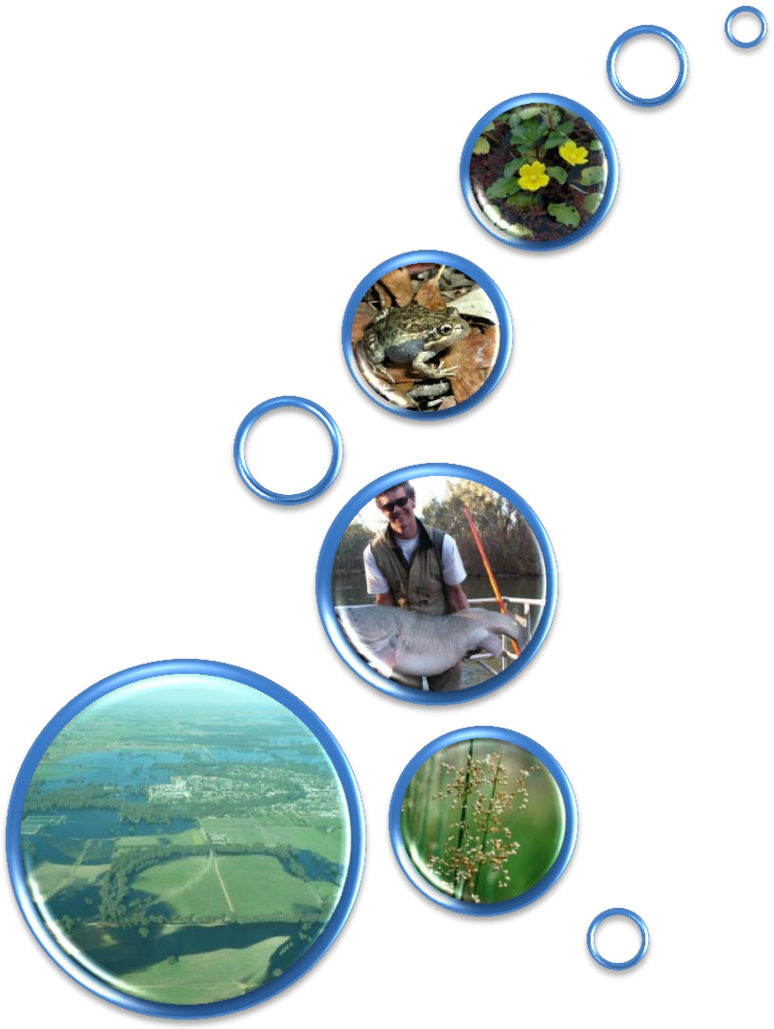
# Lower Broken Creek

## Seasonal Watering Proposal 2013 - 2014

Goulburn Broken Catchment Management Authority



GOULBURN BROKEN
CATCHMENT MANAGEMENT AUTHORITY

## Publication details

**Published by:**
Goulburn Broken Catchment Management Authority,
PO Box 1752, Shepparton 3632

© Goulburn Broken Catchment Management Authority, 2013.

Please cite this document as: GB CMA (2013). Lower Broken Creek Seasonal Watering Proposal 2013-2014. Goulburn Broken Catchment Management Authority, Shepparton.

ISBN

**Disclaimer:**
This publication may be of assistance to you, but the Goulburn Broken Catchment Management Authority does not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequences which may arise from you relying on information in this publication.

It should be noted that specific reference to funding levels in this strategy are for indicative purposes only. The level of Government investment in this plan is contingent on budgets and government priorities.

**For further information, please contact:**
Goulburn Broken Catchment Management Authority
P.O. Box 1752, Shepparton 3632
Ph (03) 5820 1100 or visit: www.GBCMA.vic.gov.au

# Executive summary

This proposal identifies the environmental water requirements of the lower Broken and Nine Mile Creeks in 2013-2014 under a range of climatic scenarios to protect or improve its environmental values and health. Environmental water is targeted to the Broken Creek below Nathalia Weir pool (reach 3), which supports the most diverse and abundant native fish communities and often has poor water quality in summer and autumn. However, water delivered to Reach 3 will also provide benefits to the upstream reaches.

The Broken Creek has been identified as a priority waterway in the Goulburn Broken Regional River Health Strategy, is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001) and stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve. The Creeks support a diverse and abundant native fish community, provide water for agriculture and urban centres, and support a variety of recreational activities such as fishing and bushwalking.

The conditions leading into the 2013-14 year have been characterised by a dry winter which saw passing flows at Rices Weir fall to zero in August. Early in the season Murray River unregulated flows and Commonwealth environmental water contributed to environmental flow requirements. Local rainfall and subsequent catchment runoff late September 2012 and early October 2012 generated two substantial but short lived freshes. From December to March Commonwealth environmental water and IVTs contributed to environmental flow targets of 250 ML/d (to increase large bodied native fish habitat during migration and breeding seasons) and 200 ML/d (to maintain dissolved oxygen levels above 5 mg/L). Due to channel capacity constraints these targets were not always met and dissolved oxygen levels fell below 5 mg/L for extended periods. There was no significant Azolla growth during the year and therefore no flows to manage Azolla growth were required.

The focus in 2013-2014 is to continue to provide the desirable flow regimes to protect and improve the native fish populations in the lower Broken Creek. This includes providing fish passage, providing improved fish habitat between September and December during the migration and breeding seasons, and importantly management of the threats to fish from excessive Azolla growth and low dissolved oxygen levels. Low dissolved oxygen (including that resulting from excessive azolla growth) prevents fish from breathing, dramatically reducing the amount of suitable habitat and potentially leading to fish deaths as occurred in 2002. The volumes of water required to provide for the all desirable environmental outcomes in the lower Broken Creek are shown in the table below (up to 68,500 ML is required).

Importantly, there is significant potential to use water-in-transit in the Murray and Goulburn River systems to provide much of these needs. Murray River water can be potentially diverted through the Broken Creek as well as Goulburn River Inter-Valley Transfers (to the Murray River) and returned to the Murray River. If these sources can be maximised, the need for additional environmental entitlement from the Goulburn system is substantially reduced. However, predicting availability is problematic. The Goulburn Water Quality Reserve is also available to deal with emergency water quality issues such as blackwater events.

The key risk to providing the desired environmental outcomes in the lower Broken Creek is the limitations placed on delivery of environmental water by irrigation demand. This limits the available channel capacity for delivery of water to the creek for environmental flow management, particularly to minimise the risk from low dissolved oxygen and Azolla accumulations. To minimise this impact as much as possible, the proposal seeks to have water available from both the Goulburn and Murray Rivers, to maximise available channel capacity. It is also proposed to release high creek flows pre-emptively when high irrigation demand is imminent.

This proposal does not take account of competing needs for environmental water use from either other river/creek systems or downstream along the Murray River. However, water deployed in the lower Broken and Nine Mile Creeks returns to the Murray River and is available for use downstream. As all of the flows proposed are well within the channel of the Creeks, there is very low risk of adverse outcomes to private assets or the general public from releasing environmental water.

Summary of environmental water volumes required to support this proposal (GL)

| REACHES 4 & 5 | VERY DRY | AVERAGE | WET |
|---|---|---|---|
| **Murray unregulated water use** | 0 GL | up to 12 GL | up to 6 GL |
| **Inter-valley water use** | up to 9 GL | up to 9 GL | up to 9 GL |
| **Murray environmental water use** | up to 27 GL | up to 23 GL | up to 23 GL |
| **Goulburn environmental water use** | up to 32.5 GL | up to 24.5 GL | up to 30.5 GL |

The maximum overall water required is 68.5 GL.

# Contents

**Tables**



**Figures**

# Glossary and acronyms

**Bankfull** - carrying capacity of the stream before spilling out onto adjacent land

**Base flow** – low flows sufficient to maintain fish passage, water quality, and pool and riffle habitats

**Catchment management authority (CMA)** – statutory authorities established to manage regional and catchment planning, waterways, floodplains, salinity and water quality

**Channel -** that part of a river where water flows at some time and includes the bed and banks, taken to mean the whole of the depression in which the water flows before it rises sufficiently to spill over onto adjacent lands as flood water

**Commonwealth Environmental Water Holder (CEWH)** – (part of the Department of Sustainability, Environment, Water, Populations and Communities) holds and manages the water entitlements purchased through the Restoring the Balance water recovery program

**CMA –** catchment management authority

**Environmental flow regime** – the timing, frequency, duration and magnitude of flows for the environment

**Environmental flow study** – a scientific study of the flow requirements of a particular basin's river and wetlands systems used to inform decisions on the management and allocation of water resources

**Environmental water entitlement** – an entitlement to water to achieve environmental objectives in waterways (could be an environmental entitlement, environmental bulk entitlement, water share, Section 51 licence or supply agreement)

**Flow -** movement downstream of water confined in the channel. The term **lotic** applies to flowing or moving water

**Flow component** – components of a river system's flow regime that can be described by timing, seasonality, frequency and duration (for example, cease to flow and overbank flows)

**Flow regime -** pattern of seasonal flow variations in any one year, usually consisting of periods of low flow during summer-autumn then high flows during winter-spring

**Freshes -** flows that produce a substantial rise in river height for a short period, but do not overtop the river bank. Freshes help maintain water quality and serve as life cycle cues for fish

**GB CMA** - Goulburn Broken Catchment Management Authority

**Geomorphology** - the physical interaction of flowing water and the natural channels of rivers including erosion and sedimentation

**Gigalitre (GL)** – one billion (1,000,000,000) litres

**High flows -** high flow within channel capacity. High flows allow full connection between all habitats in the river, which is important to fish passage during migration

**High reliability entitlement** – legally recognised, secure entitlement to a defined share of water, as governed by the reserve policy (full allocations are expected in most years)

**Instream -** refers to that area of a waterway below the surface of the water

**Inter-Valley Transfers (IVT)** – means bulk transfers of water from the Goulburn water supply system to supply water users in the Murray water supply system

**Low reliability entitlement** – legally recognised, secure entitlement to a defined share of water, as governed by the reserve policy (full allocations are expected only in some years)

**Macroinvertebrates –** aquatic invertebrates whose body length usually exceeds 1 mm (included insects, crustacean, aquatic worms and aquatic snails)

**Macrophytes** – an aquatic plant that grows in or near water and is emergent, submergent, or floating

**Megalitre (ML)** – one million (1,000,000) litres

**Overbank flow** – flood flows that overtop the banks and spill onto the floodplain

**Passing flow** – water released out of storages to operate river and distribution systems (to deliver water to end users), provide for riparian rights and maintain environmental values and other community benefits

**Planktonic algae** – floating microscopic plants that are an important food source for aquatic fauna

**Pool -** a significantly deeper area in the bed of a river

**Reach -** a length of stream that is reasonably uniform with respect to geomorphology, flow and ecology

**Riffle** – a stream section with fast and turbulent flow over a pebble bed with protruding rocks ( characterized by a broken water surface)

**Riparian vegetation -** vegetation growing on the water line, up the bank or along the very top of the bank. It is the vegetation which has the most direct affect on instream biota.

