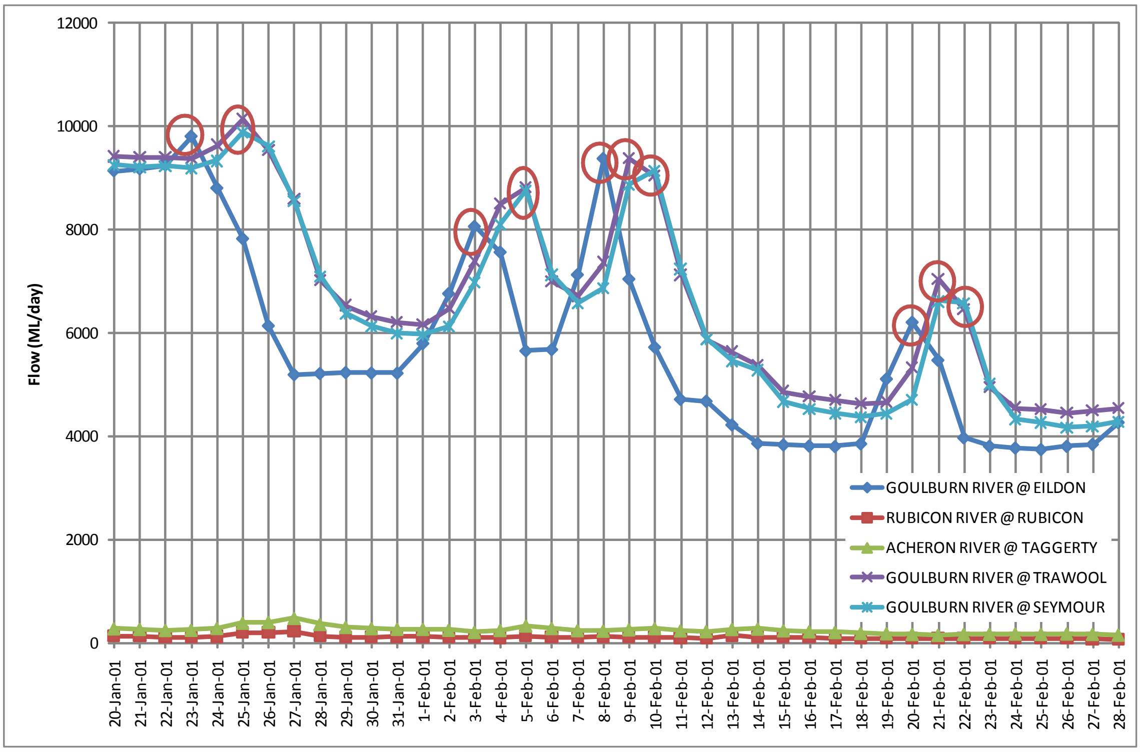

Figure 8: Goulburn River travel time: Lake Eildon to Seymour.

Figure 9 shows flow at Seymour, Shepparton, Loch Garry and McCoys Bridge at a time when the Broken River is not significantly influencing flow. This plot illustrates that travel time between Seymour and Shepparton is in the order of two days, travel time between Shepparton and Loch Garry is in the order of one day and travel time between Loch Garry and McCoys Bridge is in the order of one day.

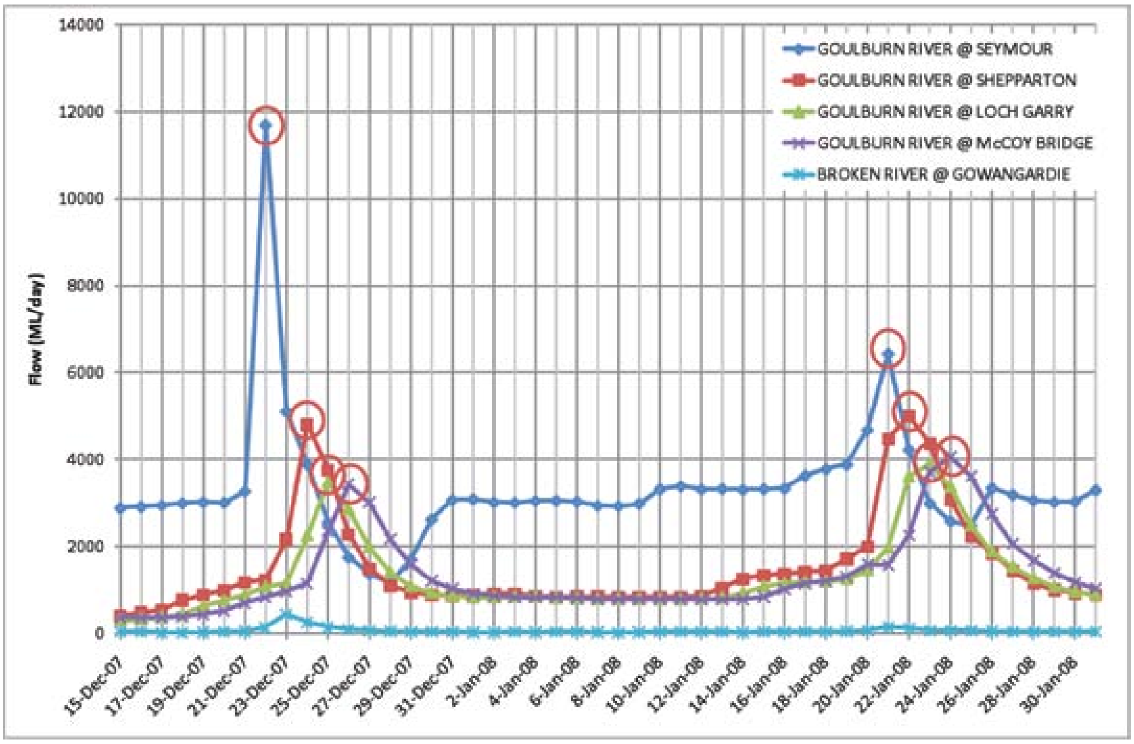

Figure 9: Goulburn River travel time: Seymour to McCoys Bridge.

Figure 10 shows flow in the upper system tributaries (Rubicon and Acheron Rivers) and at Trawool at a time when tributary inflows are driving downstream flow patterns (rather than flow at Lake Eildon). In this plot, the Rubicon and Acheron Rivers are peaking at the same time, although the Acheron River is contributing more flow. This plot shows that travel time between the peak on the outlet of the upper system tributaries and Trawool is in the order of one day. This is the same as the travel time for releases from Lake Eildon to Trawool.

This means that if a peak is observed (or predicted) on the upper system tributaries, water can be released from Lake Eildon and will reach Trawool at approximately the same time, contributing to the peak magnitude of the event.

In releasing water from Lake Eildon to supplement peak flow events from the upper system tributaries, it is important to predict total flow at Trawool (inclusive of tributary inflows and releases from Lake Eildon) to ensure releases from Lake Eildon do not cause or contribute to overbank flooding at Trawool.

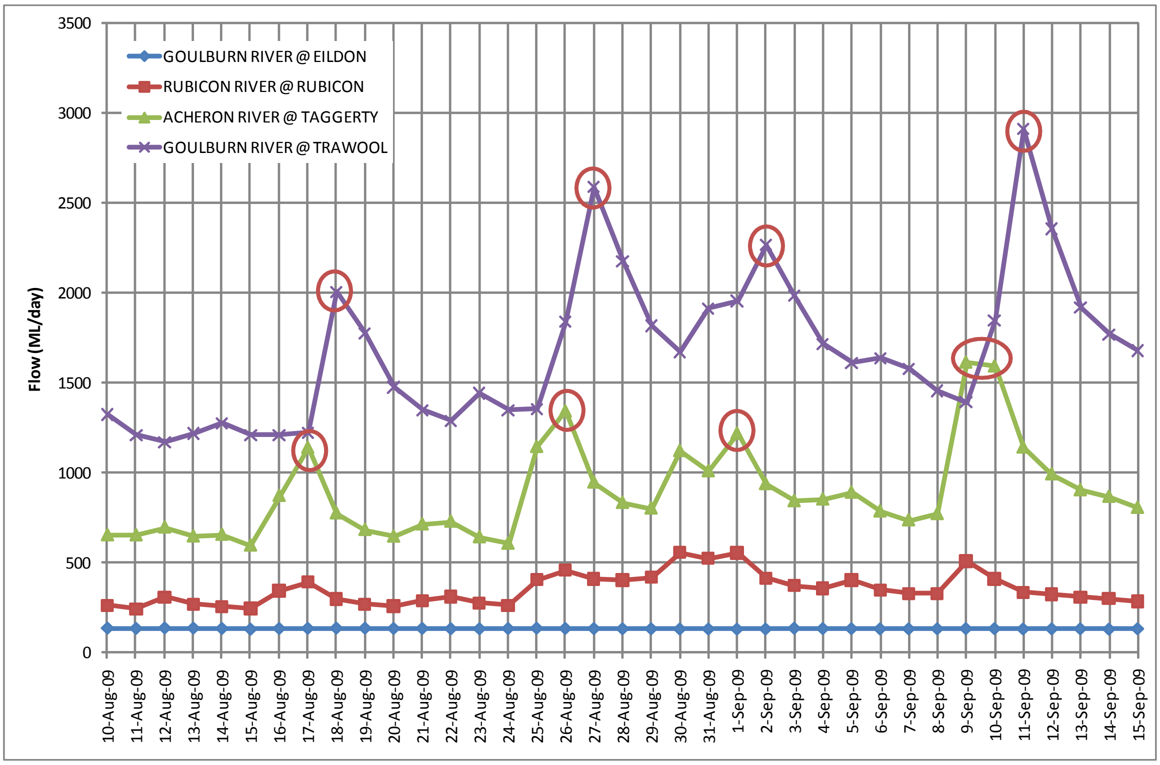

Figure 10: Goulburn River travel time: upper system tributaries.

Figure 11 shows flow on the Broken River just downstream of Lake Nillahcootie (Moorngag) and just upstream of the Goulburn River confluence (Orrvale). This plot demonstrates that travel time along the Broken River from Moorngag to Orrvale is in the order of two days. It is assumed that travel time from Orrvale to Shepparton on the Goulburn River is less than one day.

As such, peak flows observed in the upper Broken River (downstream of Nillahcootie) will reach Shepparton in approximately two days. This is less than the time taken for releases from Lake Eildon to reach Shepparton (approximately four days). Thus if a peak flow is observed in the upper Broken River, water released from Lake Eildon will not reach Shepparton in time to contribute to the event (unless the event is prolonged).

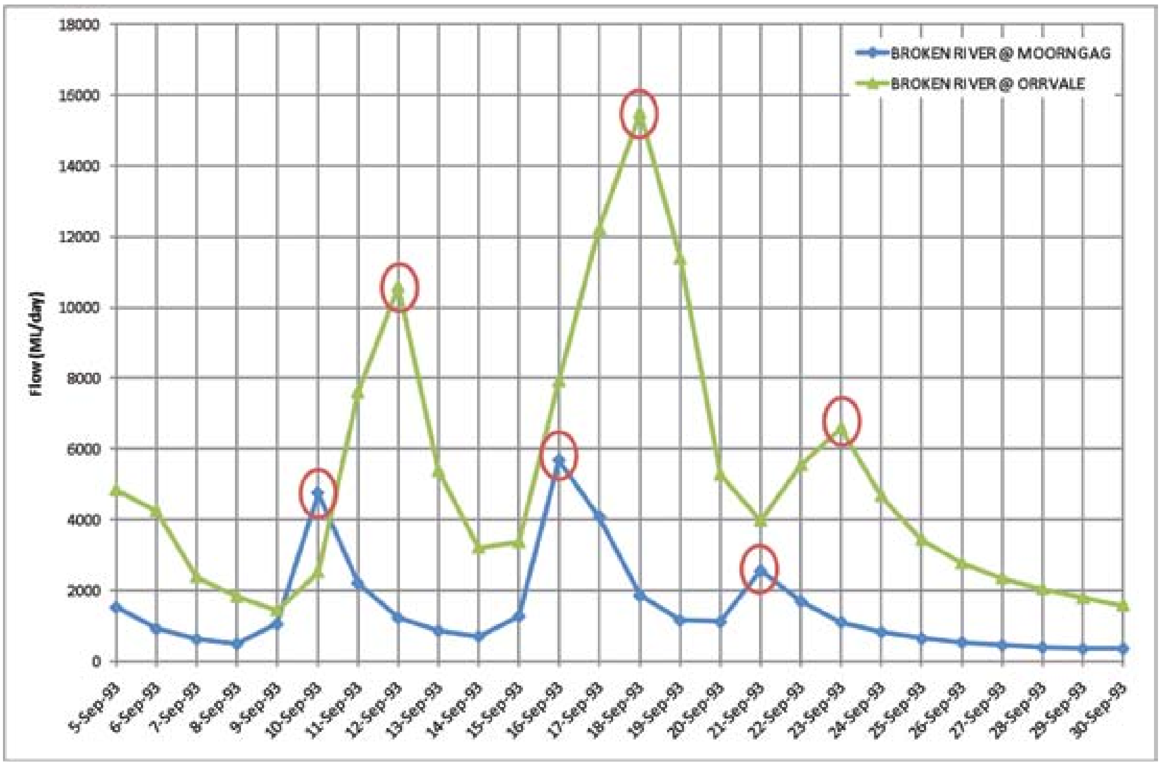

Figure 11: Goulburn River travel time: Broken River.

The volume of water required to be released from Lake Eildon to achieve a peak flow of a specific magnitude is influenced by inflows and losses along the flow path. An analysis of the correlation between flow at Shepparton and flow downstream of Goulburn Weir (Murchison) (see Figure 12) indicates that flow in the Goulburn River at Shepparton is on average approximately 38 per cent higher than flow at Murchison due to local catchment inflows downstream of Murchison (reducing the volume which must be met from releases).

The correlation between flow at different locations along the river decreases with distance upstream. This is due to the influence of system operations such as the variable nature of diversions (particularly at Goulburn Weir) and the variable nature of releases from Lake Eildon which switch on and off rapidly in response to tributary inflows and changes in demand. Further analysis of flows or extraction of modelled data is required to better understand the contribution typically made from tributaries between Lake Eildon and Goulburn Weir.