**Seasonal allocation** – the volume of water allocated to a water share in a given season, expressed as a percentage of total entitlement volume

**The Living Murray (TLM)** – an intergovernmental program, which holds an average of 500,000 ML of environmental water per year, for use at six icon sites along the River Murray

**Unregulated entitlement** – an entitlement to water declared during periods of unregulated flow in a river system, that is, flows that are unable to be captured in storages

**Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP)** – assesses the effectiveness of environmental flows in delivering ecological outcomes

**Victorian Environmental Water Holder (VEWH)** – an independent statutory body responsible for holding and managing Victorian environmental water entitlements and allocations (Victorian Water Holdings)

**Water entitlement** – the right to a volume of water that can (usually) be stored in reservoirs and taken and used under specific conditions

**Water Holdings** – environmental water entitlements held by the Victorian Environmental Water Holder

**Waterway manager** – agency responsible for the environmental management of waterways (includes catchment management authorities and Melbourne Water)

**Waterways** – can include rivers, wetlands, creeks, floodplains and estuaries

# 1 Background and system overview

## 1.1 Background

The Environmental Water Reserve (EWR) is the legally recognised amount of water set aside to meet environmental needs. The reserve includes minimum river flows, unregulated flows and specific environmental entitlements.

Environmental entitlements can be called out of storage when needed and delivered to streams or wetlands to protect or enhance their environmental values and health. Environmental entitlements are held by the Victorian Environmental Water Holder (VEWH), the Commonwealth Environmental Water Holder (CEWH), and the Murray Darling Basin Authority (MDBA). Catchment Management Authorities (CMAs) are responsible for determining the environmental water requirements of streams and wetlands, developing and submitting seasonal watering proposals to the VEWH for consideration, and managing the delivery of environmental water in accordance with the VEWH's Seasonal Watering Plan.

The VEWH prepares seasonal watering plans based on each of the CMA's seasonal watering proposals. The plans describe the desired environmental water use for rivers and wetlands across Victoria in the coming year. To help facilitate the desired environmental water use outlined in the plans, the VEWH negotiates access to environmental water managed by the CEWH and the MDBA. The VEWH then prepares seasonal watering statements that authorises CMA's to undertake the agreed watering activities, including the use of CEWH and MDBA water. As more environmental water becomes available during the season the VEWH may prepare additional seasonal watering statements. Where possible, the VEWH, CEWH and the MDBA seek to coordinate the delivery and management of environmental water to maximise ecological benefits.

## 1.2 Purpose

The purpose of this lower Broken Creek Seasonal Watering Proposal is to:

- identify the environmental water requirements of the lower Broken and Nine Mile Creeks in the coming year under a range of climatic scenarios to protect or improve its environmental values and health; and
- inform the development of environmental water priorities in the VEWH's seasonal watering plan.

The proposal is informed by scientific studies and reports that identify the flow regimes required to meet the ecological objectives of the creek. This proposal was prepared in consultation with key stakeholders and partners, and was approved by the Goulburn Broken CMA board.

## 1.3 System overview

The planning area includes the lower Broken Creek downstream of the Boosey Creek confluence and the Nine Mile Creek. The upper Broken Creek is not considered in this proposal as it has a more natural flow regime and can only receive a small volume of Commonwealth environmental water (51.2 ML). The Broken and Nine Mile Creeks lie within the Broken River Basin in northern Victoria (Figure 1). The Broken Creek has been identified as a priority waterway in the Goulburn Broken Regional River Health Strategy, is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001) and stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve. The Creeks support a diverse and abundant native fish community. Fish species supported include the threatened Murray cod (Macullachella peelii peelii), Golden perch (Macquaria ambigua), Silver perch (Bidyanus bidyanus), Unspecked hardyhead (Craterocephalus stercusmuscarum fluvus) and Crimson-spotted rainbowfish (Melanotaenis fluviatilis) (further information is provided in Appendix 1). The associated floodplain and wetland habitats support box-dominated grassy woodland communities, and numerous threatened species of state and national conservation significance including Buloke (Allocasuarina luehmannii), Bush Stone-curlew (Burhinus grallarius) and Brolga (Grus rubicunda). The Creeks and associated floodplain and wetland habitats also contain many important cultural heritage sites, provide water for agriculture and urban centres, and support a variety of recreational activities such as fishing and bushwalking.

### 1.3.1 Flow Regime

The lower Broken and the Nine Mile Creeks have been regulated for over 100 years, significantly altering their flow regimes. Under natural conditions the Creeks would have ceased to flow for extended periods during

summer and autumn. Today the Creeks are largely perennial with significant flows maintained throughout summer and autumn to supply water for irrigation, domestic and stock use. However, winter flows have been reduced due to water harvesting and are dominated by catchment induced runoff.

The Creeks lie within the Murray Valley and Shepparton Irrigation Districts. Irrigation water is primarily supplied to the Creeks from the East Goulburn Main Channel (supplied by the Goulburn River) and from the 7/3 Main Channel (supplied from Lake Mulwala on the Murray River). The channels outfall to the Creeks at Katandra Weir downstream of Katamatite (Figure 1).

Downstream of Nathalia the Broken Creek has eight shallow weirs managed to provide a near-constant water level to facilitate the extraction of irrigation, domestic and stock water by pumping. While the weir pools provide important native fish habitat, their water quality is often poor in summer and autumn.

Monitoring results indicate that this lower section of the Creek has high turbidity, low dissolved oxygen levels and elevated concentrations of nutrients and suspended solids (Sinclair Knight Merz 1996; CRC Freshwater Ecology 2001; GHD 2005). Further information on Azolla and low dissolved oxygen levels can be found in Appendix 1.

### 1.3.2 Priority reaches and measuring points

Interim flow recommendations were developed for the lower Broken and Nine Mile Creeks in 2008 (GBCMA 2008). To facilitate this process the Creeks were divided into three reaches with similar channel morphology, flow regimes and ecological values (Figure 1). The reaches are:

1. The Broken Creek downstream of the Boosey Creek confluence to the Nine Mile Creek confluence (approximately 32 km in length).
2. The Nine Mile Creek and the Broken Creek downstream of the Nine Mile Creek confluence to the upstream end of the Nathalia weir pool (approximately 87 km in length).
3. From the Nathalia weir pool to the Murray River (approximately 65 km in length).

While all reaches are important the delivery of environmental water is targeted to reach 3, which supports the most diverse and abundant native fish communities and often has poor water quality in summer and autumn (ARI 2006). However, water delivered to Reach 3 also provides benefits to reaches 1 and 2.

The key environmental flow measurement point for Reach 3 is Rices Weir. Rices Weir is the most downstream weir on the Broken Creek and is located approximately 1 km upstream of the Murray River and Broken Creek confluence (Figure 1).

### 1.3.3 Delivery constraints

Delivery of environmental water down the lower Broken and Nine Mile Creeks is primarily constrained by the availability of spare channel capacity. There are 16 channels that outfall to lower Broken and Nine Mile Creeks that collectively can supply approximately 270 ML/d (170 ML/d from the Murray Irrigation District and 100 ML/d from the Shepparton Irrigation District). However, this can be reduced during times of peak irrigation demand. Delivery of environmental water is not constrained by the risk of flooding private and public assets as environmental water volumes only represent a small proportion of the total capacity of the Creeks.