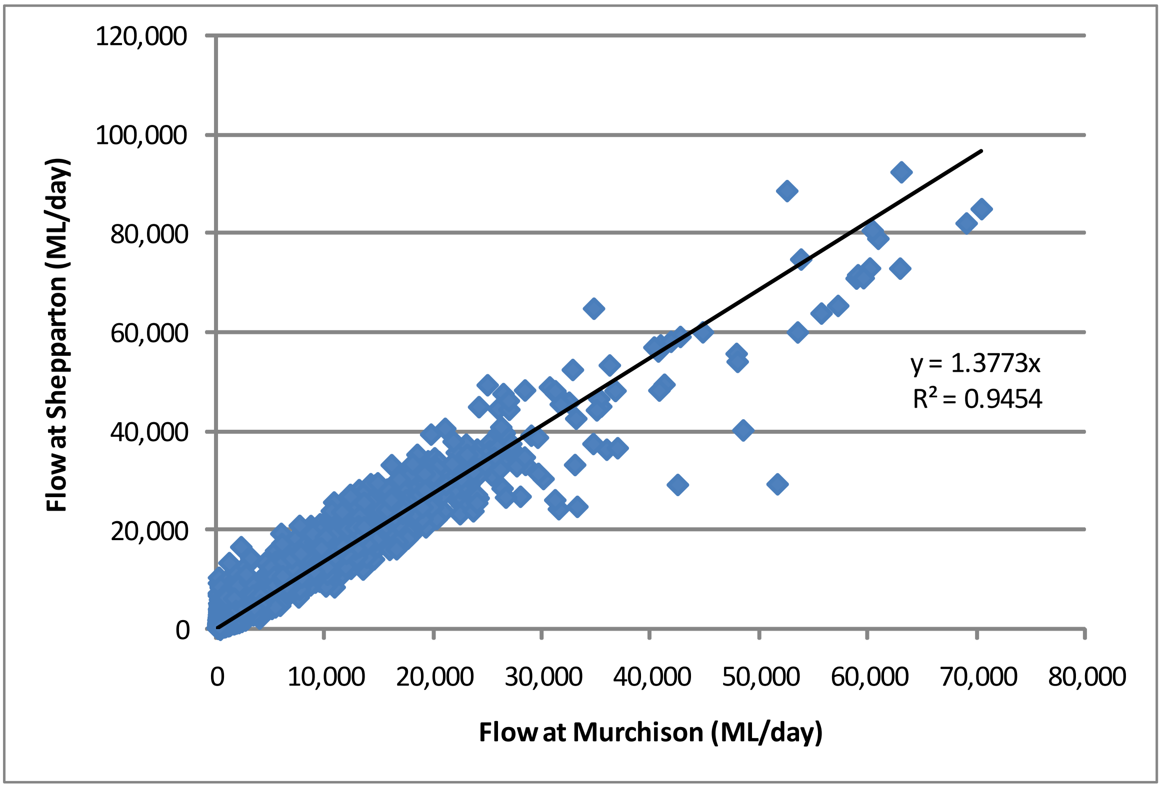

Figure 12: Correlation between flow at Shepparton and flow at Murchison.

5.5 Flooding

The Goulburn River downstream of Shepparton is confined within a levied floodway but its capacity is inadequate to convey even moderate flood events. To reduce the probability of overtopping the levees, water is allowed to pass from the floodway into Bunbartha Creek at Loch Garry, Deep Creek, Wakiti Creek, Hagens Creek and Hancocks Creek. Of these, the Loch Garry regulator has by far the highest capacity of 60,000 ML/d.

The Loch Garry regulator and levees are a part of the Loch Garry Flood Protection District. The aim of the scheme is to provide protection against frequent low level flooding. Loch Garry is a 48 bay regulator located around 16 kilometres downstream of Shepparton. Prior to the construction of the levees, floodwater would have regularly broken out of the Goulburn River at Loch Garry and flowed into Bunbartha Creek. Operation of Loch Garry is based on Shepparton river heights. Removal of bars commences 24 hours after the Shepparton gauge level has exceeded 10.36 metres (110.487 mAHD) with all bars being removed 24 hours after the river level at Shepparton has exceeded 10.96 metres. The capacity of the levied river floodway downstream of Shepparton is shown in Table 13.

Table 13: Capacity of the levied river floodway downstream of Shepparton (Water Technology 2005).

River Reach	Capacity (ML/d)	
Upstream of Loch Garry (Medland Rd)	185,000 ML/d	(40 year ARI)
Loch Garry to Deep Creek Outlet	85,000 ML/d	(7 year ARI)
Deep Creek Outlet u/s McCoys Bridge	75,000 ML/d	(5 year ARI)
McCoys Bridge	65,000 ML/d	(4 year ARI)
Downstream of McCoys Bridge to Yambuna Forest	60,000 ML/d	(3 year ARI)
Yambuna Choke	37,000 ML/d	(2 year ARI)

Flows corresponding to minor flood, moderate flood and major flood levels are shown in Table 14. Minor flooding results in inconvenience, with low lying areas next to watercourses inundated, requiring the removal of stock and equipment and the closure of minor roads. For moderate flooding, some houses may require evacuation. Under major flooding, properties and towns are likely to be isolated and major traffic routes closed, with numerous evacuations required (SKM 2006).

It should be noted that the recommended overbank (25,000 to 40,000 ML/d at Shepparton) flood event in the Lower Goulburn River is above the minor flood threshold at Shepparton, Trawool and Seymour. As such, further consultation is required with G-MW, DSE and the VEWH before environmental water could be used to contribute to these peak flow events.

Table 14: Goulburn River flood flows (SKM 2006).

Station	Name	Minor Flood (ML/d)	Moderate Flood (ML/d)	Major Flood (ML/d)
405203	Goulburn River at Lake Eildon	14,500	26,000	40,000
405201	Goulburn River at Trawool	21,700	41,500	83,000
405202	Goulburn River at Seymour	22,800	38,900	80,900
405200	Goulburn River at Murchison	29,200	58,800	79,670
405204	Goulburn River at Shepparton	22,500	67,780	87,000
405232	Goulburn River at McCoys Bridge	29,200	50,000	62,600

Flows from the Goulburn River can only pass through three gaps in the Bama Sandhills:

- at the Yambuna Choke
- through a flood course associated with Madowla Lagoon
- at high river stage, along Yambuna Creek to Warrigal Lagoon and Kanyapella Basin.

The last two of these three gaps are now blocked by levees. Flood flows also find their way through a fourth gap in the sandhills via overflows to Deep Creek and the Murray River.

The maximum capacities of each of the outlet structures along the Lower Goulburn are given in Table 15. Note that these figures are estimates of the maximum capacities during major floods, when the outlets are surcharged. Flows through Loch Garry, for example, would be significantly reduced for small to medium sized floods (Water Technology 2005).

Table 15: Lower Goulburn outlet structure capacities (Water Technology 2005).

Outlet	Capacity (ML/d)
Loch Garry regulator	60,000
Deep Creek outlet	3,000
Wakiti Creek outlet	3,100
Hagens Creek outlet	100
Hancocks Creek outlet	3,700

5.6 Storage releases

The minimum flow immediately downstream of the Lake Eildon Pondage is established by Clause 11 of the Goulburn Bulk Entitlement Conversion Order 1995. The general minimum flow requirement is 120 ML/d, however if 24 month inflows exceed trigger levels, additional passing flows described in Clause 6 of the Bulk Entitlement become available. Under these provisions, minimum flows increase to 250 ML/d, and an additional 80,000 ML can be passed downstream during November, to provide water to effluent lagoons for one day up to a maximum release of 16,000 ML/d.

During the irrigation season, releases to satisfy downstream requirements generally exceed the minimum flow requirements. G-MW bases its requirements for Lake Eildon releases on:

- Daily assessment of release requirements:
  - For supply of bulk water orders for irrigation areas, diversion customers or other authorities, including inter-valley transfers.
  - To minimise unregulated releases at Goulburn Weir by taking into account irrigation demand, natural catchment inflow below Lake Eildon and weather conditions.
  - To supply transmission losses.
  - For release requirements downstream of Goulburn Weir.
- Target operating levels at Waranga Basin, to avoid long periods of high release from Lake Eildon.
- Maximum regulated release from Lake Eildon, which is 10,000 ML/d.

Inter-valley transfers have resulted from net trade from the Goulburn to the Murray River systems. Water may be called out from Lake Eildon at different times of the year to assist in meeting Murray River requirements. The transfer of water from Lake Eildon to the Murray River can be achieved through the following river systems:

- Goulburn River, utilising the reach downstream of Goulburn Weir.
- Broken Creek, utilising the East Goulburn Main Channel to outfall water to Broken Creek and then through to Rice's Weir.
- Campaspe River, utilising the Waranga Western Channel to outfall water to the Campaspe downstream of Campaspe Siphon.

Additional water loss is estimated and applied when using the Broken Creek and Campaspe River bypass routes.

When Lake Eildon is being operated to meet a downstream release requirement, G-MW places an order for the flow required downstream of the regulating pondage with AGL Hydro. AGL Hydro then operates the power station and regulates the pondage to best meet requirements (within agreed pondage operating limits), whilst passing the ordered flow downstream. This includes communicating what flows can be passed through the pondage hydro station with the power station operator. If the Lake Eildon power station is unavailable, then G-MW regulates water using the low level outlet, spillway valves or spillway gates, into the pondage. AGL Hydro continues to manage releases from the pondage to meet downstream flows.

The pondage provides AGL Hydro with some flexibility to make higher releases during periods of higher electricity demand without additional water being released downstream of the pondage. However, there are times when releases for electricity generation will exceed the pondage's ability to regulate the water. AGL Hydro has up to 80,000 ML a year that it can pass downstream of the pondage in addition to G-MW's downstream requirements. The pattern of releases is unknown, but is likely to be affected by electricity pool prices, the volume of irrigation releases already generating electricity, and the ability of AGL Hydro to generate power from its portfolio of electricity supply sources. Releases must comply with the conditions of the bulk entitlement as follows:

- Maximum rate of rise is 150 mm/h with a maximum flow increase of 3,500 ML/d.
- Maximum rate of fall is an instantaneous fall of 150 mm and then 30 mm/h to a maximum of 450 mm/d for the first day, with 30 mm/h and 300 mm/d thereafter.

The two target curves in Schedule 5 of the G-MW Goulburn Bulk Entitlement 1995 form the basis of the flood operating procedures for Lake Eildon (Figure 13). The two curves represent the target filling for normal and wet years, with the wet year curve used where G-MW considers that wet conditions will continue, and the risk of Lake Eildon not filling is low.

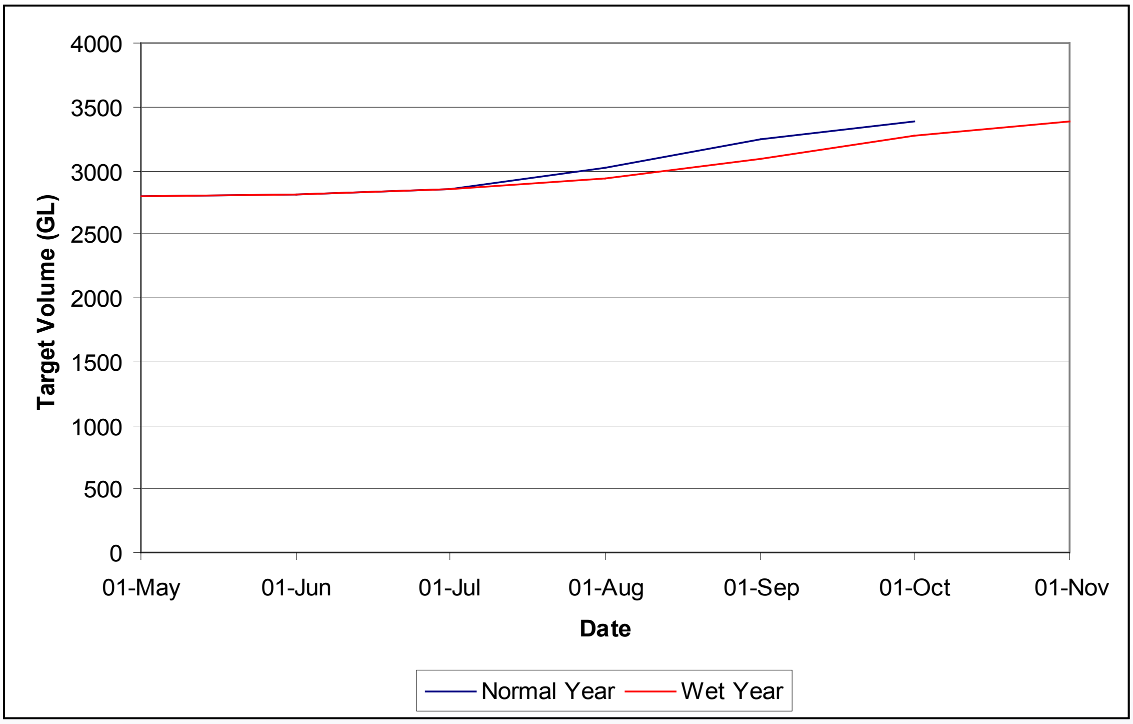

Figure 13: Lake Eildon filling targets – Schedule 5 of the G-MW Bulk Entitlement (SKM 2006).

Operations will initially allow Lake Eildon to fill to the selected target curve. Once the target curve has been reached, releases are made to keep to the target curve. During periods of high inflows, the storage may be allowed to exceed the target curve to provide some flood mitigation. Releases are then made to return the storage to the target storage level. The magnitude and timing of releases is based on the rate of inflow to the storage, any ability to surcharge the storage, downstream inflows and flooding, and the potential for further significant inflows. The release capacity from Lake Eildon is shown in Table 16.

Table 16: Lake Eildon discharge capacity (SKM 2006).

Storage Volume (% of capacity)	Storage Volume (ML)	Storage Level (m)	Discharge Capacity (ML/d)
10.0	338,790	248.9	20,500
16.6	562,391	255.3	20,300
20.0	677,580	257.8	23,600
30.0	1,016,370	264.2	24,500
40.0	1,355,160	269.2	23,400
50.0	1,693,950	273.5	25,000
60.0	2,032,740	277.2	26,300
70.0	2,371,530	280.5	27,450
77.4	2,622,235	282.8	28,200
80.0	2,710,320	283.6	34,330
90.0	3,049,110	286.3	92,835
100.0	3,387,900	288.9	183,930

Goulburn Weir, which forms Lake Nagambie, is a concrete and masonry structure that provides a sufficient water level to allow diversions to the Stuart-Murray Canal, Cattanach Canal and the East Goulburn Main Channel. At its full supply level of 124.24 mAHD its capacity is 25,000 ML, and it has a surface area of 1,130 hectares. Lake Nagambie is used extensively for recreation.

The offtake to the Stuart-Murray Canal is located immediately west of the weir structure, while offtakes to the East-Goulburn Main Channel (east side of the weir) and Cattanach Canal (west side of the weir) are located further upstream of the weir.

The Goulburn Bulk Entitlement sets minimum flow criteria at two points downstream of Goulburn Weir. The first immediately downstream of Goulburn Weir requires a weekly average of 250 ML/d, and a minimum daily rate of 200 ML/d. The second passing flow requirement occurs at McCoys Bridge and varies over the year. Requirements are:

- For November to June inclusive a minimum average monthly flow of 350 ML/d and a daily requirement of no less than 300 ML/d.
- For July to October inclusive a minimum average monthly flow of 400 ML/d with a daily requirement of not less than 350 ML/d.

Other demands downstream of Goulburn Weir include in-valley consumptive demand from rural and urban customers, and any inter-valley transfer volumes to be passed to the Murray River.

Demands downstream of Goulburn Weir and minimum passing flows at McCoys Bridge can be met fully or in part by unregulated tributary inflows, including inflows from the Broken River.

Goulburn Weir operations need to consider meeting downstream requirements, maintaining discharge capacities from the weir and maximising the volume of unregulated inflows that can be harvested to Waranga Basin. During the June to September period, with no or low demand requirements, the operating level of Goulburn Weir is generally varied within 300 mm below full supply level (FSL) to increase harvesting capacity. Up to 7,000 ML/d can be harvested into the Waranga Basin. However as irrigation demand and the need to allow the offtakes to operate at or near capacity increases, the ability to vary the level at Goulburn Weir diminishes. In addition, the community around Lake Nagambie generally prefers the pool level to remain near FSL for public amenity reasons.

Inflows exceeding the diversion capacity to Goulburn Weir can be harvested up to FSL, however once the storage reaches FSL all additional inflows above diversion capacity are passed downstream.

5.7 Interactions with other assets

The Goulburn system, which supplies the Lower Goulburn River, is also a source of supply for:

- baseflows in Broken Creek (via the East Goulburn Main Channel)
- deliveries along the Waranga Western Channel to the Campaspe and Loddon Rivers and the Boort wetlands
- deliveries to the Murray River sites, of which Koondrook-Perricoota Forest is the closest to the outlet of the Goulburn River.

Co-ordination of flow events with watering of Barmah-Millewa Forest is likely to provide benefits for the Murray River sites being watered downstream of the Goulburn River. Travel time along the Murray River from Hume Dam is longer than the travel time along the Goulburn River from Lake Eildon, so environmental water managers are able to order deliveries to match outflows from the Barmah-Millewa Forest. However, high or flood flows from the Goulburn River can cause Murray River flows to bank up (back water impacts), forcing more Murray River water north through the Edward-Wakool system and reducing flow rates through the Barmah-Millewa Forest. It is not clear at what magnitude back-water impacts commence and this is an area requiring further investigation.

It is also noted that flooding of the Goulburn River into Koondrook-Perricoota Forest via the Murray River can create water quality problems in the Wakool River, such as blackwater events, which occur when organic matter from the floodplain (or upper banks) becomes entrained in the water column, particularly during warm conditions.

5.8 Water delivery costs

5.8.1 Delivery costs

Environmental water holdings in the Goulburn system incur an annual service point fee of $200. However, there is no delivery cost for environmental water delivered from Lake Eildon to the Goulburn River.

Storage costs for 2011-12 for the Goulburn system are $3.54 per ML held in the spillable water account, $6.98 per ML of high reliability water share and $3.54 per ML of low reliability water share. Storage charges are also applicable to water shares held in other systems, from which water may be traded to the Goulburn system (e.g. the Murray River).

Note that delivery charges are subject to review on an annual basis. Refer to http://www.g-mwater.com.au/customer-services/feesandcharges for more information.

5.8.2 Carryover costs

Carryover is unlimited in the Goulburn system. Any allocation and carryover greater than 100 per cent of the total entitlement is quarantined in the spillable water account. This water becomes available to trade or use once Goulburn Murray Water makes a declaration that there is a low risk (less than 10 per cent probability) of the storage spilling later in the season. After the declaration is made, any water that has not spilled is transferred out of the spillable water account back into the available balance of the allocation bank account, and a volumetric charge is applied (G-MW 2011).

6. Governance

6.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). The NRSWS also presents the community an agreed level of health target for the Goulburn River system. The Victorian Government has agreed to try and meet the health target through various mechanisms, including the use of environmental water. G-MW has responsibility for the planning and delivery of water to the Lower Goulburn River. In doing so, G-MW collaborates with:

- The GB CMA to deliver environmental water, including the Goulburn system water quality reserve, and inter-valley transfers to the Murray River. Note that while G-MW can make recommendations regarding the delivery of inter-valley transfers to support GB CMA objectives, the actual delivery of inter-valley transfers is governed by the MDBA who are working towards the management of the larger Murray-Darling Basin and are not compelled to follow G-MW's recommendations.
- The VEWH, responsible for managing Victorian environmental water holdings.

Water shares in the Goulburn system can be used to deliver water from the headworks storage in Lake Eildon, Goulburn Weir, Waranga Basin and Greens Lake.

6.2 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to the Lower Goulburn River include:

- The VEWH as the manager of Victorian environmental water holdings.
- GB CMA as the environmental water manager for the Goulburn system.
- G-MW as the BE holder, manager of the major reservoirs and irrigation areas in the catchment, and also the licensing authority responsible for groundwater and surface water licensed diversions.
- Goulburn Valley Water is responsible for urban water supply in the catchment.

Both the GB CMA and G-MW cooperate with the VEWH in the delivery of environmental water, as well as with the MDBA in relation to water transfers (inter-valley transfers) from the Murray system.

6.3 Approvals, licences, legal and administrative issues

6.3.1 Water shepherding and return flows

In Victoria, the policy position presented in the *Northern Region Sustainable Water Strategy* is to allow all entitlement holders to reuse or trade their return flows downstream provided that (DSE 2009):

- there is adequate rigour in the calculation and/or measurement of return flows
- the return flows meet relevant water quality standards
- additional losses (if any) are taken into account
- the return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site
- the system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system.

The Australian Government does not currently have the ability to deliver water from its water shares for the Goulburn system, so it must transfer its allocations to the VEWH for water to be used. If environmental water allocations are transferred to the VEWH then the ability to reuse those flows in the Murray River depends on the conditions of the individual entitlements.

If the point of delivery for environmental water is specified as at McCoys Bridge, which is near the confluence of the Goulburn River and Murray River, then this will ensure that all reaches of the Goulburn River receive the benefit of environmental water released from Lake Eildon.

If in the future environmental water is delivered directly to the Lower Goulburn River, then credits for return flows to the Murray River can be granted under G-MW's bulk entitlements for the Victorian Murray and Goulburn systems. The application for the credits would be submitted by G-MW and the credits would be granted to G-MW. Environmental water managers would then need an agreement with G-MW and MDBA Murray River Operations to have these return flows credited to their allocation bank account for the Murray River downstream of Barmah Choke.

6.4 Trading rules and system accounting

6.4.1 Water trading

The Goulburn River from Lake Eildon to Goulburn Weir is located in Trading Zone 1A, while the Goulburn River from Goulburn Weir to the Murray river is located in Trading Zone 3. A map showing the Victorian and southern NSW water trading zones is shown inFigure 14. Table 17 provides an overview of trading capability between zones.

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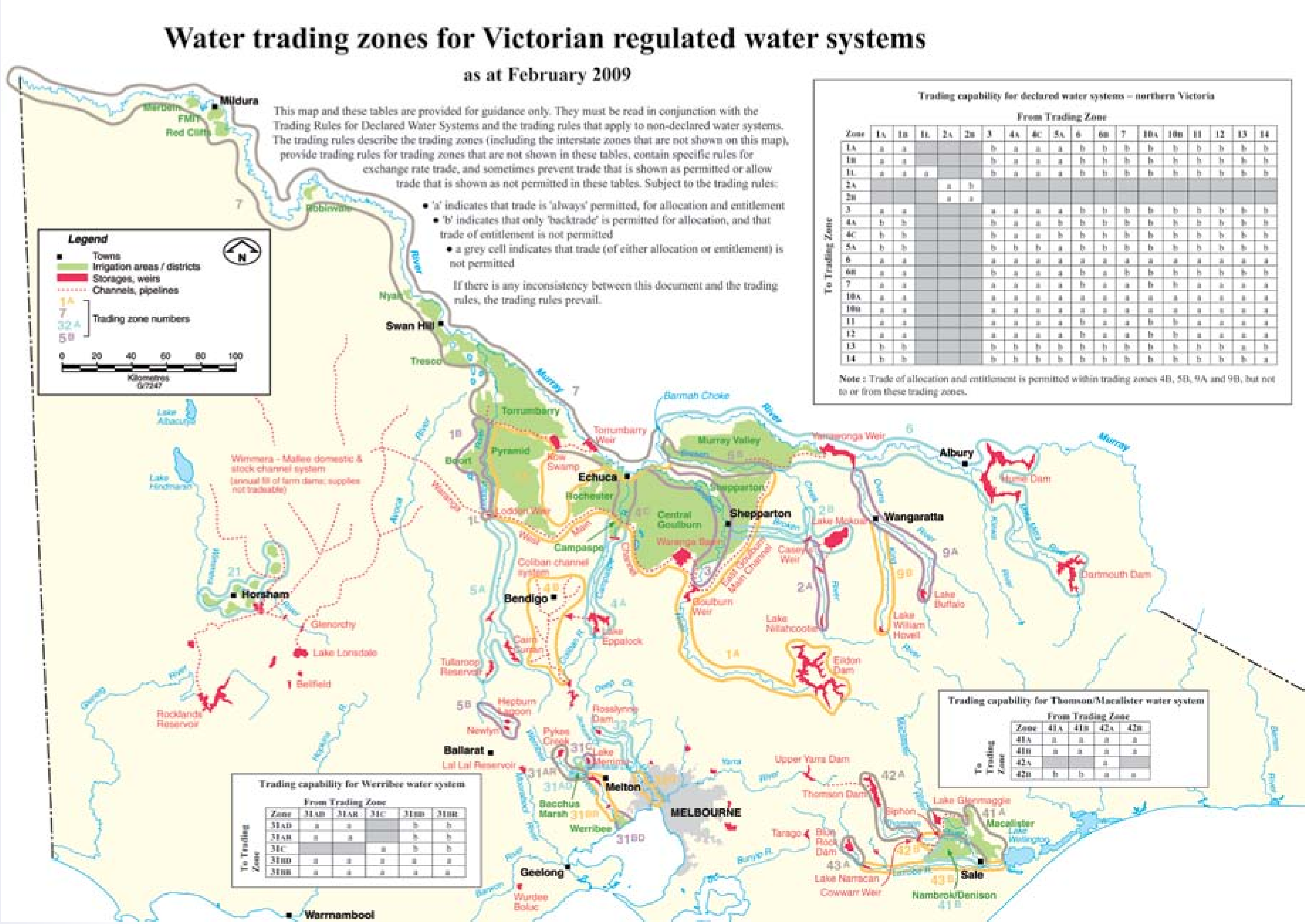


Trading capability for declared water systems – northern Victoria

From Trading Zone (columns); To Trading Zone (rows)

Zone	1A	1B	1L	2A	2B	3	4A	4C	5A	6	6B	7	10A	10B	11	12	13	14
1A	a	a				b	a	a	a	b	b	b	b	b	b	b	b	b
1B	a	a				b	a	a	a	b	b	b	b	b	b	b	b	b
1L	a	a	a			b	a	a	a	b	b	b	b	b	b	b	b	b
2A				a	b													
2B				a	a													
3	a	a				a	a	a	a	b	b	b	b	b	b	b	b	b
4A	b	b				b	a	a	b	b	b	b	b	b	b	b	b	b
4C	b	b				b	a	a	b	b	b	b	b	b	b	b	b	b
5A	b	b				b	b	b	a	b	b	b	b	b	b	b	b	b
6	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
6B	a	a				b	a	a	a	b	a	b	b	b	b	b	b	b
7	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
10A	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
10B	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
11	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
12	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
13	b	b				b	b	b	b	b	b	b	b	b	b	b	a	b
14	b	b				b	b	b	b	b	b	b	b	b	b	b	b	a

Note : Trade of allocation and entitlement is permitted within trading zones 4B, 5B, 9A and 9B, but not to or from these trading zones.

Trading capability for Werribee water system

From Trading Zone (columns); To Trading Zone (rows)

Zone	31AD	31AR	31C	31BD	31BR
31AD	a	a		b	b
31AR	a	a		b	b
31C			a	b	b
31BD	a	a	a	a	a
31BR	a	a	a	a	a

Trading capability for Thomson/Macalister water system

From Trading Zone (columns); To Trading Zone (rows)

Zone	41A	41B	42A	42B
41A	a	a	a	a
41B	a	a	a	a
42A			a	
42B	b	b	a	a

Figure 14: Trading zone boundaries (Victorian Water Register 2011).

Table 17: Summary of trading rules.

Into trading zone:	Zones	From trading zone: 1A Greater Goulburn	1B Boort	1L Loddon Weir Pool	3 Lower Goulburn	4A Campaspe	4C Lower Campaspe	5A Loddon	6 Vic. Murray: Dartmouth - Barmah	6B Lower Broken Creek	7 Vic. Murray: Barmah to S.A.	10A NSW Murray above Barmah	10B Murray Irrigation Limited	11 NSW Murray below Barmah	12 South Australian Murray	13 Murrumbidgee	14 Lower Darling
1A	Greater Goulburn	■	■		□	■	■	■	□	□	□	□	□	□	□	□	□
1B	Boort	■	■		□	■	■	■	□	□	□	□	□	□	□	□	□
1L	Loddon Weir Pool	■	■	■	□	■	■	■	□	□	□	□	□	□	□	□	□
3	Lower Goulburn	■	■		■	■	■	■	□	□	□	□	□	□	□	□	□
4A	Campaspe	□	□		□	■	■	□	□	□	□	□	□	□	□	□	□
4C	Lower Campaspe	□	□		□	■	■	□	□	□	□	□	□	□	□	□	□
5A	Loddon	□	□		□	□	□	■	□	□	□	□	□	□	□	□	□
6	Vic. Murray -Dartmouth to Barmah	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
6B	Lower Broken Creek	■	■		□	■	■	■	□	■	□	□	□	□	□	□	□
7	Vic. Murray – Barmah to South Australia	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
10A	NSW Murray above Barmah	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
10B	Murray Irrigation Limited	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
11	NSW Murray below Barmah	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
12	South Australian Murray	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
13	Murrumbidgee	□	□		□	□	□	□	□	□	□	□	□	□	□	■	□
14	Lower Darling	□	□		□	□	□	□	□	□	□	□	□	□	□	□	■

Additional Trading Rules

All trade except to unregulated tributaries is with an exchange rate of 1.00. Trade into the unregulated river zones of the Goulburn (zones 110, 111, 112 and 130) can only be transferred as a winterfill licence, which becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trade (of allocation or entitlement) into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to 4 per cent per year from irrigation districts in Victoria. G-MW advises via media release when these limits are reached for individual irrigation districts. There are various exemptions for this limit specified in the trading rules on the Victorian Water Register. For more information on water trading rules, see the Victorian Water Register (http://waterregister.vic.gov.au/).