### 1.3.4 Water sources

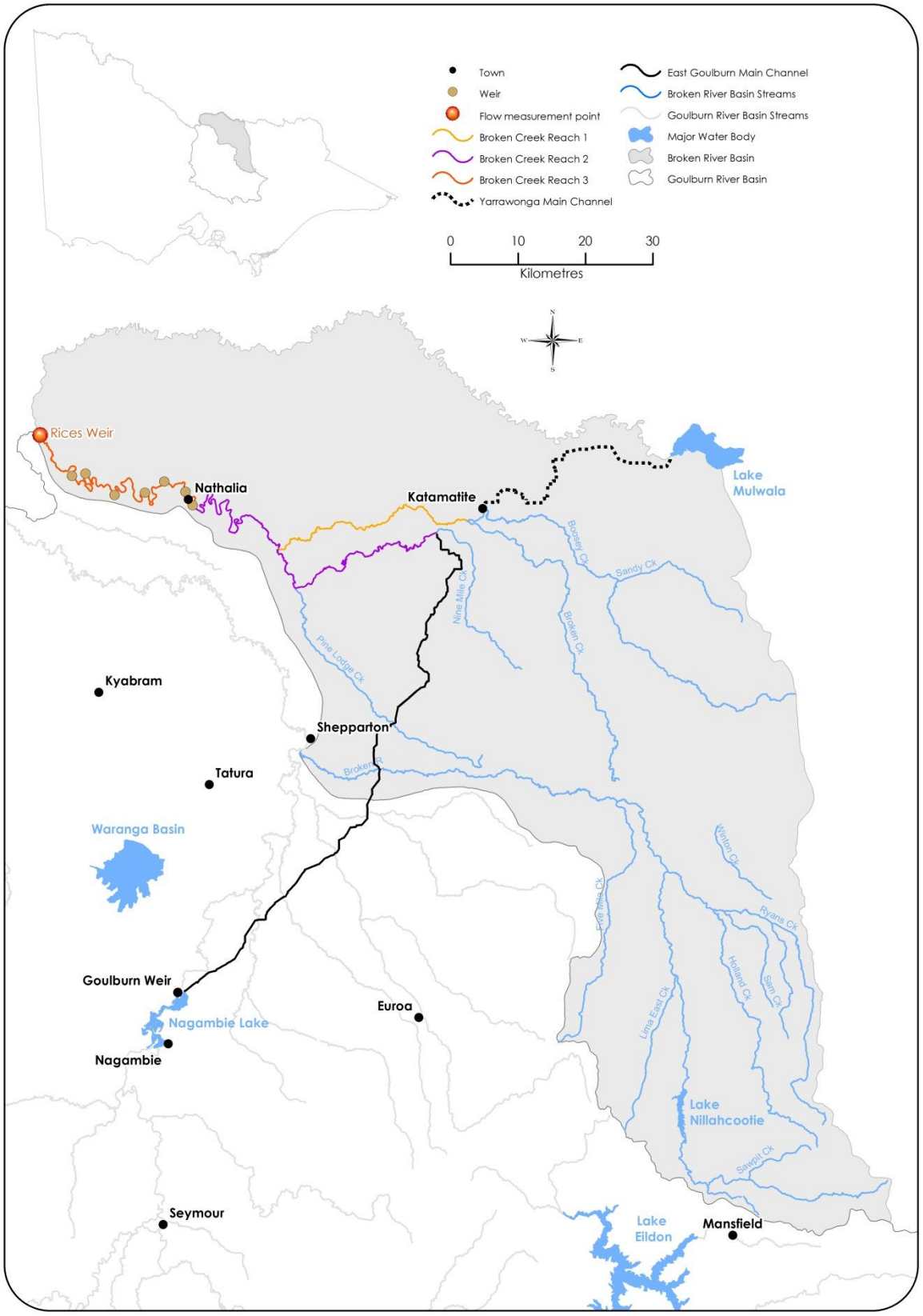
Environmental water available for use in the lower Broken and Nine Mile Creeks include:

- a water quality allowance established in the Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995 and subsequent amendments;
- environmental entitlements held by the VEWH, the CEWH and the MDBA;
- unregulated flows; and
- Inter-Valley Transfers (Table 1)

Table 1: Environmental water available for use in the lower Broken and Nine Mile Creeks

| ENVIRONMENTAL WATER | RESPONSIBLE AGENCY | DESCRIPTION | CONDITIONS |
|---|---|---|---|
| **Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995** | | | |
| Goulburn Water Quality Allowance | G-MW | 30 GL per year. | Maintenance of water quality. |
| **Entitlements and Inter-Valley Transfers** | | | |
| Murray River flows | MDBA | Unregulated flows | Available when Murray flow is unregulated. |
| Goulburn and Murray Irrigation supplies | G-MW | Irrigation water | Supply is dictated by demand and channel capacity. |
| Victorian River Murray Flora and Fauna Entitlement | VEWH | 27,600 ML high reliability entitlement. | Availability determined by agreement with VEWH. |
| Goulburn Environmental Water Savings Supply Deed | VEWH | One-third of water savings created in the Goulburn System as a result of modernisation works completed as part of Stage 1 of the Northern Victorian Irrigation Renewal Project. 23GL is assumed to be available for 2012/13. | Availability determined by agreement with VEWH.<br>Volume based on works implemented and water losses saved in previous year's climate. |
| Environmental Entitlement (Goulburn-System – Living Murray) 2007 | MDBA | 49,625 ML high reliability entitlement and 156,980 ML low reliability entitlement, and 35 GL of carryover from 2011/12 | Water allocated to this entitlement must be used for the Living Murray 'icon sites'. However, this water can provide environmental benefits in the Broken Creek on route to the Murray River. |
| Commonwealth Environmental Water Holdings | CEWH | 146,418 ML Goulburn high reliability water share and10,654 ML Goulburn low reliability water share as at 29 February 2012. | Water use is subject to agreement with the CEWH. |
| Goulburn River Inter-Valley Transfers | MDBA/G-MW | 136,000 ML of high reliability water supply plus 120,000 ML of carryover. | As needed in the Murray system, with some flexibility on when and how this water is moved from Lake Eildon to the Murray system. |
| Shepparton Modernisation Project | VEWH | 1,500 ML high reliability entitlement and 7,600 ML low reliability entitlement. | The entitlement is not yet available. |

Figure 1: Lower Broken and Nine Mile Creeks



# 2 Flow objectives and recommendations

This section outlines the environmental flow objectives established for the lower Broken and Nine Mile Creeks, and the corresponding flow recommendations including the volume, timing, duration and frequency of flow components.

## 2.1 Objectives and recommendations

Interim environmental flow objectives and recommendations where developed for the lower Broken and Nine Mile Creek in 2008 by the Goulburn Broken Catchment Management Authority to facilitate the development of the Northern Region Sustainable Water Strategy (DSE 2009). The development of the flow objectives and recommendations were based on information in existing river health and catchment strategies, consultant reports, scientific papers and wetland and park management plans. This information was supplemented by discussions with people with an intimate knowledge of the Creeks, its ecological values, management and operation. The report established flow objectives and recommendations for native fish (principally for large bodied native fish – Murray cod, Golden perch and Silver perch) and key threats to native fish habitat including dissolved oxygen levels, and algal and Azolla growth.

In 2010 the Lower Broken Creek and Nine Mile Creek Environmental Water Plan was prepared to assess the ecological impacts of planned NVIRP water savings initiatives and identify mitigation measures. The plan was prepared with the assistance of a scientific reference group and established objectives for:

- geomorphology;
- floodplain vegetation, in-channel vegetation;
- floodplain wetlands;
- native fish;
- macroinvertebrates; and
- threatened flora and fauna.

However, flow recommendations were only developed for native fish (principally for large bodied native fish – Murray cod, Golden perch and Silver perch). These built upon the interim environmental flow objectives and recommendations, and recent management and operational experiences in the lower Broken and Nine Creeks. In addition, it recommended greater variation in water levels where possible to:

- promote an increase in the cover and diversity of native aquatic and fringing vegetation; and
- increase stimulus for native fish migration.

Table 2 outlines the environmental objectives and flow recommendations for reaches 1 – 3, their origin and an explanation of any amendments. As outlined in section 1.3.2 the priority reach for environmental water management is reach 3 due to its diverse and abundant native fish community. The fish passage recommendation for reaches 1-3 are passing flows through the fish ladders. The remaining flow recommendations are passing flows at Rices Weir.

As outlined in section 1.3.3, the delivery of environmental water to the lower Broken and Nine Creeks can only occur via Shepparton and Murray Valley Irrigation District infrastructure during the irrigation season (approximately mid-August to mid-May). Although there is spare channel capacity to deliver current flow recommendations, this can be reduced during times of peak irrigation demand.

Table 2: Environmental objectives and flow recommendations for the lower Broken and Nine Mile Creeks (ML/day)

| FLOW COMPONENT | ECOLOGICAL VALUE | ECOLOGICAL OBJECTIVES | SEASON | FLOW (ML/DAY) | | | REPORT | COMMENT |
|---|---|---|---|---|---|---|---|---|
| | | | | Reach 1 | Reach 2 | Reach 3 | | |
| Base flow<br>(provide fish passage) | Native fish | Provide native fish passage through fish ladders. | August - May | 40 | 40 | 40 | 2008<br>2010 | There are two weirs in the middle of Reach 1, two at the top of Reach 2 and eight along the length of Reach 3. Al of the weirs have vertical-slot fish ladders to allow passage up and downstream, and require approximately 40 ML/d for operation. Fish passage is desirable all year. However, the fish ladders only operate during the irrigation season when sufficient flows can be maintained. |
| Base flow<br>(minimise Azolla growth) | Native fish | Minimise Azolla growth to help maintain DO levels above 5 mg/L. | August - November | NA | NA | 120 | 2008<br>2010 | In the 2008 Interim Environmental Flow Recommendations for the lower Broken Creek and Nine Mile Creek a flow of 80 ML/d was recommended to minimise Azolla growth. This flow recommendation was increased to 120 ML/d in the 2011-12 Lower Broken Creek Seasonal Watering Proposal. |
| Base flow<br>(remove large Azolla blooms) | Native fish | To eradicate large Azolla blooms to help maintain DO levels above 5 mg/L. | August - November | NA | NA | 250 | 2008<br>2010 | This flow is only required in the event of a large Azolla bloom for a short period of time (approximately 14 days). The flow is designed to move built up rafts of Azolla downstream.<br><br>In the 2008 Interim Environmental Flow Recommendations for the lower Broken Creek and Nine Mile Creek a flow up to 200 ML/d to control large Azolla blooms was recommended. Following the management of large Azolla blooms in 2008-2009 it was determined that flows of up to 250 ML/d may be required. This flow recommendation was adopted in the 2010 Lower Broken Creek and Nine Mile Creek Environmental Watering Plan. |
| Base flow<br>(maintain DO levels above 5 mg/L) | Native fish | Provide habitat for native fish by maintaining DO levels above 5 mg/L. | October - May | NA | NA | 250 | 2008<br>2010 | In the 2008 Interim Environmental Flow Recommendations for the lower Broken Creek and Nine Mile Creek a flow up to 200 ML/d to maintaining DO levels above 5 mg/L was recommended between December and March. Following the management of DO levels after 2008 it was determined that flows of up to 250 ML/d are required between October and May. This flow recommendation was adopted in the 2010 Lower Broken Creek and Nine Mile Creek Environmental Watering Plan. |

| FLOW COMPONENT | ECOLOGICAL VALUE | ECOLOGICAL OBJECTIVES | SEASON | FLOW (ML/DAY) | | | REPORT | COMMENT |
|---|---|---|---|---|---|---|---|---|
| | | | | Reach 1 | Reach 2 | Reach 3 | | |
| Base flow<br>(increase native fish habitat during migration and breeding seasons) | Native fish | Increase large bodied native fish habitat during migration and breeding seasons. | September - December | NA | NA | 250 | 2008<br>2010 | Further research and monitoring is required to confirm the recommended flow results in the desired ecological response. |