A service standard for allocation trade processing times has been implemented by the Council of Australian Governments (COAG):

- Interstate – 90 per cent of allocation trades between NSW/Victoria processed within 10 business days.
- Interstate – 90 per cent of allocation trades to/from South Australia processed within 20 business days.
- Intrastate – 90 per cent of allocation trades processed within 5 business days.

This means that the environmental water managers must make any allocation trades well in advance of a targeted runoff event.

Water trading attracts water trading fees. If water trading occurs without the use of a broker, the fees are currently less than $80 for Victoria within state trade. See the Victorian Water Register for Victorian fee schedules at http://www.waterregister.vic.gov.au/Public/ApplicationFees.aspx.

6.4.2 Water storage accounting

Unlimited storage carryover is allowed in the Goulburn system, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of Lake Eildon spilling. Any water in the spillable water account cannot be accessed until the risk of spilling has passed (assessed by the G-MW Water Resources Manager based on storage levels and likely inflows). If a spill occurs, prior to a declaration being made by G-MW, then the balance held in the spillable water account will be reduced in proportion to the volume to spill (G-MW 2011). The annual deduction for evaporation is 5 per cent of carried over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $3.52 per ML for the Goulburn system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

6.4.3 Water delivery accounting

G-MW has an allowance for conveyance losses within its bulk entitlement for the Goulburn system. If conveyance losses increase because water is being delivered to environmental assets, then these additional losses would be negotiated between G-MW and environmental water holders.

7. Risk assessment and mitigation

The risk assessment outlined in Table 18 provides an indication of the risks associated with the delivery of environmental water in the Lower Goulburn system. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 6.

Table 18: Risk associated with water delivery in the Lower Goulburn River.

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Controls
Acid sulfate soils	There is no evidence of acid sulfate soil issues along the Goulburn River.	Unlikely	Moderate	Low	Maintenance of continuous flows should minimise this risk.
Salinity	Releases from Lake Eildon and Goulburn Weir to the Lower Goulburn River are of good quality and do not pose salinity risks at the volumes proposed.	Unlikely	Minor	Low	Salinity is monitored and the Goulburn water quality reserve could be called upon to reduce (dilute) saline water, if this was necessary (unlikely).
Invasive species	Carp breeding can occur, along with that of native fish. Invasive aquatic macrophytes (e.g. *Sagittaria*) occur across the region.	Likely	Moderate	Medium	Carp - none practicable. Invasive aquatic macrophytes – continued surveillance and eradication or control.
Low DO (e.g. from blackwater events)	Fish kills have occurred in the Goulburn River, with low DO being implicated although the exact cause of these deaths was difficult to determine (e.g. Koehn 2004, Sinclair 2004). Recent low DO events have been attributed to catchment runoff from bushfire-affected tributaries. A blackwater event and fish kill has recently (December 2010) occurred with the second of two floods experienced along the river this winter/spring.	Possible, depending on antecedent conditions.	Major	High	Continue the GB CMA monitoring of DO to assess recovery in DO expected as flow is dominated from Lake Eildon releases, rather than inflows from tributary catchments (including bushfire affected catchments). Most flows proposed will not leave the river channel, reducing the risk of low DO and blackwater that might occur with flooding. The risk of low DO with flooding could also be reduced by limiting controlled overbank flows to winter-spring.
Water loss	There is high uncertainty regarding magnitude of losses downstream of Lake Eildon, particularly at high flow rates. Modelling suggests that in the order of 100 GL can be retained on the floodplain in overbank events (G. Earl, GB CMA, pers. comm. 2011).	Likely	Minor	Medium	Review losses along Goulburn River. Allow for losses, if necessary, when estimating allocations.
Estimation of water availability and volumes required	Volumes associated with water delivery options depend on modelling. Modelling accuracy may result in underestimation of the volumes actually required. This increases the likelihood of shortfalls in actual volumes of water required to achieve objectives.	Possible	Moderate	Medium	Confirmation that volume(s) released achieve the desired hydrological and ecosystem outcomes and adjustment of volumes as required (within flow constraints – see flooding risks below).
Cold water releases from Lake Eildon.	The release of colder bottom waters from Lake Eildon mainly affects water temperature between Lake Eildon and Seymour. It is not expected to affect water temperature below Goulburn Weir.	Unlikely	Minor	Low	

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Controls
Flooding	Risk of flooding sites along the river, commencing at 14,500 ML/d downstream of Lake Eildon.	Unlikely	Moderate	Low	Flows resulting from environmental water releases will be actively managed by river operators to remain below minor flood levels (14,500 ML/d immediately downstream of Lake Eildon).
	Excessive erosion and bank instability	Unlikely	Moderate	Low	Appropriate rates of rise and fall at Lake Eildon avoid excessive bank erosion.
	Loss of public amenity and risk to recreational users of the river.	Possible	Minor	Low	Notification of potential loss of public amenity and potential hazards with delivery of flow events.
	Inability to achieve environmental objectives for overbank events due to flow constraints.	Likely	Moderate	Medium	Overbank flow objectives are not currently feasible due to delivery constraints.

8. Environmental Water Reserves

8.1 Environmental water provisions

G-MW's bulk entitlement (Eildon-Goulburn Weir) specifies a number of environmental water provisions. Minimum passing flows under the entitlement are:

- A minimum flow of 120 ML/d from the Eildon Pondage Weir. This is increased to 250 ML/d when 24-month Lake Eildon inflows are high. Threshold 24-month inflows are listed in Clause 6 of the entitlement.
- A minimum average weekly flow of 250 ML/d from Goulburn Weir over any seven day period, at a daily rate of no less than 200 ML/d.
- Any additional flow necessary to maintain a minimum average monthly flow at the McCoys Bridge gauging station of 350 ML/d for the months of November to June inclusive (at a daily rate of no less than 300 ML/d) and 400 ML/d for the months of July to October inclusive (at a daily rate of no less than 350 ML/d).

Other environmental water specified under the entitlement includes:

- 80,000 ML for flood release. This water is available to be released below Eildon Pondage Weir in November under very specific circumstances relating to 24 and 12 month inflows and maximum release constraints.
- 30,000 ML for water quality. This water is available only as required to maintain water quality in the waterway.

8.2 Current water holdings

Commonwealth environmental water holdings (as at October 2010) in the Goulburn system are summarised in Table 19. These include 65,000 ML of high reliability water share and 10,000 ML of low reliability water share in the Goulburn system. The volume of Commonwealth environmental water available for use in the Goulburn system can be increased at any time by selling allocations tagged as sourced from elsewhere in the southern connected Murray-Darling Basin and purchasing an equivalent volume in the Goulburn system, subject to the trading rules described in Section 6.4 and the availability of water for purchase in the Goulburn system. The volume of Commonwealth environmental water elsewhere in the southern Murray-Darling Basin (as at October 2010) includes up to approximately 194,000 ML upstream of the Barmah Choke and 308,000 ML downstream of the Barmah Choke. These volumes continue to change as the Australian Government continues its purchasing of water entitlements – the most up to date figures can be found at www.environment.gov.au/ewater.

Environmental water currently held under Bulk Entitlements by the VEWH in the Goulburn system are summarised in Table 20.

.

Table 19: Commonwealth environmental water holdings (as at October 2010).

System	Licence Volume (ML)	Water share type
NSW Murray above Barmah Choke	0.0	High security
	155,752.0	General security
VIC Murray above Barmah Choke	32,361.3	High reliability water share
	5,674.1	Low reliability water share
Ovens*	70.0	
Total above Barmah Choke	**32,361.3**	**High security/reliability**
	161,426.1	**Low security/reliability**
NSW Murray below Barmah Choke	386.0	High security
	32,558.0	General security
VIC Murray below Barmah Choke	78,721.9	High reliability water share
	5,451.3	Low reliability water share
Murrumbidgee***	64,959.0	General security
	20,820.0	Supplementary
Goulburn	64,919.6	High reliability water share
	10,480.0	Low reliability water share
Broken**	20.0	High reliability water share
	4.2	Low reliability water share
Campaspe	5,124.1	High reliability water share
	395.4	Low reliability water share
Loddon	1,179.0	High reliability water share
	527.3	Low reliability water share
South Australia	43,297.4	High reliability
Total below Barmah Choke (excluding Ovens, Broken and Murrumbidgee licences)	**193,628.0**	**High security/reliability**
	114,371.0	**Low security/reliability**

Notes:

* The Australian Government holds 70.0 ML of regulated river entitlement on the Ovens System; however this water cannot be traded outside of the Ovens Basin.

** The Australian Government holds 20.0 ML of high reliability water share and 4.2 ML of low reliability water share on the Broken System; however this water cannot be traded outside of the Broken Basin.

*** The Australian Government holds 20,820 ML of supplementary water shares on the Murrumbidgee System; however this water cannot be traded outside of Murrumbidgee system.

Table 20: Environmental water held by the VEWH in the Goulburn system.

Water holding	Volume	Comments
Environmental Entitlement (Goulburn System – The Living Murray) Further Amending Order 2009	141,046 ML of low reliability water shares (sales package). 19,164 ML of high reliability water shares (G-MW recovery package). 20,461 ML of high reliability water shares (Shepparton irrigation area modernisation project). 15,780 ML of low reliability water shares (Shepparton irrigation area modernisation project).	Committed to meet Living Murray objectives, but may be useful in the Lower Goulburn in transit.
Bulk Entitlement (Goulburn System – Snowy Environmental Reserve) Amendment Order 2009	3,900 ML of high reliability water share (pipelining of Normanville waterworks district). 14,812 ML of high reliability water share (Goulburn system improved measurement of small volume supplies to irrigation districts program). 2,000 ML of high reliability water share (Goulburn strategic measurement project).	Generally released in summer to supply Murray irrigation demands.
Goulburn River Environmental Entitlement 2010	1,432 ML of high reliability water share (Wimmera-Mallee Pipeline Savings)	Trading zone 1B
Environmental Entitlement (Goulburn System – Environmental Water Reserve) 2010	Prior to the completion of Stage 1 of the Northern Victoria Irrigation Renewal Project (NVIRP): The volume of water that has been allocated to the environment from the modernisation savings account. After the completion of Stage 1: The volume equivalent to one-third of the total volume saved in the Goulburn component of the Goulburn Murray Irrigation District, with the characteristics of high reliability and low reliability water shares.	Exact volumes to be confirmed after completion of NVIRP works. This entitlement was gazetted but was disallowed in the Victorian Parliament in June 2010.

8.3 Seasonal allocations

Victorian allocations are announced by G-MW twice monthly and are published at http://www.g-mwater.com.au/news/allocation-announcements/current.asp. Long-term seasonal allocations for the Goulburn system and Murray River are shown for October and April as indicative of spring and autumn in Figure 15 and Figure 16. This information is sourced from the MSM-Bigmod post-TLM run (#22061).

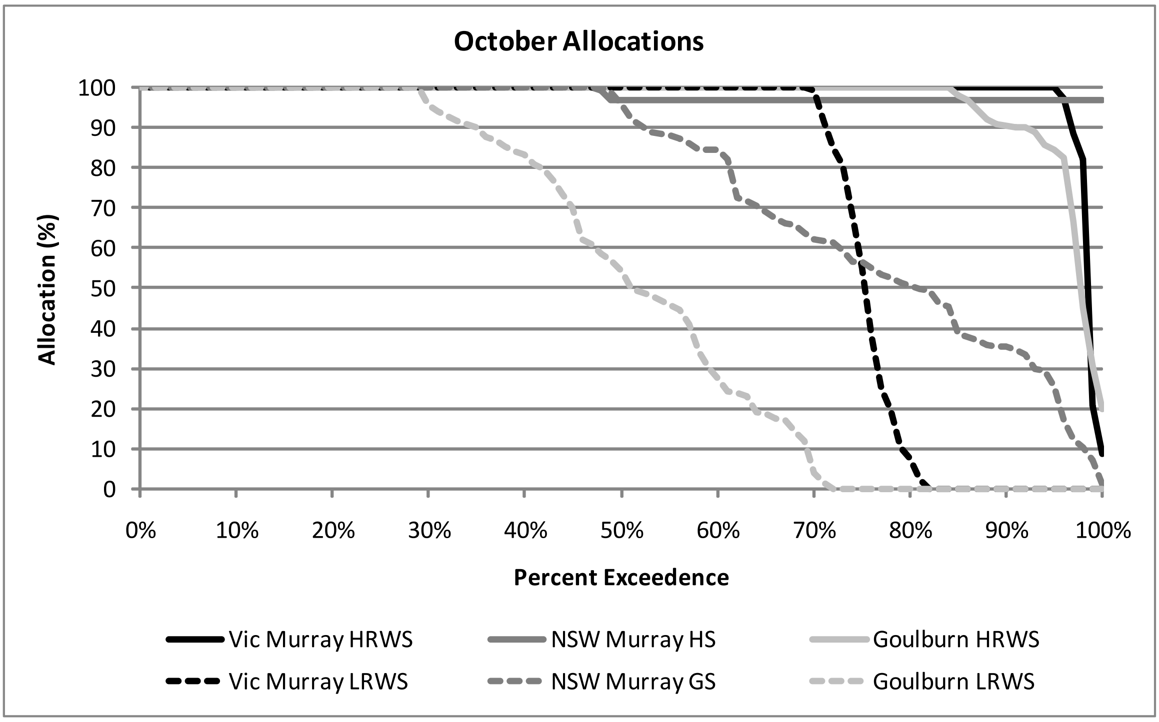


Figure 15: October seasonal allocations for the Goulburn and Murray River systems.

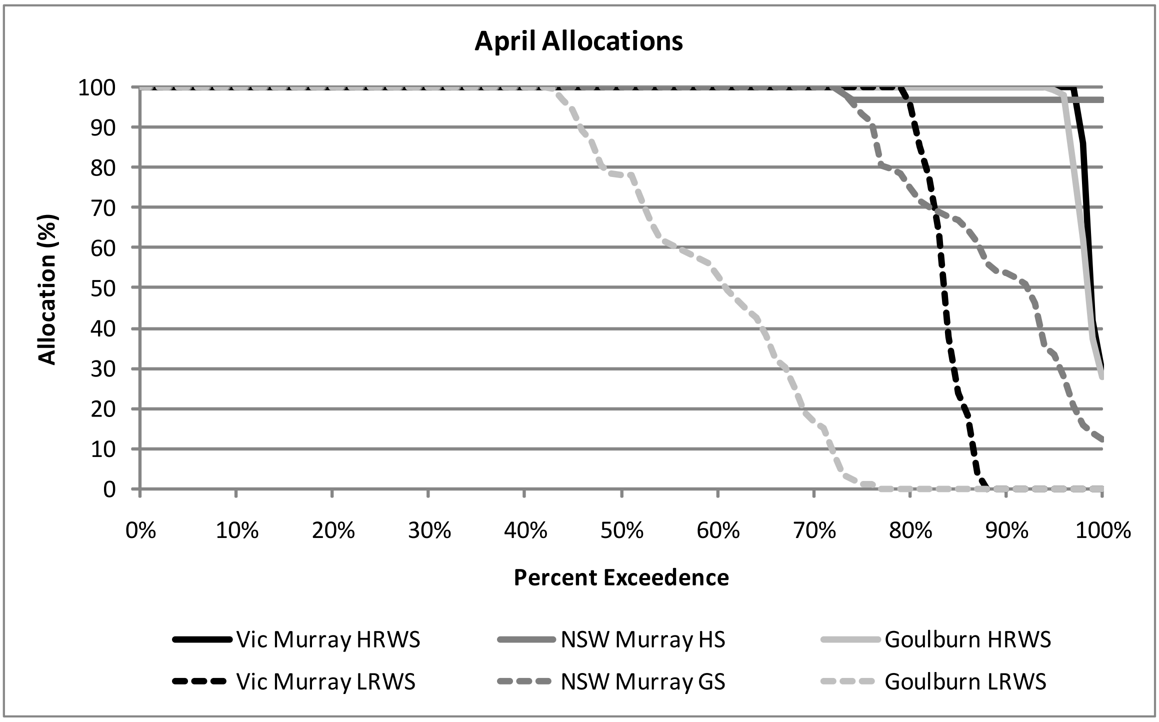


Figure 16: April seasonal allocations for the Goulburn and Murray River systems.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 21. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 22. The calculation of the volume of water expected to be available to the environment under each climate condition is based on the volume and type of entitlements held and the expected announced allocation for each climate condition (from modelling). This table shows that around 20 per cent of high reliability water shares (13,000 ML based on October 2010 holdings) would be expected to be available in the Goulburn system in spring of a very dry year and around 100 per cent of high reliability water shares and 95 per cent of low reliability water shares (75,000 ML based on October 2010 holdings) would be expected in a wet year. Note that the models used to derive these allocations can over-estimate allocation in very dry years.

Tables 21 and 22 were provided by SKM and based on allocation information from the MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #22061).

Table 21: Likely announced allocation for Commonwealth environmental water holdings, under different climate scenarios.

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (%)				April Allocation (%)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
NSW Murray above Barmah Choke	General Security	155,752.0	1	62	96	100	12	100	100	100
Victorian Murray above Barmah Choke	High reliability water share	32,361.3	9	100	100	100	29	100	100	100
	Low reliability water share	5,674.1	0	99	100	100	0	100	100	100
Ovens	High reliability water share	70.0	100	100	100	100	100	100	100	100
NSW Murray below Barmah Choke	High security	386.0	97	97	97	100	97	100	100	100
	General Security	32,558.0	1	62	96	100	12	100	100	100
Victorian Murray below Barmah Choke	High reliability water share	78,721.9	9	100	100	100	29	100	100	100
	Low reliability water share	5,451.3	0	99	100	100	0	100	100	100
Murrumbidgee	General Security	64,959.0	10	42	55	64	10	68	100	100
	Supplementary	20,820.0	0	0	0	100	0	0	0	100
Goulburn	High reliability water share	64,919.6	20	100	100	100	28	100	100	100
	Low reliability water share	10,480.0	0	4	54	96	0	17	78	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 22: Likely volume available to the environment from Commonwealth environmental water holdings (as at October 2010).

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (GL)				April Allocation (GL)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
NSW Murray above Barmah Choke	General Security	155,752.0	2.2	97.2	149.1	155.8	19.3	155.8	155.8	155.8
Victorian Murray above Barmah Choke	High reliability water share	32,361.3	2.9	32.4	32.4	32.4	9.4	32.4	32.4	32.4
	Low reliability water share	5,674.1	0.0	5.6	5.7	5.7	0.0	5.7	5.7	5.7
Ovens*	High reliability water share	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total above Barmah Choke			**5.1**	**135.2**	**187.2**	**193.8**	**28.7**	**193.8**	**193.8**	**193.8**
NSW Murray below Barmah Choke	High security	386.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	General Security	32,558.0	0.5	20.3	31.2	32.6	4.0	32.6	32.6	32.6
Victorian Murray below Barmah Choke	High reliability water share	78,721.9	7.1	78.7	78.7	78.7	22.8	78.7	78.7	78.7
	Low reliability water share	5,451.3	0.0	5.4	5.5	5.5	0.0	5.5	5.5	5.5
Murrumbidgee*	General Security	64,959.0	6.5	27.3	35.7	41.6	6.5	44.2	65.0	65.0
	Supplementary	20,820.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goulburn	High reliability water share	64,919.6	13.0	64.9	64.9	64.9	18.2	64.9	64.9	64.9
	Low reliability water share	10,480.0	0.0	0.4	5.7	10.0	0.0	1.8	8.2	10.5
Broken*	High reliability water share	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low reliability water share	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Campaspe	High reliability water share	5,124.1	1.7	5.1	5.1	5.1	2.2	5.1	5.1	5.1
	Low reliability water share	395.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4
Loddon	High reliability water share	1,179.0	0.0	1.2	1.2	1.2	0.0	1.2	1.2	1.2
	Low reliability water share	527.3	0.0	0.0	0.3	0.5	0.0	0.1	0.4	0.5
South Australia	High reliability	43,297.4	19.0	43.3	43.3	66.9	26.6	43.3	43.3	44.3
Total below Barmah Choke			**48.1**	**247.4**	**272.3**	**307.7**	**80.8**	**278.1**	**305.6**	**309.0**
Total			**53.2**	**382.6**	**459.5**	**501.5**	**109.5**	**471.8**	**499.4**	**502.8**

* Commonwealth holdings on the Ovens and Broken system and supplementary holdings on the Murrumbidgee system cannot be traded outside of the source trading zone. As such, holdings in these basins do not contribute to total water availability.

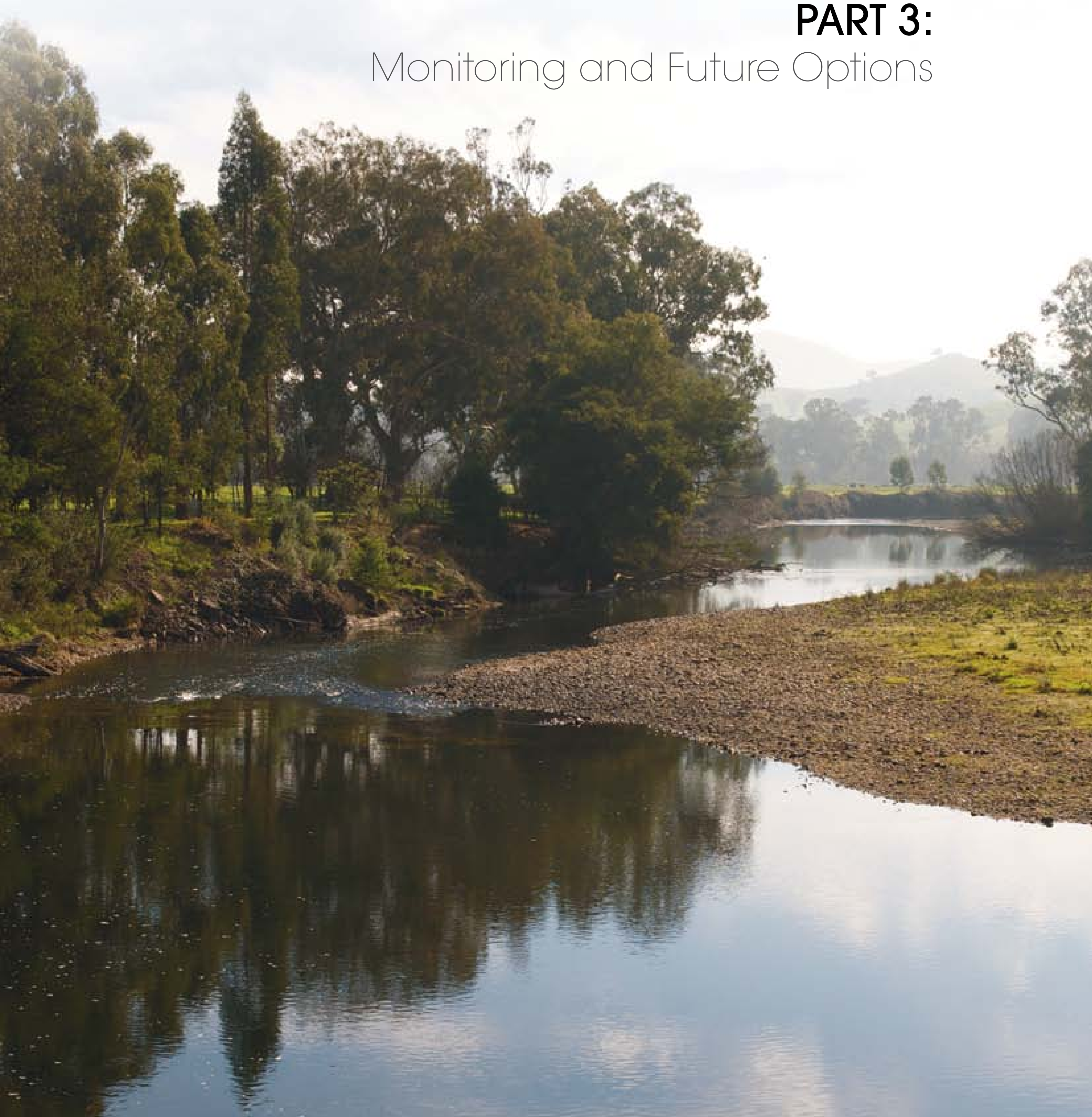
8.4 Water availability forecasts

A description of likely water availability for the Victorian Murray and Goulburn systems is provided by G-MW when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day). However, when allocations to high reliability water shares are less than 100 per cent, allocation announcements are made on the 1st and 15th of each month (or the next business day).

The current allocation announcement and a description of likely future water availability for the remainder of the season can be sourced from: http://g-mwater.com.au/news/allocation-announcements/current.asp. Historical announcements and forecasts can be sourced from: http://g-mwater.com.au/news/allocation-announcements/archive.asp.

Additionally, G-MW publishes a seasonal allocation outlook prior to the start of each irrigation season providing a forecast for opening October and February allocations for the following season. The seasonal allocation outlooks are published on G-MW's website (see Media Releases). In years with high water availability, only the seasonal allocation outlook may be prepared (i.e. water availability forecasts may not be provided with allocation announcements).

PART 3:
Monitoring and Future Options



9. Monitoring, evaluation and improvement

9.1 Existing monitoring programs and frameworks

Assessing ecosystem response to specific environmental flow releases as a form of intervention analysis is a challenging exercise (Chee et al. 2006). Being able to apply traditional study designs is often problematic, as control sites (similar features to the test site, but without the intervention) are usually lacking (i.e. there is not another Goulburn River). Similarly, establishing 'before' conditions is difficult given the nature of river regulations and flows delivered from natural rainfall-runoff events.

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established specifically to assess ecosystem response to new environmental flow regimes. VEFMAP is being implemented across northern Victorian rivers, including the Goulburn, Campaspe and Loddon Rivers (Chee et al. 2006, SKM 2007). Water quality and quantity is monitored as part of the Victorian Water Quality Monitoring Network and the North East Regional Water Monitoring Partnership (NERWMP). The following section provides a guide to the parameters that could be considered for future monitoring of environmental water releases. They do not provide guidance on aspects of study design, site selection and sampling frequency.

There are numerous long-term flow gauges along the Goulburn River. Key streamflow gauges are listed in Table 23. A full list of available streamflow gauges can be found on the Victorian Water Resources Data Warehouse (DSE 2010). G-MW collects operational data for headwork storages and irrigation distribution channel systems.

Table 23: Flow monitoring along the Goulburn River.

Reach Number	Reach Description	Relevant Hydrographic Stations		
		Site ID	Site Name	Adequacy of Gauge (pers comm. Leon Tepper – Thiess Tatura)
1	Lake Eildon to Molesworth	405203C	Goulburn River @ Eildon	There is an unstable stage/discharge relationship at this site due to seasonal weed growth along the gauging station reach. This has most impact on flows of <1,000 ML/d. For flows between 1,000 and 4,000 ML/d the uncertainty is better than 8% at 95% confidence limit.
2	Molesworth to Seymour	405201B	Goulburn River @ Trawool	Likely issues with lower flows (<1,000 ML/d). The site relies on a natural channel control giving poor low flow sensitivity and a mildly unstable stage discharge relationship. Low flow gaugings are undertaken 2 km upstream of the site.
3	Seymour to Nagambie	405202B	Goulburn River @ Seymour	The stage/discharge relationship is stable. Flow data uncertainty is better than 4% at 95% confidence level.
4	Goulburn Weir to Shepparton	405259A	Goulburn River @ Goulburn Weir	Flood measurement only >3.5 m. Upon request only.
		405200A	Goulburn River @ Murchison	The conventional method of monitoring flow using a stage discharge relationship is not adequate for this site. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is therefore currently being used to collect flow data. The result is that the uncertainty in flow is now better than 7% at 95% confidence level.
		405204C	Goulburn River @ Shepparton	Since major works on and around the low level rock weir downstream of this site, the low flow data is only reasonable. The site is still stabilising. The flow accuracy is within +5.0 to +7%. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is needed.
5	Shepparton to the Murray River	405276A	Goulburn River @ Loch Garry	Flood site only.
		405232C	Goulburn River @ McCoys Bridge	The low flow data is reasonable with flow accuracy at +5 to +7%. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is needed. The sites accuracy can be questioned once flood flows depart from the main stream upstream of the monitoring site.
Living Murray contribution	Conformance assessed at Reach 5	405232	Goulburn River @ McCoys Bridge	See above.