# 3 Current situation

## 3.1 2012-2013 season review

Flow past Rices Weir in July 2012 was characteristically low (<20 ML/d) and dropped to zero in early August 2012 (Figure 2). The irrigation season commenced on the 15th August 2012 and seasonal determinations for the Goulburn, Broken and Murray systems were 61%, 18% and 26% of high-reliability water shares respectively. From the 15th August 2012 to October 2012 average daily flow past Rices Weir steadily increased from 143 ML/d to 330 ML/d (Table 3 and Figure 2). During this time both Murray River unregulated flows and Commonwealth environmental water contributed to environmental flow requirements for the operation of the 12 fish ladders and flows of 250 ML/d to increase large bodied native fish habitat during migration and breeding seasons (Figure 3). The fish ladders were opened in mid-August and will be closed at the end of the irrigation season in May 2013.

Environmental releases represented between 20% and 64% of passing flows at Rices Weir between August 2012 and October 2013 (Table 3). Local rainfall and subsequent catchment runoff, particularly from the Boosey Creek system in late September 2012 and early October 2012 generated two substantial but short lived freshes with average daily flows at Rices Weir of 449 ML/d and 707 ML/d respectively (Figure 2).

The seasonal determinations for the Goulburn, Broken and Murray systems increased to 100% of high-reliability water shares by the 1st November 2012. During the peak irrigation period from November 2012 to February 2013 average daily flow past Rices Weir steadily decreased from 262 ML/d to 204 ML/d (Table 3 and Figure 2). During this time Commonwealth environmental water contributed to the majority of environmental flows and inter valley transfers contributed to environmental flows in December and January (Figure 3). Environmental flow targets of 250 ML/d (to increase large bodied native fish habitat during migration and breeding seasons) and 200 ML/d (to maintain dissolved oxygen levels above 5 mg/L) were difficult to maintain due to reduced spare channel capacity. Consequently, these flow targets were only met 65% and 83% of the time respectively (Figure 2). Low flows, increasing ambient and water temperatures also resulted in average daily dissolved oxygen levels at the surface and bottom of the water column at Rices Weir dropping below 5 mg/L for extended periods (Figure 4). From late December 2012 to mid-January 2013 average daily dissolved oxygen levels at the bottom of the water column at Rices Weir fell below 5 mg/L for 27 consecutive days and 25 consecutive days from early February to March (Figure 4). However, no impacts on native fish populations were detected as a result of the dissolved oxygen levels falling below the 5 mg/L target.

Environmental releases represented between 80% and 100% of passing flows at Rices Weir between November 2012 and February 2013 (Table 3). Local rainfall and subsequent catchment runoff in late February 2013 generated a short lived fresh with average daily flows past Rices Weir peaking at 432 ML/d (Figure 2).

There was no significant Azolla growth during the year and therefore no flows to manage Azolla growth were required. Approximately 60% of environmental flows delivered to lower Broken and Nine Mile Creeks were delivered via the Murray Irrigation District and 40% via the Goulburn Irrigation District (Figure 5).

Table 3: Environmental water contribution to flows at Rices Weir

| MONTH | RICES WEIR | | ENVIRONMENTAL WATER | | |
|---|---|---|---|---|---|
| | Total Flow ML | Ave Daily Flow ML/d | Total Flow ML | Ave Daily Flow ML/d | % of Rices Weir Total Flow |
| August^ | 3008 | 143 | 628 | 30 | 20.9 |
| September | 9205 | 307 | 5907 | 196 | 64.2 |
| October | 10254 | 330 | 6172 | 205 | 60.2 |
| November | 7864 | 262 | 6591 | 219 | 83.8 |
| December | 7666 | 247 | 6863 | 221 | 89.5 |
| January | 6545 | 211 | 6652 | 214 | 101.6 |
| February | 5715 | 204 | 4988 | 178 | 87.3 |
| March* | 2138 | 356 | 1072 | 178 | 50.1 |

^ August 11th - 31st

* March 1st - 6th

## 3.2 Current ecological conditions

In December 2010 a major flood event occurred along the Broken and Nine Mile Creeks, which was accompanied by a blackwater event with low dissolved oxygen levels and some fish deaths. Fish monitoring undertaken post the flood event in 2011 indicated that the event had no significant impact on the diversity and abundance of the native fish population (ARI 2012). In March 2012 another major flood event occurred along the Broken and Nine Mile Creeks, which was also accompanied by a blackwater event with low dissolved oxygen levels and a small number of fish deaths. However, no fish monitoring occurred post the flood event to determine the impact on the diversity and abundance of the native fish population.

## 3.3 Flow components delivered

As described in section 2.1 the key flow components for the lower Broken and Nine Mile Creeks are base flows to:

- to provide native fish passage;
- minimise Azolla growth;
- maintain DO levels above 5 mg/L; and
- increase native fish habitat during migration and breeding seasons.

The key flow components that have occurred in the lower Broken and Nine Miles Creeks since 2002-2003 at Rices Weir as a result of delivering environmental water, and unregulated and regulated flows are outlined below in Table . In summary:

- Base flows to provide native fish passage through the fish ladders have been met in in most years (the construction of fish ladders was completed by 2002).
- Although the Azolla flow target has only been fully met in 2010-2011 and 2011-2012, significant Azolla accumulation has only occurred in 2002-2003, 2007-2008 and 2008-2009.
- Flows to maintain DO levels have only been fully met in 2010-2011 and 2011-2012. Despite this, significant native fish deaths have only been recorded in 2002-2003.
- Flows to increase native fish habitat during migration and breeding seasons have only been partly met in the last three years and in 2004-2005 and 2005-2006.

Table 4: Historical achievement of flow component values for the lower Broken and Nine Mile Creeks

| Flow component | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Provide native fish passage | | | | | | | | | | | |
| Minimise Azolla growth | | | | | | | | | | | |
| Maintain DO levels above 5 mg/L | | | | | | | | | | | |
| Increase native fish habitat during migration and breeding seasons | | | | | | | | | | | |

No significant part of the flow component achieved (target flow met for less than 50% of the required duration)
Flow component partially provided (target flow met for more than 50% of the required duration)
Flow component completely provided (target flow met for the required duration)

Note - The flow component to remove large Azolla blooms is not considered in the table above as it is a contingency flow and the flow component to minimise Azolla growth is considered to be completely provided in years when there is no significant Azolla growth. Environmental flow objectives and recommendations where not developed for the lower Broken and Nine Mile Creek until 2008 and Commonwealth environmental water only became available for use in the lower Broken and Nine Mile Creeks in 2010-2011. Prior to 2010-2011 flow was managed by:

- regulated and unregulated flows;
- redirecting Goulburn River and Murray River flows through the lower Broken and Nine Mile Creeks; and
- deployment of the Goulburn River Water Quality Reserve.

## 3.4 Key observations and learnings from 2011-2012

The Commonwealth Environmental Water Holder commissioned targeted intervention monitoring of fish, macro-invertebrate, vegetation and geomorphic responses to the delivery of environmental water down the lower Broken and Nine Mile Creeks in 2012-2013. As part of this program Murray cod and golden perch were tagged with acoustic transmitters and their movements monitored using an array of acoustic listening stations positioned along the Broken

Creek. Preliminary results reveal no evidence of synchronized movement of fish away from the study area over the 2012-2013 summer period, with most Murray cod and golden perch occupying restricted ranges. A small proportion of fish undertook occasional larger distance movements, including through several fishways. Although there were short periods when DO decreased to low levels, these periods did not coincide with these larger distance movements of fish. Larger distance movements of fish typically coincided with increases in flow, which serve to demonstrate the role of flow in facilitating movement along the lower Broken and Nine Mile Creeks. Final results of the intervention monitoring are expected to be available by the end of the financial year.

There is anecdotal evidence that the lower Broken and Nine Mile Creeks have become less turbid over the last 2-3 years due to increased flows. As a result water ribbon (*Triglochin procerum)* is re-establishing in sections of the lower Broken and Nine Mile Creeks. This species is thought to have been common along the Creeks, but its abundance and distribution was reduced by poor water quality.

Other key observations include:

- Stands of Cumbungi (Typha sp.) lost during the 2012 flood have not yet returned.
- There has been no significant Azolla growth since 2008-2009. The reason for this is unclear.

## 3.5 Climatic outlook for 2013-2014

According to the latest weather outlook information from the Bureau of Meteorology the likelihood that the Goulburn and Broken Catchments will receive above average rainfall from April to June 2012 is 40-45% and there is 70% chance that there will be warmer than normal days. Lake Eildon is currently 73% full, Dartmouth Dam is 93% full and the Hume Dam is 49% full. Overall, other than the state of the water storages, the climate outlook provides no particular guidance for 2012-2013 flow management.