As well as flow monitoring at the sites listed in Table 23, water quality parameters (including colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidised nitrogen, pH, total phosphorus and turbidity) are measured on a monthly basis at:

- Eildon (site 405203)
- Trawool (site 405210)
- Seymour (site 405202)
- Goulburn Weir (site 405259)
- Murchison (site 405200)
- Shepparton (site 405204)
- McCoys Bridge (site 405232).

In addition, the G-MW undertakes continuous DO monitoring at Goulburn Weir and the GB CMA monitors DO at Shepparton and McCoys Bridge. This allows the GB CMA and G-MW to respond to the onset of low DO conditions by increasing flow delivered to the Lower Goulburn River from Lake Eildon and Goulburn Weir.

Fish populations (including fish larvae) along the Lower Goulburn River are surveyed annually as part of the Murray-Darling Basin Sustainable Rivers Audit (SRA), whilstmacroinvertebrate communities are monitored by EPA Victoria as part of its fixed sites monitoring network and also as part of the SRA (SKM 2007). Vegetation condition on the river bank is assessed as part of the Index of Stream Condition assessment, which adopts the 'habitat hectares' approach that compares species and life forms at randomly selected sites against a benchmark. Index of Stream Condition vegetation assessments are conducted at the top of the bank and provide little consistent information about plants lower down the river bank and in the river channel.

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) monitoring has been established for the Lower Goulburn River to monitor habitat availability and the response of vegetation, fish populations and macroinvertebrate populations to environmental flows. Given that this document is aligned with previous environmental flow recommendations for the Goulburn River, the VEFMAP provides a valuable baseline from which to assess ecosystem response to future environmental flows. Parameters to be monitored are considered further in sections 9.3 and 9.4.

9.2 Operational water delivery monitoring

Monitoring the delivery of environmental water along the Lower Goulburn River can be undertaken using the flow gauging sites previously listed in 9.1. In addition, the Department of Sustainability, Environment, Water, Population and Communities has a pro forma Operational Monitoring Report to capture information related to releases, such as event details, risk management, initial observations and other issues (included at Appendix 4). This information is expected to form input into subsequent delivery plans, as well as any applications for return flow credits.

9.3 Key parameters for monitoring and evaluating ecosystem response

The environmental watering objectives for the Lower Goulburn River (Table 3) seek to:

- Provide suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages and for in-channel and littoral vegetation.
- Provide deep water habitat for large-bodied native fish.
- Entrain litter packs available as food/habitat source for macroinvertebrates.
- Maintain water quality suitable for macroinvertebrates.
- Provide snag habitat within the euphotic zone to provide habitat and food source for macroinvertebrates.
- Maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity.
- Increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine particulate matter.
- Achieve phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition more resembling un-impacted sites to support dynamic, diverse food webs.

VEFMAP monitoring established for the Lower Goulburn River (SKM 2007) includes:

- Physical habitat surveys - river cross sections, qualitative estimate of habitat area and velocity, visual estimate of substratum composition, woody debris load assessment.
- Water quality assessment - monthly in-situ physico-chemical water quality monitoring.
- Riparian and in-channel vegetation surveys.
- Adult fish surveys.
- Macroinvertebrate surveys.

VEFMAP provides information that can be used to assess future environmental flow releases, including that achieved with the delivery of environmental water. Current monitoring undertaken as part of VEFMAP for the Goulburn River, including flow components, hypotheses and indicators, is summarised in Appendix 5.

9.4 Potential monitoring gaps

VEFMAP was established to assess ecosystem responses to changes in watering regimes over time (e.g. five years). It was not designed to assess ecosystem responses to individual or short-term flow events. The main issue for assessing the effectiveness of environmental water (in isolation) is to establish a study design that provides the best possible inference that ecosystem response is due to any particular environmental release(s). Particular attention is required on establishing the 'before' conditions to allow 'before-after' comparisons. Appropriate experimental designs are best considered once the type for flow release(s) is determined (e.g. baseflow, fresh, overbank flow). Monitoring considerations when planning to deliver environmental water are summarised in Table 24 (see also Appendix 5 for references to VEFMAP).

Table 24: Monitoring considerations for the delivery of environmental water.

Asset/ ecosystemattribute	Objective	Existing monitoring	Additional monitoring required
Aquatic and riparian vegetation	Enhance the extent and diversity of aquatic vegetation (in-channel and wetlands). Increased contribution to processes such as river productivity. Maintain diversity of riverbank vegetation. Reduce extent and impact of weeds. Maintain continuity and cover of riverbank vegetation. Enhance the extent and diversity of aquatic vegetation.	VEFMAP frequency will not be sufficient to detect changes in response to individual watering events.	Frequency and timing of monitoring to coincide with individual watering events to assess the effect of its environmental water in isolation from the wider water regime.
Macroinvertebrates	Trophic structure and diversity with a more balanced representation of all functional groups. Ausrivas O/E scores = Band A. Biomass equivalent to rivers elsewhere (e.g. Ovens). Maintain dynamic, diverse food webs that support higher organisms and contribute to river health.	As above.	As above.
Native fish	Suitable in-channel habitat for all life stages. Suitable off-channel habitat for all life stages. Passage for all life stages. Cues for adult migration during spawning season. Access to floodplain and off-channel habitats for spawning and/or larval rearing. Low flows recruitment and survival. Floodplain and bench inundation for exchange of food and organic material between floodplain and channel.	As above.	As above.
Geomorphology	Maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity.	Existing monitoring is appropriate for larger channel-forming events (i.e. approaching bankfull discharge).	Additional monitoring can be considered to evaluate sediment movement and pool depth for smaller flow freshes.
Phytoplankton, periphyton and macrophyte production	Phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition more resembling un-impacted sites to support dynamic, diverse food webs.	None.	Additional monitoring is required.

10. Opportunities

The GB CMA is investigating options to use the volume stored in Goulburn Weir to release flows to coincide with natural flow peaks along the Broken River, thereby providing enhanced flows in the Lower Goulburn River downstream of Shepparton. The volume released from Goulburn Weir would then require some supplementing from Lake Eildon releases. This would involve some operational adjustments, such as managing deliveries along the irrigation channels supplied from Goulburn Weir. This is currently being considered by the GB CMA, but may only be feasible during winter. If the use of Goulburn Weir is not possible, opportunities to deliver the desired summer to autumn fresh on the back of inter-valley transfers should be further explored with G-MW.

There are a number of breaks in the levee system along the Lower Goulburn River, which means that at 40,000 ML/d, approximately 15 per cent of the water goes to the Deep Creek system and then the Murray River. The GB CMA is considering putting regulators on these breaks to keep more water on the floodplain between the river channel and the levees. Regulating structures are also being considered for the Loch Garry system. These are some areas of vegetated floodplain below Loch Garry that could be watered, and this would also help with operating the river more efficiently. Both these opportunities are being considered by the CMA (G. Earl, GB CMA, pers. comm. 2011).

Water from the Goulburn River can also be used to supplement flows to assets on the Murray River downstream. Coordinating the use of environmental water with other releases in the Murray River is an area to be considered once watering options plans for Murray River assets have been prepared.

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Appendix 1: Key species and communities

Key species in the Lower Goulburn River.

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Plants					
Amphibromus fluitans	River swamp wallaby grass	V	May		-
Aristida jerichoensis var. subspinulifera	Jericho wire-grass	-	Known		L
Brachyscome muelleroides	Mueller Daisy	V	Likely		L
Callitriche cyclocarpa	Western water-starwort	V	Known		L
Craspedia canens	Grey billy-buttons	-			L
Cullen parvum	Native scurf-pea	-	Known		L
Myriophyllum porcatum	Ridged water-milfoil	V	Likely		L
Sclerolaena napiformis	Turnip Copperbur	E	Likely		L
Swainsona murrayana	Slender Darling-pea	V	Likely		L
Invertebrate					
Synemon plana	Golden sun month	CE	May		L
Fish					
Bidyanus bidyanus	Silver perch	-	Known	-	L
Craterocephalus fluviatilis	Murray Hardyhead	V	May	-	L
Maccullochella macquariensis	Trout cod	E	Known	-	L
Maccullochella peelii peelii	Murray cod	V	Known	-	L
Macquaria australasica	Macquarie Perch	E	May	-	L
Melanotaenia fluviatilis	Murray-Darling rainbow fish	-	Known	-	L
Tandanus tandanus	Freshwater catfish	-	Known	-	L
Amphibians					
Litoria raniformis	Southern bell or growling grass frog	V	Known		L

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Pseudophryne bibronii	Brown toadlet	-	Known		L
Reptiles					
Aprasia parapulchella	Pink-tailed worm lizard	V	Likely		L
Delma impar	Striped legless lizard	V	Likely		L
Varanus varius	Lace goanna	-			L
Birds					
Anseranas semipalmata	Magpie goose				L
Anthochaera Phrygia *(Xanthomyza Phrygia)*	Regent honeyeater	E	May	Terrestrial, wetlands	L
Apus pacificus	Fork-tailed swift	-	May	Marine	-
Ardea alba	Great egret	-	May	Marine, wetlands	L
Ardea ibis	Cattle egret	-	May	Marine, wetlands	-
Botaurus poiciloptilus	Australasian bittern	E	Known		L
Botaurus poiciloptilus	Australasian bittern	E	Known		
Burhinus grallarius	Bush stone curlew	-	Known		L
Chthonicola sagittata	Speckled warbler	-	Known		
Gallinago hardwickii	Latham's snipe	-	Known	Wetlands	-
Grantiella picta	Painted honeyeater	-	Known		L
Grus rubicunda	Brolga	-	Known		L
Haliaeetus leucogaster	White-bellied sea-eagle	-	Likely	Terrestrial	L
Hirundapus caudacutus	White-throated needletail	-	May	Terrestrial	-
Lathamus discolor	Swift parrot	E	Likely		L
Merops ornatus	Rainbow bee-eater	-	May	Terrestrial	-
Neophema pulchella	Turquoise parrot	-	Known		L
Ninox connivens connivens	Barking owl	-	Known		L
Ninox strenua	Powerful owl	-	Known		L
Pedionomus torquatus	Plains wanderer	V	May		L
Polytelis swainsonii	Superb parrot	V	May		L

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Rostratula australis	Australian painted snipe	V	May		L
Stictonetta naevosa	Freckled duck	-	Known		L
Tyto novaehollandiae novaehollandiae	Masked owl	-	Known		L
Mammals					
Petaurus norfolcensis	Squirrel glider	-	Known		L
Dasyurus maculatus maculatus	Spot-tailed quoll	V	May		L
Phascogale tapoatafa	Brush-tailed phascogale	-	Known		L

E Endangered

CE Critically endangered

L Listed (threatened)

V Vulnerable

The presence of species has been ascertained through:

* EPBC Act, Protected Matters Search Tool website
Department of Sustainability and Environment, Biodiversity Interactive Map website
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Wetland ecological vegetation classes recorded along the lower Goulburn floodplain (DSE 2011).

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Wetland EVCs	992	Water body – Fresh	734.9	384.6	1,119.5	N/A – no vegetation	N/A – no vegetation	No – No Native vegetation recorded (also no EVC template)	–	1
	168	Drainage-line Aggregate	394.3	28.8	423.1	Vulnerable	Endangered	Yes	Drainage-line Aggregate	–
	1022	Drainage-line Aggregate / Riverine Swamp Forest Mosaic	21.4	2.0	23.5	Vulnerable	Endangered	Yes		–
	334	Billabong Wetland Aggregate	355.2	61.4	416.6	Depleted	Vulnerable	Yes	Billabong Wetland Aggregate	–
	172	Foodplain Wetland Aggregate	69.0	87.1	156.1	Depleted	Vulnerable	Yes	Floodplain Wetland Aggregate	–
	804	Rushy Riverine Swamp	51.6	88.0	139.6	Depleted	Depleted	Yes	Rushy Riverine Swamp	–
	1090	Tall Marsh / Open Water Mosaic	–	120.4	120.4	Least concern	Depleted	Yes	Tall Marsh / Open Water Mosaic	–
	1081	Spike-sedge Wetland / Tall Marsh Mosiac	–	49.7	49.7	Vulnerable	Vulnerable	Yes	Spike-sedge Wetland / Tall Marsh Mosaic	–
	810	Floodway Pond Herbland	–	0.4	0.4	Depleted	Vulnerable	Yes	Floodway Pond Herbland	–
	74	Wetland Formation	–	4.3	4.3	Endangered	Endangered	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–
	125	Plains Grassy Wetland	–	0.2	0.2	Endangered	Endangered	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Floodplain EVCs	295	Riverine Grassy Woodland	3,898.8	2,163.9	6,062.7	Vulnerable	Vulnerable	Yes		–
	871	Riverine Grassy Woodland / Plains Woodland / Gilgai Wetland Complex	15.0	–	15.0	Depleted	N/A – not present	Yes	Riverine Grassy Woodland	–
	1040	Riverine Grassy Woodland / Riverine Swampy Woodland Mosaic	9.1	6.8	15.9	Vulnerable	Endangered	Yes		–
	56	Floodplain Riparian Woodland	2,011.9	1,143.1	3,156.2	Depleted	Vulnerable	Yes	Floodplain Riparian Woodland	1
	1035	Floodplain Riparian Woodland / Sedgy Riverine Forest Mosaic	–	48.8	48.8	Depleted	Vulnerable	Yes		–
	816	Sedgy Riverine Forest	1,471.4	2,073.9	3,545.4	Depleted	Vulnerable	Yes	Sedgey Riverine Forest	–
	815	Riverine Swampy Woodland	857.0	487.1	1,344.1	Vulnerable	Vulnerable	Yes	Riverine Swampy Woodland	–
	814	Riverine Swamp Forest	250.0	453.4	703.4	Depleted	Depleted	Yes		–
	1099	Riverine Swampy Woodland / Plains Grassy Wetland Mosaic	55.9	–	55.9	Endangered	N/A – not present	Yes	Riverine Swamp Forest	–
	1068	Riverine Swamp Forest / Sedgy Riverine Forest Mosaic	68.8	4.7	73.5	Depleted	Vulnerable	Yes		–
	68	Creekline Grassy Woodland	–	109.4	109.4	Endangered	Endangered	Yes	Creekline Grassy Woodland	–
	106	Grassy Riverine Forest	21.3	–	21.3	Depleted	Depleted	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–
	823	Lignum Swampy Woodland	0.1	–	0.1	Vulnerable	Vulnerable	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Terrestrial EVCs	803	Plains Woodland	2,059.1	194.6	2,253.7	Endangered	Endangered	No – EVC is not flood dependent	–	–
	103	Riverine Chenopod Woodland	276.2	–	276.2	Endangered	Endangered	No – EVC is not flood dependent	–	–
	264	Sand Ridge Woodland	91.6	71.4	163.0	Endangered	Endangered	No – EVC is not flood dependent	–	–
	55	Plains Grassy Woodland	–	57.6	57.6	Endangered	Endangered	No – EVC is not flood dependent	–	–
	66	Low Rises Woodland	4.0	9.6	13.6	Endangered	Vulnerable	No – EVC is not flood dependent	–	–
	985	Sandy Beach	–	4.9	4.9	Endangered	Endangered	No – EVC is not flood dependent	–	–
	267	Plains Grassland / Plains Grassy Woodland / Gilgai Wetland Mosaic	1.3	–	1.3	Endangered	Endangered	No – EVC is not flood dependent	–	–
	882	Shallow Sands Woodland	1.0	–	1.0	Vulnerable	Endangered	No – EVC is not flood dependent	–	–

Appendix 2: Flow Recommendations for Reaches 4 & 5

The following provides the flow recommendations outlined in Cottingham et al (2007).