Figure 2: Flow at Rices Weir during 2012-2013

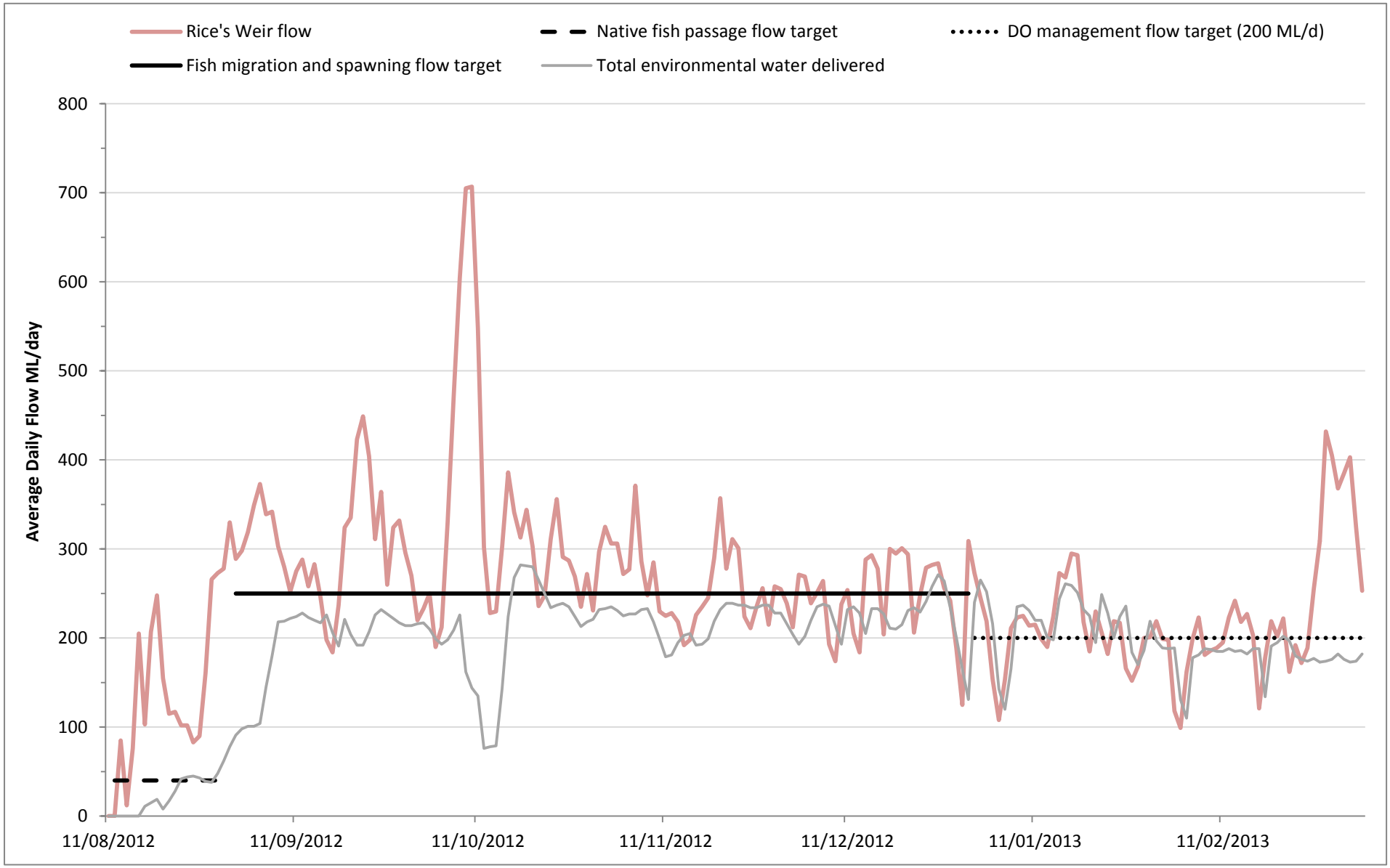


Figure 3: Sources of environmental water delivered during 2012-2013

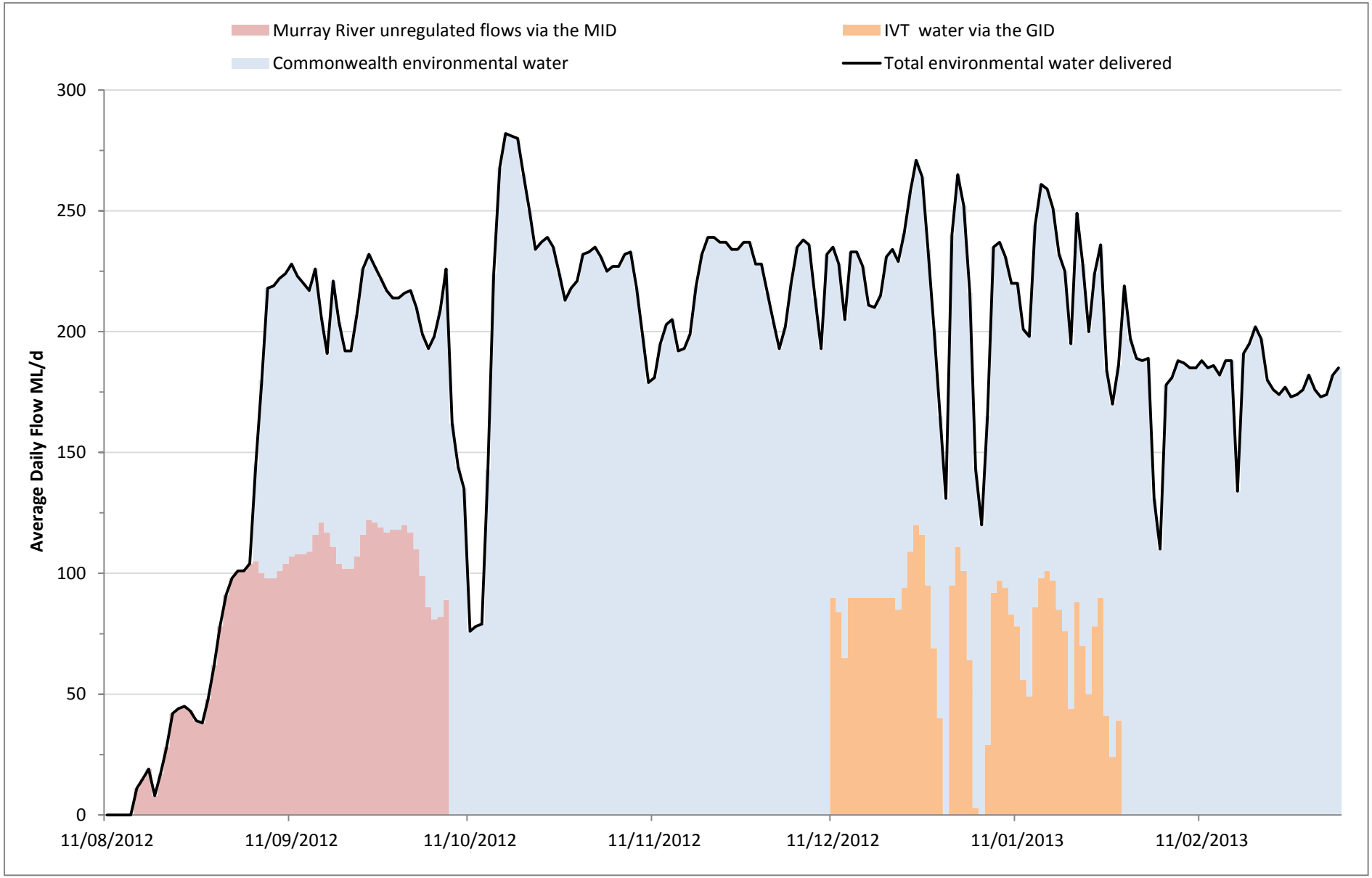


Figure 4: Dissolved oxygen levels and flow at Rices Weir during 2012-2013

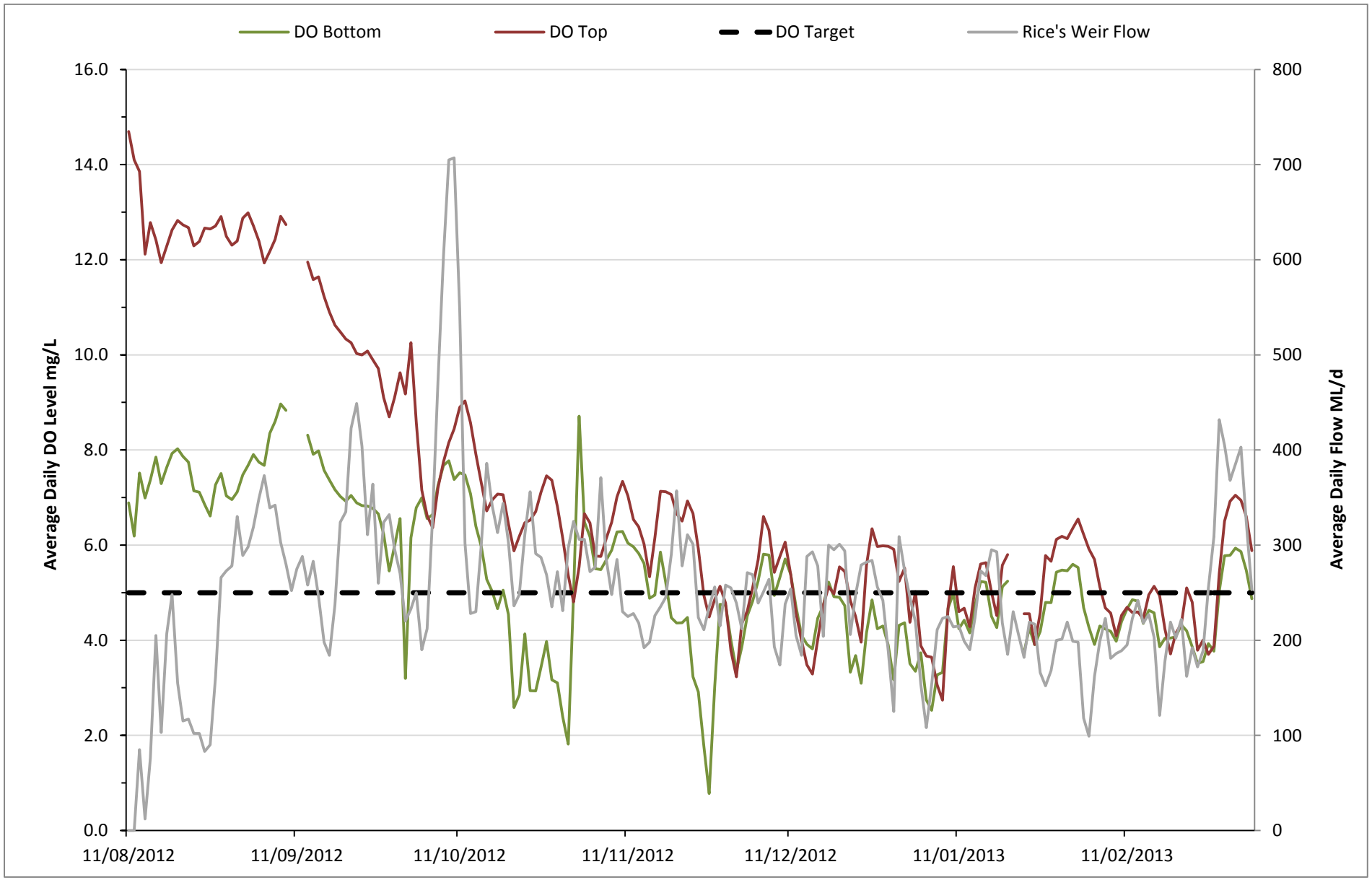
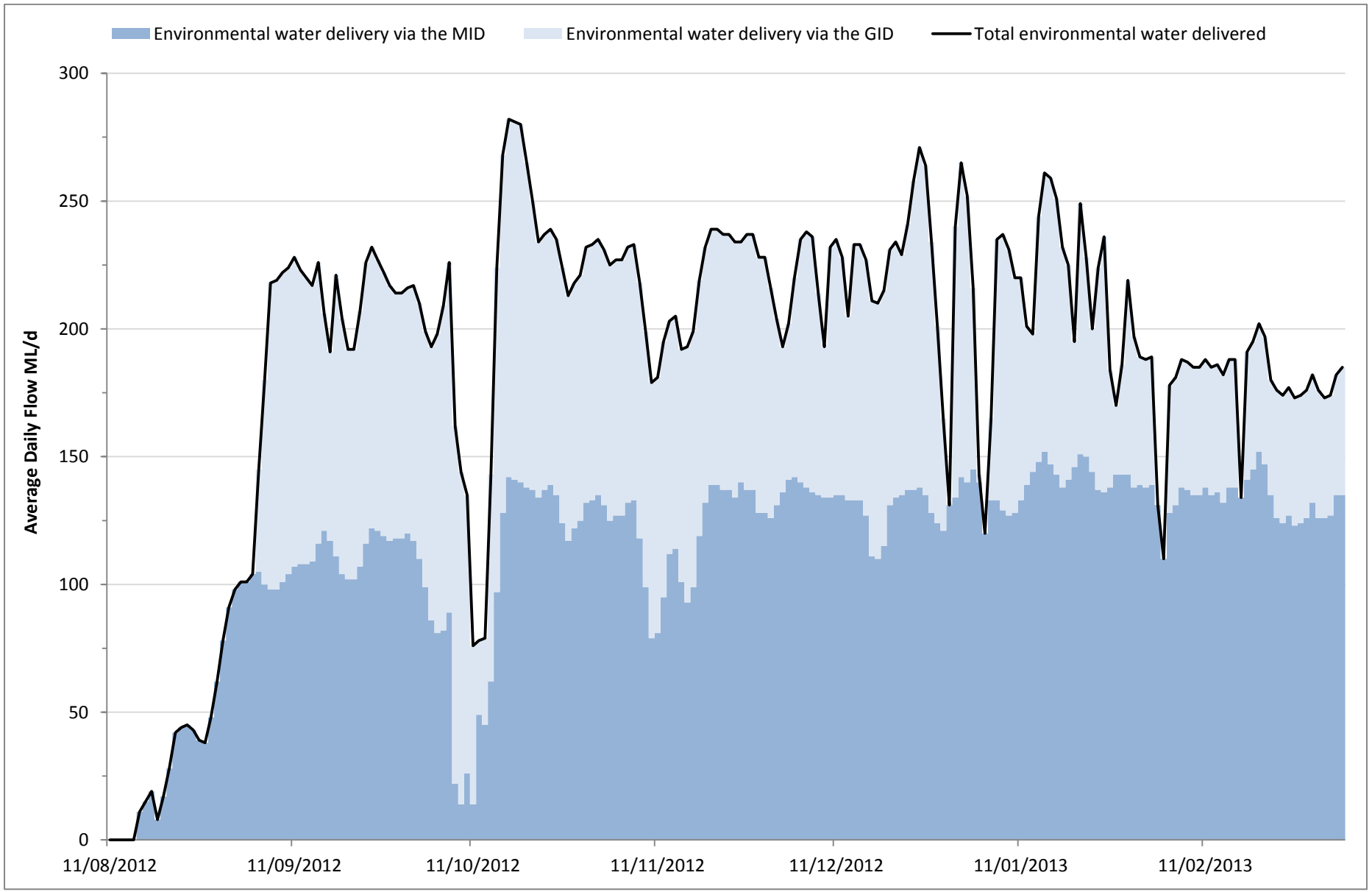


Figure 5: Environmental water delivered via the MID and GID during 2012-2013



# 4 Priority watering actions

## 4.1 Background

The needs of reach 3 drive environmental water planning, with reaches 1 and 2 benefiting from the passing flows. The key environmental water measurement point for reach 3 is Rices Weir.

The Broken Creek has no environmental entitlements or water storages. Therefore, all environmental water must be delivered to the lower Broken and Nine Mile Creeks via irrigation channels from the Murray River or the Goulburn River. Given the flow needs of the lower Broken and Nine Mile Creeks are small relative to the water resources available to meet them from the Murray and Goulburn River systems, the ecological needs of the Creeks are not constrained by resource availability. However, they are constrained by the availability of spare channel capacity and access to water-in-transit down the Goulburn and Murray Rivers to supplement environmental water entitlement use. Importantly, the actual management of water through the season needs to be adaptive and flexible, with water delivery decisions adjusting as the season unfolds, particularly in response to the variable flow needs of Azolla and dissolved oxygen management.

## 4.2 Priorities

Due to the regulation of the lower Broken and Nine Mile Creeks its environmental flow needs are relatively fixed from year to year. A total of 40 ML/day is required to operate the fish ladders. This allows fish to migrate and move for breeding and potentially escape poor water quality. Two of the priority flow components are heavily driven by the last ten years of Azolla and dissolved oxygen management experience. Experience has shown that Azolla growth can be minimised by a steady base-flow of 120 ML/day, with occasional flushes up to 250 ML/day to disperse large blooms. Dissolved oxygen can be managed by a steady base-flow of 150 ML/day, but can need up to 250 ML/day for extended periods (particularly in response to very hot weather). The flows required to manage Azolla and dissolved oxygen are a very high priority, as Azolla growth and low dissolved oxygen levels can reduce available native fish habitat and result in fish deaths. A flow of 250 ML/day to improve native fish habitat during the migrating/breeding season is also important to promote native fish recruitment and dispersal. These priority flow components are summarised in Table 5 and Figure 6.

In addition, the GBCMA in consultation with G-MW will seek to provide greater variation in water levels by extending or adding to natural high flow events to:

- promote an increase in the cover and diversity of native aquatic and fringing vegetation; and
- increase stimulus for native fish migration.

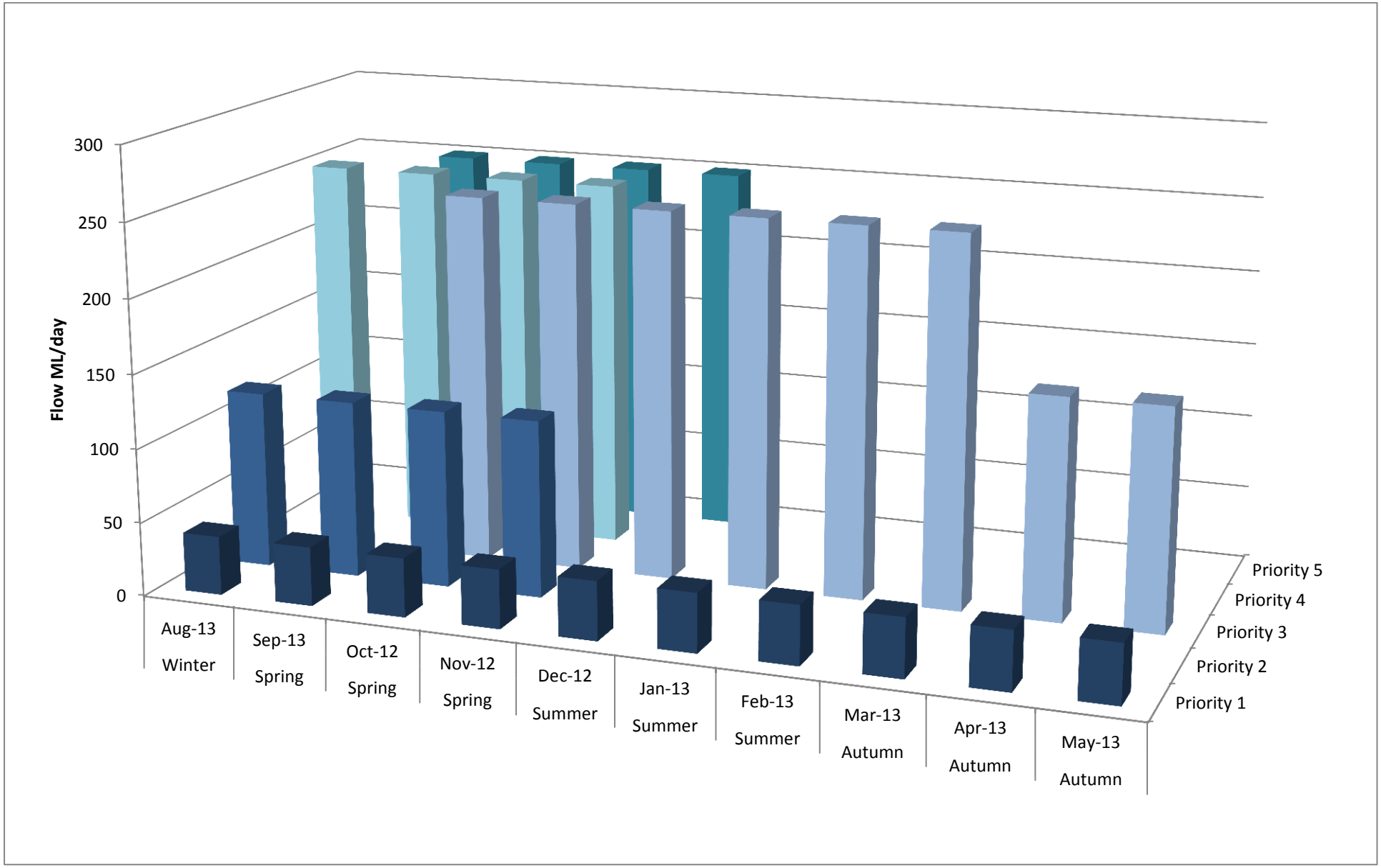
The flow priorities will improve the social amenity of the lower Broken and Nine Mile Creeks by improving water quality and recreational fishing opportunities. No negative social or economic impacts associated with the flow priorities have been identified.

Table 5: Summary of priority environmental flow components

| PRIORITY | FLOW COMPONENT | SEASON | FLOW (ML/DAY) | TOTAL VOLUME (ML) ESTIMATE | CUMULATIVE VOLUME (ML) | REACH |
|---|---|---|---|---|---|---|
| 1 | Provide native fish passage | August 2013 – May 2014 | 40 | 10,900 | 10,900 | 1-3 |
| 2 | Minimise Azolla growth | August 2013 – November 2013 | 120 | 12,960 | 19,540 | 3 |
| 3 | Maintain DO levels above 5 mg/L | October 2013 – May 2014 | 150 – 250 | 34,050 – 56,750 | 39,630 – 62,330 | 3 |
| 4 | Remove large Azolla blooms | August 2013 – November 2013 (flushing flows for up to 14 days) | 120 - 250 | 3,500 | 40,540 – 63,240 | 3 |
| 5 | Increase native fish habitat during migration and breeding seasons | September 2013 – December 2013 | 250 | 30,500 | 44,440 – 67,140 | 3 |

Note - the flow component to maintain DO levels above 5 mg/L is provided as a flexible range. Flow up to 250 ML/d is expected to be required until the end of March 2014 and lower flows of approximately 150 ML/d is expected to be required from April 2014 to mid-May 2014.

Figure 6: Priority environmental flow components



# 5 Scenario planning

Environmental flow planning aims to supplement the use of environmental water entitlements with Murray River unregulated flows and IVTs. Catchment runoff may contribute short flow peaks in winter and spring, but do not significantly contribute to environment flow needs. Unseasonal summer floods as experienced in 2010 and 2012 are unpredictable. Therefore, their potential contribution to flow in the Creeks is not considered in the scenario planning. However, environmental water may be required to restore dissolved oxygen levels in the Creeks after flood waters pass. This can be accommodated under existing priority watering actions.

The scenarios are based on current conditions within the water supply system such as the volumes of water stored in the reservoirs. They then assume the availability of all environmental water entitlements and their associated water allocations in the Goulburn and Murray system, and determine how best to maximise the environmental outcomes from their use. Importantly, the planning is not concerned with the probability of any particular climate scenario (or in picking the most likely scenario) – it merely ensures there is a plan if any scenario does occur. For the Goulburn and Murray system, while various indicators are available, predicting climatic conditions in the current autumn/early winter for the coming season (both winter/spring and summer/autumn) has little reliability.

The scenarios have been picked to highlight the key decisions that will need to be made about environmental water deployment for 2013-2014, and hence can change from year to year. Importantly, the actual management of water through the season needs to be adaptive, with water deployment decisions adjusting as the season unfolds, particularly in response to timing issues within the season. Table outlines the range of scenarios for water use in the lower Broken and Nine Mile Creeks in the 2013-2014 year.

Table 6: Scenario summary descriptions for the lower Broken and Nine Mile Creeks

| REACH 3 | SCENARIO 1<br>VERY DRY<br>90% POE | SCENARIO 2<br>AVERAGE<br>50% POE | SCENARIO 3<br>WET<br>30% POE |
|---|---|---|---|
| **Water Supply** | 100% HRWS Murray and Goulburn allocations<br>Perhaps 60% available as private carryover | 100% HRWS Murray and Goulburn allocations<br>Perhaps 60% available as private carryover | 100% HRWS Murray and Goulburn allocations<br>Perhaps 20% available as private carryover |
| **Expected Creek Flow and Water Management** | 18-20 ML/day in July | 25 ML/day from August to November, with a 700-900 ML/day high flow and 200-300 ML/day freshes | 45-50 ML/day from August to October, with a 2,500-3,000 ML/day high flow and 600 ML/day fresh |
| | No flow past Rices Weir from August to May | No flow past Rices Weir from November to May | No flow past Rices Weir from November to May |
| | 186 GL of IVT available to deploy | 186 GL of IVT available to deploy | 156 GL of IVT available to deploy |
| | 30 GL Water Quality Reserve available | 30 GL Water Quality Reserve available | 30 GL Water Quality Reserve available |
| **Environmental Entitlement Volumes Available Volumes** | Murray and Goulburn | Murray and Goulburn | Murray and Goulburn |
| **Environmental Objectives** | Provide native fish passage | Provide native fish passage | Provide native fish passage |
| | Minimise Azolla growth | Minimise Azolla growth | Minimise Azolla growth |
| | Maintain DO levels above 5 mg/L | Maintain DO levels above 5 mg/L | Maintain DO levels above 5 mg/L |

| REACH 3 | SCENARIO 1<br>VERY DRY<br>90% POE | SCENARIO 2<br>AVERAGE<br>50% POE | SCENARIO 3<br>WET<br>30% POE |
|---|---|---|---|
| | Remove large Azolla blooms | Remove large Azolla blooms | Remove large Azolla blooms |
| | Increase native fish habitat during migration and breeding seasons | Increase native fish habitat during migration and breeding seasons | Increase native fish habitat during migration and breeding seasons |
| **Preferable Murray Diversions and Inter-Valley Transfer (IVT) Water Use** | No water available to divert | Divert unregulated Murray water from mid-August to October at 150 ML/d (6 -12 GL) | Divert unregulated Murray water from mid-August to November at 150 ML/d ( 6 GL) |
| | Divert IVT water from January to March at up to 100 ML/day (9 GL) | Divert IVT water from January to March at up to 100 ML/day (9 GL) | Divert IVT water from January to March at up to 100 ML/day (9 GL) |
| **Preferable Environmental Water Use** | Use Goulburn and Murray environmental water from August to May at up to 250 ML/day (59.5 GL) | Use Goulburn and Murray environmental water from August to May at up to 250 ML/day (47.5 - 53.5 GL) | Use Goulburn and Murray environmental water from August to May at up to 250 ML/day (53.5 GL) |
| | Release Water Quality Reserve water in response to emergency water quality problems (e.g. blackwater) | Release Water Quality Reserve water in response to emergency water quality problems (e.g. blackwater) | Release Water Quality Reserve water in response to emergency water quality problems (e.g. blackwater) |

Importantly, if diversion of Murray River water or Goulburn Inter-Valley Transfers is not available, additional environmental entitlement water is required. If all flows come from environmental entitlements, up to 68.5 GL could be required. If channel capacity constraints limit supply from one side of the creek, the maximum use from the other side of the creek could be 27 GL from Murray entitlements and up to 50 GL from Goulburn entitlements.

As described in section 4.2, the environmental flow needs of the lower Broken and Nine Mile Creeks are relatively fixed from year to year. Therefore, a similar volume of water as described above will be required in 2014-2015.

# 6 Triggers and actions

The lower Broken and Nine Mile Creeks have relatively fixed environmental watering needs (i.e. largely independent of annual climatic conditions). Catchment runoff may contribute to early base flows and Azolla flushing flows. However, for the large part, flows must be brought in from the Murray and Goulburn Rivers. The environmental watering needs are variable on a short term basis, depending on the occurrence of Azolla and dissolved oxygen levels.

The Broken Creek flows into the Murray River at Barmah Forest. Therefore, water-in-transit along the Murray River or water being sent from the Goulburn River to the Murray River can be diverted via the Broken Creek to meet significant parts of its environmental flow needs. The availability of these sources will need to be confirmed with River Murray Water as seasonal conditions unfold.