Flow duration bounds identified for Reach 4 ecological objectives.

Note: The values in the table represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedence levels for extreme dry (10th percentile), dry (30th percentile), median and wet years (70th percentile).

			Recommended						
Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI4	F003b	540		0.90	0.95	0.95	0.98	0.99	
MI1	F007a	310	0.70	0.80	1.00	1.00			
MI3	F007a	310	0.99	0.99	0.99	0.99	0.99		
MI2	F008b	400	0.90	0.93	0.95	0.98	0.98		
n. fish	F008b	400	0.74	0.95	0.99	0.99	0.99		
n. fish	F007b	500	0.97	0.98	0.99	0.99	0.99		
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830	0.70	0.93	0.95	0.98	0.98		
Geo3	F026i	856	0.36	0.71	0.94	1.00	1.00	1.0	1.00
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96	1.0	1.00
MI1	F007c	1500		0.10	0.30	0.45	0.75		
MI3	F007c	1500		0.15	0.30	0.40	0.70		
Geo3	F026g	1660		0.30	0.47	0.63	0.74	0.94	1.00
Geo3	F026f	2223		0.11	0.25	0.40	0.60	0.71	1.00
Geo3	F026e	3142		0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490				0.05	0.24	0.37	0.64
Geo3	F026c	6590					0.08	0.16	0.42
Geo3	F026b	10700						0.04	0.27

			Recommended						
Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Geo3	F026a	19000							
Summer Upper Bound									
Geo3	F026i	856	0.36	0.71	0.94				
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96		
MI1	F007c	1500			0.70	0.90	0.90		
Geo3	F026g	1660	0	0.30	0.47	0.63	0.74	0.94	
Geo3	F026f	2223	0	0.11	0.25	0.40	0.60	0.71	
Geo3	F026e	3142	0	0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490	0	0	0	0.05	0.24	0.37	0.64
Geo3	F026c	6590	0	0	0	0	0.08	0.16	0.42
Geo3	F026b	10700	0	0	0	0	0	0.04	0.27
Geo3	F026a	19000	0	0	0	0	0	0	0.07
Autumn Lower Bound									
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.50	0.65	0.80	0.95	0.98	
Winter Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.80	0.86	0.88	0.90	0.96	
MI4	F003b	540		0.85	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	

Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	Recommended					Maximum
				10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	
Spring Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.81	0.85	0.91	0.95	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	
n.fish	F027a	24000				0.05	0.13	0.31	
Spring Upper Bound									
n.fish	F027a	24000		0	0	0.08	0.19	0.47	

Flow duration bounds identified for Reach 5 ecological objectives.

Note: The values represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedence levels for extreme dry (10th percentile), dry (30th percentile), median and wet years (70th percentile).

				Recommended					
Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI1	F007a	240		0.70	0.80	1.00	1		
MI3	F007a	240		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	320		0.90	0.90	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.90	0.95	0.95	0.98	0.99	
MI6	F003b	770		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.70	0.92	0.95	0.98	0.98	
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00
Geo3	F026g	1993	0.02	0.17	0.40	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
Plankt. Algae	F002c	6060				0	0.17		
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Summer - Upper Bound									
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00

						Recommended			
Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Geo3	F026g	1993	0.02	0.17	0.4	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.50	
MI4	F004c	5610		0.01	0.01	0.02	0.25	0.45	
Plankt. algae	F002c	6060					0.19	0.30	
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
MI2	F002b	8910		0.01	0.01	0.01	0.05	0.15	
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Autumn - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.50	0.65	0.80	0.95	0.98	
Autumn - Upper Bound									
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.60	
MI4	F004c	5610					0.03	0.10	
MI2	F002b	8910		0.01	0.01	0.01	0.01	0.05	
Winter - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	

Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	Recommended 10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
MI4	F003b	770		0.85	0.9	0.95	0.98	0.99	
MI6	F003b	770		0.8	0.9	0.95	0.99	0.99	
MI2	F008c	940		0.9	0.92	0.95	0.98	0.98	
Winter - Upper Bound									
MI2	F002b	8910		0.2	0.3	0.65	0.8	0.9	
Spring - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.9	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.90	0.92	0.95	0.98	0.98	
Plankt. algae	F002c	6060							
Spring - Upper Bound									
MI4	F004c	5610		0.42	0.70	0.85	0.95	1.00	
Plankt. algae	F002c	6060		0.35	0.66	0.73	0.86	1.00	
MI2	F002b	8910		0.10	0.40	0.65	0.80	1.00	
n. fish	F027a	24000		0	0.05	0.13	0.26	0.54	

Flow stressors and their components

Code	Description	Elements
F001	Mean hydraulic residence time (hours/km)	-
F002	Proportion of time when euphotic depth is less than *n* times the mean depth	*n* = 0.2, 0.25, 0.3
F003	Proportion of time when mean shear stress is less than *n* N/m^2 - leading to deposition of fine sediments	*n* = 1, 2, 3
F004	Proportion of time when mean shear stress is more than *n* N/m^2 – leading to possibly biofilm instability	*n* = 5, 6, 7
F005	Water level fluctuation characterised by the amphibious habitat index calculated at euphotic depth for the *n*% exceedence flows (in the pre-regulation regime)	*n* = 10, 20, 30, …, 90
F006	Maximum inundation duration at heights up the bank corresponding to the water surface levels for the *n*% exceedence flows (in the pre-regulation regime)	*n* = 10, 20, 30, …, 90
F007	Proportion of time when there is less than *n* m^2/m slow shallow habitat (d<0.5 m, v<0.05 m/s).	*n* = 1, 2, 3, …, 5
F008	Proportion of time when there is less than *n* m^2/m deep water habitat defined as d>1.5 m	*n* = 5, 10, 15, 20
F009	Maximum continuous rise in stage (m)	-
F010	The distribution of daily change in stage characterised by the n^{th} per centile values (m)	*n* = 10, 90
F011	Mean illuminated volume of water (m^3 per m length of channel)	-
F012	Mean ratio of euphotic depth to mean water depth	-
F013	Mean ratio offall velocity (*n* m/s) to mean water depth	*n* = 0.2, 0.4 and 0.94
F014	Mean illuminated area of benthos (m^2 per m length of channel)	-
F015	Mean illuminated area of benthos with velocity less than *n* m/s (m^2 per m length of channel)	*n* = 0.2, 0.3, 0.4 and 0.9
F016	Proportion of time when benthos has been in euphotic zone for at least *n* days, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F017	Number of independent events when benthos has been in euphotic zone for at least *n* days, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F018	Mean water depth (m) during periods when benthos is in euphotic zone for at least *n* days calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F019	Proportion of time benthos is in the euphotic zone, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90
F020	Proportion of time benthos is below the euphotic zone, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90

Code	Description	Elements
F021	Number of overbank events	
F022	The distribution of daily rises in stage characterised by the n^{th} per centile values (m)	*n* = 10, 90
F023	The distribution of daily falls in stage characterised by the n^{th} per centile values (m)	*n* = 10, 90
F024	The distribution of daily falls in stage characterised by the n^{th} per centile values (m) for flow bands defined by the flows Qi ML/d	*n* = 10, 50, 90 = 0, 4000, 100000
F025	Proportion of time water level is within a range defined by water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90
F026	Proportion of time water level is above a specified depth above bed corresponding to the*m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90
F027	Proportion of time flow exceeds24,000 Ml/d	

Summary of relationships between flow-related objectives and flow stressors

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Source of food for fish and invertebrates and influence on river nutrient and chemical conditions.	Planktonic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F001	Su, Sp	Increased channel retention due to reduced water velocity and/or hydraulic retention zones allows accumulation of biomass if growth rates exceed loss rates.
			F002	Su, Sp	Proportion of time planktonic algae spend in the euphotic zone determines whether net production is possible or not.
			F012	Sp	Proportion of time planktonic algae spend in the euphotic zone multiplied by mean surface irradiance determines the relative level of production.
			F013	Su, Sp	Water depth influences the rate of deposition of planktonic algae (It takes longer for settling in deeper water).
Source of food for fish and invertebrates, habitat, and influence on river nutrient and chemical conditions.	Periphytic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F014	Su, Sp	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks).
			F015	Su, Sp	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Sp	Establishment of biofilm requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect biofilm.
Contributes to primary production, habitat for macroinvertebrates and native fish.	Macrophytes	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F014	Su, Au, Wi, Sp	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks).
			F015	Su, Au, Sp	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Su, Au, Sp	Establishment of aquatic macrophytes requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect macrophytes.
Natural gradient of native terrestrial vegetation up the river banks.	Terrestrial bank vegetation	Maintain native terrestrial cover at top of banks and reduce cover of terrestrial vegetation in areas of the bank influenced by flow regulation.	F006	Dec-Apr	Duration of submergence (inundation) has potential to drown out terrestrial vegetation, due to carbon and oxygen starvation; critical values for duration tolerance expected to vary between seasons, being much longer in cool (autumn-winter) than in warm growing (spring-summer) season.

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Diverse and resilient aquatic macroinvertebrate fauna that are an integral part of food webs.	MI1	Provision of conditions suitable for aquatic vegetation, which provides habitat for macroinvertebrates.	F007	Su	Slow shallow velocities required for establishment of aquatic vegetation.
			F010	Wi	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
			F022	Su, Au, Wi, Sp	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
			F023	Su, Au, Wi, Sp	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
	MI2	Submersion of snag habitat within the euphotic zone to provide habitat and food source for macroinvertebrates.	F002	Su, Au, Wi, Sp	Quantity and variety of snags dependent on volume (possibly modified by biodiversity and productivity of snag biofilm - depth and variability of light climate).
			F004	Su, Au	High shear stresses can lead to biofilm instability.
			F008	Su, Au, Wi, Sp	Loss of pools.
			F025	Dec-Apr	Reduction in flow result in drying of large woody debris.
	MI3	Provision of slackwater habitat favourable for planktonic production (food source) and habitat for macroinvertebrates (MI3).	F007	Su	Increased flow velocity and rapid rates of rise and fall affect availability of shallow, slackwater habitat for macroinvertebrates.
			F023	Su, Au, Wi, Sp	Daily fall in stage.
			F024	Dec-Apr	Daily fall in stage.
	MI4	Entrainment of litter packs available as food/habitat source for macroinvertebrates (MI4).	F003	Su, Au, Wi, Sp	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F004	Su, Au, Sp	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F021	Su, Au, Wi, Sp	Overbank events may entrain organic matter
	MI6	Maintenance of water quality suitable for macroinvertebrates.	F003	Su, Au, Wi, Sp	Temperature, nutrients and salinity assumed not significant, pollution effects (toxicants) not known. Sediment deposition noted and known to remove susceptible taxa.

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Diversity of native species, naturally self-reproducing populations of native fish, threatened and iconic native species.	Native Fish	Suitable in-channel habitat for all life stages.	F007	Su, Aut, Wi, Sp	Slow shallow habitat required for larvae/juvenile recruitment and adult habitat for small bodied fish.
			F008	Su, Au, Wi, Sp	Deep water habitat for large bodied fish.
		Cues for adult migration during spawning season.	F022	Su, Sp	Flow variation required as a cue for migration and spawning.
			F023	Su, Sp	Flow variation required as a cue for migration and spawning.
		Suitable off-channel habitat for all life stages.	F027	Sp	Inundation of floodplain required by some species and for transport of nutrients and organic matter to drive food webs.
Natural Channel Form and Dynamics.	Geo1	Avoid notching.	F025	Dec-Apr	Long duration of stable flow followed by rapid draw-down. Impact likely to be exacerbated by loss of bank side vegetation.
	Geo2	Avoid slumping.	F023	Su	Excessive rates of fall in river level.
	Geo3	Maintain pool depth.	F026	Su	Unseasonal events that fill pools with sediment but do not flush them.
	Geo6	Maintain natural rates of geomorphic disturbance.	F006	Dec-Apr	High velocity discharge increases disturbance of sand substrates and aquatic macrophytes.

13.

Appendix 3: Monthly environmental water demand shortfalls

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – extreme dry (high reliability water share allocation of 70% or less).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
January	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	5.4	n/a	n/a	n/a	n/a
February	0.0	0.0	0.0	2.1	n/a	n/a	n/a	n/a	4.0	8.6	n/a	n/a	n/a	n/a
March	0.0	0.0	0.0	0.1	n/a	n/a	n/a	n/a	5.1	6.0	n/a	n/a	n/a	n/a
April	0.0	0.0	0.0	0.5	n/a	n/a	n/a	n/a	4.2	7.0	n/a	n/a	n/a	n/a
May	0.0	0.0	0.0	1.9	n/a	n/a	n/a	n/a	4.7	8.2	n/a	n/a	n/a	n/a
June	0.0	0.4	0.0	3.2	n/a	n/a	n/a	n/a	0.0	9.7	n/a	n/a	n/a	n/a
July	0.0	0.0	0.0	2.1	n/a	n/a	n/a	n/a	0.0	8.4	n/a	n/a	n/a	n/a
August	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	6.3	n/a	n/a	n/a	n/a
September	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	6.0	n/a	n/a	n/a	n/a
October	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	1.4	2.7	n/a	n/a	n/a	n/a
November	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	3.0	n/a	n/a	n/a	n/a
December	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.0	n/a	n/a	n/a	n/a

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – dry (100% high reliability water share allocation, and low reliability water share allocation of 0-20%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.5	0.0	6.5	0.0	12.9	0.0	13.8
April	n/a	n/a	n/a	n/a	0.0	4.4	0.0	5.6	0.0	7.8	0.0	14.6	0.0	15.5
May	n/a	n/a	n/a	n/a	0.0	5.5	0.0	6.7	0.0	8.8	0.0	15.4	0.0	16.3
June	n/a	n/a	n/a	n/a	0.0	5.4	0.0	6.7	0.0	8.8	0.0	15.6	0.0	16.6
July	n/a	n/a	n/a	n/a	0.0	5.1	0.0	6.3	0.0	8.4	0.0	15.0	0.0	15.9
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	2.2
October	n/a	n/a	n/a	n/a	0.0	1.0	0.0	2.2	0.0	4.3	0.0	10.9	0.0	11.8
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.2	0.0	2.4	0.0	9.2	0.0	10.2
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – median (100% high reliability water share allocation, and low reliability water share allocation of 21-80%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	5.1	0.0	6.3	0.0	8.4	0.0	15.0	0.0	15.9
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	1.4	0.0	8.0	0.0	8.9
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.2	0.0	2.4	0.0	9.2	0.0	10.1
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.3	0.0	4.4	0.0	6.5	1.2	12.8	2.0	13.7
April	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.6	0.0	6.8	0.0	13.6	0.0	14.5
May	n/a	n/a	n/a	n/a	0.0	5.4	0.0	6.6	0.0	8.7	0.0	15.3	0.0	16.2
June	n/a	n/a	n/a	n/a	0.0	6.2	0.0	7.4	0.0	9.6	0.0	16.4	0.0	17.3

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – wet (100% high reliability water share allocation, and low reliability water share allocation of 81-100%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	3.8	0.0	5.0	0.0	7.1	0.0	13.7	0.0	14.6
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	7.0
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	6.4
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	4.8	0.0	6.0	0.0	8.0	0.0	14.4	0.0	15.2
April	n/a	n/a	n/a	n/a	0.0	3.1	0.0	4.3	0.0	6.5	0.0	13.3	0.0	14.2
May	n/a	n/a	n/a	n/a	0.0	5.7	0.0	6.9	0.0	9.0	0.0	15.6	0.0	16.5
June	n/a	n/a	n/a	n/a	0.0	2.5	0.0	3.8	0.0	5.9	0.0	12.7	0.0	13.7

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – extreme dry (high reliability water share allocation of 70% or less).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	5.9	n/a	n/a	n/a	n/a
August	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.1	n/a	n/a	n/a	n/a
September	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	3.5	n/a	n/a	n/a	n/a
October	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.9	4.5	n/a	n/a	n/a	n/a
November	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	1.2	2.1	n/a	n/a	n/a	n/a
December	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.0	n/a	n/a	n/a	n/a
January	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	4.9	n/a	n/a	n/a	n/a
February	0.0	0.0	0.0	1.4	n/a	n/a	n/a	n/a	4.9	7.9	n/a	n/a	n/a	n/a
March	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	4.5	5.3	n/a	n/a	n/a	n/a
April	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	3.4	6.2	n/a	n/a	n/a	n/a
May	0.0	0.0	0.0	1.2	n/a	n/a	n/a	n/a	4.0	7.5	n/a	n/a	n/a	n/a
June	0.0	0.0	0.0	1.9	n/a	n/a	n/a	n/a	0.0	8.4	n/a	n/a	n/a	n/a

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – dry (100% high reliability water share allocation, and low reliability water share allocation of 0-20%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	1.4	0.0	2.6	0.0	4.7	0.0	11.3	0.0	12.2
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.6	0.0	2.7	0.0	9.3	0.0	10.2
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2.1	0.0	8.9	0.0	9.8
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.5	0.0	6.6	0.0	12.9	0.0	13.8
April	n/a	n/a	n/a	n/a	0.0	2.4	0.0	3.7	0.0	5.8	0.0	12.6	0.0	13.6
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	2.5	0.0	3.8	0.0	5.9	0.0	12.8	0.0	13.7

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – median (100% high reliability water share allocation, and low reliability water share allocation of 21-80%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	2.2	0.0	3.4	0.0	5.5	0.0	12.1	0.0	13.0
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	5.6
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	1.2	0.0	8.1	0.0	9.0
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	2.8	0.0	3.9	0.0	5.9	0.0	12.1	0.0	12.9
April	n/a	n/a	n/a	n/a	0.0	1.9	0.0	3.1	0.0	5.3	0.0	12.1	0.0	13.0
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	3.3	0.0	4.5	0.0	6.7	0.0	13.5	0.0	14.4

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – wet (100% high reliability water share allocation, and low reliability water share allocation of 81-100%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	6.6
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	6.4
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	1.3	0.0	2.5	0.0	4.5	0.0	10.9	0.0	11.8
April	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2.0	0.0	8.8	0.0	9.7
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	4.0

Appendix 4: Operational Monitoring Report

Commonwealth Environmental Watering Program

Operational Monitoring Report

Please provide the completed form to <insert name and email address>, within two weeks of completion of water delivery or, if water delivery lasts longer than 2 months, also supply intermediate reports at monthly intervals.

Final Operational Report Intermediate Operational Report Reporting Period: From To

Site name	**<EWDS to prefill>**	**Date**
Location	GPS Coordinates or Map Reference for site (if not previously provided)	
Contact Name	*Contact details for first point of contact for this watering event*	
Event details	*Watering Objective(s) <EWDS to prefill>*	
	Total volume of water allocated for the watering event *CEW:* *Other(please specify) :*	
	Total volume of water delivered in watering event *CEW:* *Other (please specify):*	*Delivery measurement* *Delivery mechanism:* *Method of measurement:* *Measurement location:*
	Delivery start date (and end date if final report) of watering event	
	Please provide details of any complementary works	
	If a deviation has occurred between agreed and actual delivery volumes or delivery arrangements, please provide detail	
	Maximum area inundated (ha) (if final report)	
	Estimated duration of inundation (if known)[1]	
Risk management	*Please describe the measure(s) that were undertaken to mitigate identified risks for the watering event (eg. water quality, alien species); please attach any relevant monitoring data.* *Have any risks eventuated? Did any risk issue(s) arise that had not been identified prior to delivery? Have any additional management steps been taken?*	
Other Issues	*Have any other significant issues been encountered during delivery?*	
Initial Observations	*Please describe and provide details of any species of conservation significance (state or Commonwealth listed threatened species, or listed migratory species) observed at the site during the watering event?*	
	Please describe and provide details of any breeding of frogs, birds or other prominent species observed at the site during the watering event?	
	Please describe and provide details of any observable responses in vegetation, such as improved vigour or significant new growth, following the watering event?	
	Any other observations?	
Photographs	*Please attach photographs of the site prior, during and after delivery*[2]	

1 Please provide the actual duration (or a more accurate estimation) at a later date (e.g. when intervention monitoring reports are supplied).

2 For internal use. Permission will be sought before any public use.

Appendix 5: Summary of VEFMAP monitoring in Reaches 4 and 5 of the Goulburn River

Summary of VEFMAP monitoring arrangements for environmental water use in the Goulburn River (from SKM 2007, Chee et al. 2006).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Geomorphology					
Winter/spring freshes	Does increased frequency of winter-spring fresh events: a) Increase the frequency of geomorphologically significant events (e.g. redistribution of bed and bank sediments)? b) Iincrease channel complexity (e.g. areas of the stream bed which are flushed free of fine deposits, deeper pools and variability in bench elevations)? c) Iincrease channel width and depth? d) Iincrease rates of meander development (i.e. bank erosion on the outside bank, point bar development, increased sinuosity and eventually bend cut-off and billabong formation)?	Flow and physical habitat (channel dimensions) to assess: • Frequency of channel disturbances • Frequency of bed disturbances • Rate of bench deposition • Bed complexity • Bench development and variability • Mean channel top width, cross-section area and thalweg depth • Bank erosion on outside of meander bends • Point bar development.	Two physical habitat sites in each of Reach 4 and Reach 5. Three flow sites in Reach 4 and two flow sites in Reach 5.	Physical habitat - first year (2008) and after channel forming events thereafter. Flow – continuous at all sites.	VEFMAP provides baseline information for assessing effects of environmental water. May require repeat measurements to provide 'before' data if channel dimensions have not been surveyed after recent (2010) flood events.
Bankfull and overbank flows	As above	As above	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Habitat & macroinvertebrates					
Summer/autumn low flows and freshes	• Do implemented environmental flows maintain in-channel shallow and slow water areas? • Do implemented environmental flows maintain adequate area and depth of at least 0.1 metres in shallow, slow water and riffle/run habitats? • Do implemented environmental flows maintain adequate volume and depth in permanent pools? • Do implemented environmental flows maintain connectivity? • Do implemented environmental flows maintain macroinvertebrate community structure? • Do implemented environmental flows increase fish recruitment? • Do implemented environmental flows maintain fish assemblages and/or population structure?	• Shallow and slow water areas • Riffle/run depth and area • Permanent pool depth and volume • Connectivity • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • See conceptual model for Fish Spawning & Recruitment • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Physical habitat - first year (2008) and after channel forming events thereafter. Annually	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring baseflows	• Do implemented environmental flows increase in-channel shallow and slow water areas? • Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of permanent pool habitats? • Do implemented environmental flows result in sustained inundation of in-channel macrophytes, channel edge macrophytes, tree roots, woody debris, branch piles, in channel bars, overhanging or undercut banks? • Do implemented environmental flows increase abundance of macrophytes? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Shallow and slow water areas • Riffle and/or run area • Permanent pool depth and volume • Inundation of representative physical habitat features • See conceptual model for Aquatic and Riparian Vegetation • Cover of submerged and amphibious species • Cover of submerged and amphibious species • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Annually	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring freshes	• Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of pool habitats? • Do implemented environmental flows result in temporary inundation of higher-level channel edge macrophytes, tree roots, woody debris, bars, benches, overhanging/ undercut banks? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/ or population structure?	• Riffle and/or run area • Permanent pool depth and volume • Inundation of higher elevation representative physical habitat features • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/ sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Annually	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Aquatic & riparian vegetation					
Spring baseflow	• Do implemented environmental flows increase in-channel shallow and slow water areas? • Do implemented environmental flows increase run area? • Do implemented environmental flows result in sustained inundation of channel bed, channel edges, in-channel bars, low-lying benches, runners and anabranches in Zone A*? • Do implemented environmental flows • a) IIncrease germination and seasonal growth of submerged and amphibious fluctuation-responder species in Zone A*? • b) IReduce species richness of terrestrial 'dry' species in Zone A*?	• Shallow and slow water area • Run depth and area • Inundation of geomorphic features in Zone A* • Cover of submerged and amphibious species in Zone A* • Species composition, number of submerged, amphibious and terrestrial species in Zone A* • Proportion of exotic plant species.	Two sites in each of Reach 4 and 5	Every two years	As above
	• What is the pattern of inundation and drying in Zones A* & B* imposed by the implemented environmental flows? • What is the composition of the resultant plant community?	• Cover of amphibious and terrestrial species in Zones A* & B* • Species composition, number of amphibious and terrestrial species in Zones A* & B* • Proportion of exotic plant species	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring freshes & bankfull flows	• Do implemented environmental flows wet high-level benches, upper banks, runners and anabranches in Zones B* & C*? • Do implemented environmental flows increase germination and establishment of terrestrial 'damp', terrestrial 'dry' and amphibious fluctuation-tolerator species? • Do implemented environmental flows improve canopy condition of in situ riparian trees and shrubs?	• Wetting of geomorphic features in Zones B* & C* • Species composition, number of amphibious and terrestrial species in Zones B* & C* • Proportion of exotic plant species • Germination of seedlings of over storey and mid-storey species • Canopy condition.	As above	As above	As above
Summer baseflow	• Do implemented environmental flows maintain area of in-channel shallow and slow water and run habitats? • Do implemented environmental flows wet in-channel bars, low-lying benches, channel edges, runners and anabranches in Zone A*? • Do implemented environmental flows improve canopy condition of adjacent riparian trees and shrubs?	• See conceptual model for Habitat Processes • Shallow and slow water areas • Run depth and area. • Wetting of geomorphic features in Zone A* • Canopy condition.	As above	As above	As above
Native fish					
Autumn-early winter freshes/ bankfull flows	• Do implemented environmental flows trigger spawning of diadromous fish? (Only relevant in river reaches inhabited by diadromous fish species such as galaxiids, eels and Australian grayling)	• Presence/absence of diadromous fish larvae	Six sites in each of Reach 4 and 5	Annually	VEFMAP may be appropriate for considering effects of environmental water, but it may also be difficult to separate from other influences, including recent flow history (i.e. antecedent conditions).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter-spring baseflows freshes	• Do implemented environmental flows increase overall quantity and diversity of in stream habitat?	• See conceptual model for Habitat Processes • Shallow and slow water areas • Run area • Permanent pool depth and volume • Inundation of physical habitat features • Inundation of higher elevation physical habitat features • In-channel and littoral cover of macrophytes.	As above	As above	As above
Spring-early summer bankfull flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Density of post-larval fish.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring-early summer base flows	• Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'low flow specialist' and generalist fish species? • Do implemented environmental flows maintain adequate in stream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	• Presence/absence of 'low flow specialist' and generalist fish larvae • See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish.	As above	As above	As above
Spring-early summer overbank flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows inundate floodplain areas to create increased slackwater habitat? • Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'flood specialist' non-diadromous fish species? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Area of slackwater habitat in floodplain • Presence/absence of 'flood specialist' non-diadromous fish larvae • Density of post-larval fish.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Summer-autumn low flows	• Do implemented environmental flows maintain adequate in stream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	• See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish.	As above	As above	As above
Water Quality					
All components (year- round)	• No specific hypotheses	Colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidized nitrogen, pH, total phosphorus and turbidity.	Two sites in each of Reach 4 and 5	As per NERWMP	Dedicated monitoring program may be required, depending on the water quality variable to be tested.

Zone A*:From mid-channel to stream margin (or the area covered by water during times of baseflow).

Zone B*:From stream margin to a point mid-way up the flank of the bank (or the point that is infrequently inundated).

Zone C*:From mid-way up the flank of the bank to just beyond the top of the bank.

Appendix 6: Risk assessment framework

Risk likelihood rating

Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Could occur at some time
Unlikely	Not expected to occur
Rare	May occur in exceptional circumstances only

Risk consequence rating

Critical	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
Major	Severe loss of environmental amenity and danger of continuing environmental damage
Moderate	Isolated but significant instances of environmental damage that might be reversed with intensive efforts
Minor	Minor instances of environmental damage that could be reversed
Insignificant	No environmental damage

Risk analysis matrix

LIKELIHOOD	CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Critical
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Medium	High


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