Unregulated Murray water is potentially available in spring, providing Murray Valley channel capacity is available for use. However, the Goulburn Inter-Valley Transfers have a limited period in which they can be delivered (which depends on seasonal conditions and Murray system supply needs) and potentially a limited volume for transfer. Hence the proposal identifies the need for Goulburn environmental entitlement water to be available to supply the lower Broken Creek from the Goulburn supply system in the months when Goulburn Inter-Valley Transfers are not available. Water is also required to respond to 'low dissolved oxygen emergencies', and it is proposed the Goulburn Water Quality Reserve is used to meet these needs.

The key issue for this proposal is the potential difficulty in gaining access to enough channel capacity to provide the required flow rates at different times of the year, particularly in spring and autumn. The proposal therefore aims to have water available from both the Goulburn and Murray Rivers at the same time, to maximise spare channel capacity. In addition, a flow may be delivered down the lower Broken and Nine Mile Creeks to reduce Azolla build-up before irrigation demand significantly increases in spring and reduces environmental water delivery opportunities.

Under the proposal, if channel capacities allow, environmental water would be added to the lower Broken and Nine Mile Creeks as necessary to maintain the required flows at Rices Weir. The following is a list of the key triggers and actions that will guide environmental water delivery decisions:

- Unregulated flows in Broken Creek will determine how much additional water needs to be added to meet flow targets.
- The minimum flow of 40 ML/day required to operate the fish ladders would commence at the start of the irrigation season in mid-August 2013. The water will be preferably sourced from Murray River unregulated flows.
- If Azolla accumulates (e.g. 10-20% cover in weir pool at Rices Weir ) in August a flow of 120 ML/day would be delivered.
- The minimum flow would increase to 250 ML/day in September to the end of December (or as long as possible) to increase native fish habitat. This requires environmental water to be delivered from both the Murray and Goulburn systems as the maximum delivery capacity of the Murray channels to the lower Broken and Nine Mile Creeks is 170 ML/day.
- If 250 ML/day can not be provided consistently, surges to 250 ML/day for up to 2 weeks would be pursued (if required) to minimise Azolla build-up, and particularly pre-emptively if a period of low channel delivery capacity availability is imminent. Prolific Azolla growth increasingly blanketing areas of the creek water surface would trigger fresh releases.
- Once dissolved oxygen levels start to decrease towards 4 mg/l, (from October onwards), the minimum flow of 150 ML/day would be provided if possible, increasing up to 250 ML/day as temperatures rise and dissolved oxygen levels decrease. Decisions will aim to pre-empt issues rather than wait for problems to manifest.
- The risk of dissolved oxygen levels dropping below 5mg/L reduces in autumn (approximately April) as water temperatures decrease. Flows will be then reduced to approximately 100-150 ML/d.
- Flows would cease in mid-May at the end of the irrigation season.

In summary, this proposal nominates the use of in-transit water from the Murray River and Goulburn Inter-Valley Transfers, with additional environmental water entitlements as summarised in **Error! Reference source ot found.**. As environmental water delivery is constrained by spare channel capacity, it is expected that the maximum volumes identified in Table 7 for some or all of these water sources will not be delivered.

Table 7: Summary of environmental water volumes required to support this proposal (GL)

| REACHES 4 & 5 | VERY DRY | AVERAGE | WET |
|---|---|---|---|
| **Murray unregulated water use** | 0 GL | up to 12 GL | up to 6 GL |
| **Inter-valley water use** | up to 9 GL | up to 9 GL | up to 9 GL |
| **Murray environmental water use** | up to 27 GL | up to 23 GL | up to 23 GL |
| **Goulburn environmental water use** | up to 32.5 GL | up to 24.5 GL | up to 30.5 GL |

The maximum overall water required is 68.5 GL.

# 7 Implementation arrangements

## 7.1 Delivery losses and re-crediting

Under an agreement between Goulburn-Murray Water and the Victorian Environmental Water Holder, environmental water delivered through the channel systems incurs a 10% loss. That means that 90% of the water added to the Broken Creek is available to be re-credited to the Murray system for further use downstream. Murray unregulated flows diverted through Broken Creek incur no loss, and whatever flow returns to the Murray adds to the unregulated flows passing at that point. Inter-Valley Transfers from the Goulburn River incur no loss and flow returning to the Murray is credited as an Inter-Valley Transfer supplied from the Goulburn supply system to the Murray supply system.

## 7.2 Costs

The Environmental Water Manager does not have to make any payment for headwork costs relating to the environmental entitlements. If chargeable, these costs are met by the entitlement holders. Delivery of environmental water entitlements with interruptible supply incurs out-of-pocket expenses for delivery costs. Under agreement between Goulburn-Murray Water and the Victorian Environmental Water Holder, delivery using Shepparton irrigation channels costs $11.35/ML (2011/12 price – current prices not available) and using Murray Valley irrigation channels costs $5.48/ML (2011/12 price – current prices not available). If Murray system delivery is optimised, delivery of up to 68,500 ML could cost up to $516,835 (27,000 ML x $5.48 + 32,5000 ML x $11.35). These costs will need to be funded by environmental entitlement holders. Inter-Valley Transfers and unregulated Murray flows incur no charge for delivery through Broken Creek.

## 7.3 Notice and time required

Four days notice is generally required for ordering water from Goulburn or Murray system storages. Releases from Lake Eildon take approximately 2½ days to reach Goulburn Weir. Flows through the Shepparton channel system can occur within hours. If outfalled from the East Goulburn Main channel, water can take 7 days to reach Nathalia, and potentially a further day to reach Rices Weir (by manipulating the weirs). The smaller capacity Hicks and Hollands outfalls flow directly into weir pools at Nathalia and downstream. Releases from Hume Dam take 2 days to reach Lake Mulwala, with a further day to reach the Broken Creek through the Yarrawonga main channel and spur channels. The main 7/3 channel outfall enters the creek upstream of the East Goulburn Main channel, while other smaller outfalls can input water into the downstream weir pools.

# 8 Risk assessment and management

## 8.1 Environmental Water Delivery

The key risks associated with the proposed water delivery of each flow component include: current environmental flow recommendations are inaccurate which may result in ecological objectives not been met; the resource manager cannot deliver the require volumes due to restricted channel capacity; improving conditions for non-native species such as European carp; and unable to provide evidence environmental objectives were met from the environmental water releases. These have been assessed as either a medium or high risk while remaining risks have been assessed as low (Table 8). The risk the resource manager cannot deliver the required volumes due to restricted channel capacity is higher during summer and autumn. The remaining risks are not influenced by the season.

Table 8: Risk assessment of the proposed lower Broken and Nine Creeks water delivery

| RISK CATEGORY | Risk # | Risk type | FLOW COMPONENT | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Quality issues lead to non-achievement of objectives | 1.0 | Release volume is insufficient in meeting required flow at target point | Low | Low | Low | Low | Low |
| | 1.1 | Current recommendations on environmental flow inaccurate | Low | Medium | Medium | Medium | Medium |
| | 1.2 | Storage operator maintenance works affect ability to deliver water | Low | Low | Low | Low | Low |
| | 1.3 | Resource manager cannot deliver require volume or inflow rate (outlet/capacity constraints, insufficient storage volume) | Low | Medium | High | High | High |
| Time | 2.0 | Limited CMA resource to deliver environmental release | Low | Low | Low | Low | Low |
| Cost | 3.0 | Cost of delivery exceeds available funding | Low | Low | Low | Low | Low |
| Human | 4.0 | Environmental release cause personal injury to river user | Low | Low | Low | Low | Low |
| Environmental | 5.1 | Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, ASS etc.) | Low | Low | Low | Low | Low |
| | 5.2 | Improved conditions for non-native species (e.g. carp) | Medium | Medium | High | High | High |
| Compliance | 6.0 | Environmental water account is overdrawn | Low | Low | Low | Low | Low |
| | 6.1 | Environmental releases causes flooding of private land | Low | Low | Low | Low | Low |
| | 6.2 | Environmental releases causes flooding to public infrastructure | Low | Low | Low | Low | Low |
| | 6.3 | Environmental releases causes flooding of Crown land | Low | Low | Low | Low | Low |
| Reputation | 7.0 | Unable to provide evidence in meeting environmental objective | Low | Medium | Medium | Low | Medium |
| | 7.1 | Key stakeholders not supportive of environmental water release | Low | Low | Low | Low | Low |

Flow components:

1. Provide native fish passage
2. Minimise Azolla growth
3. Maintain DO levels above 5 mg/L

4. Remove large Azolla blooms
5. Increase native fish habitat during migration and breeding seasons

Table 9 below outlines the mitigation strategies that will be employed by the Goulburn Broken CMA to address the high and medium risks identified above. Importantly risks associated with our current level of knowledge need attention now, but will take time to reduce the associated risks.

Table 9: Mitigation action plan

| RISK # | RISK TYPE | FLOW COMPONENT | RISK MITIGATION STRATEGY | IMPACT OF RISK MITIGATION |
|---|---|---|---|---|
| 1.1 | Current recommendations on environmental flow inaccurate | 2-5 | Keep focus on monitoring outcomes from flow management and reassess recommendations as necessary | Adaptively improves recommendations and lowers risk over time |
| 1.3 | Resource manager cannot deliver require volume | 2-5 | Have environmental water available from both the Murray and Goulburn systems | Maximises available channel capacity |
| 5.2 | Improved conditions for non-native species (e.g. carp) | 1-5 | None available | NA |
| 7.0 | Unable to provide evidence in meeting environmental objective | 1, 3 and 5 | Seek involvement, contributions and results from monitoring and research programs | Progressively lower risk over time |

# 9 Monitoring and reporting

## 9.1 Current monitoring programs

A number of programs are currently conducted by the Goulburn Broken CMA to monitor environmental flow and river and ecological conditions. The main program for environmental flow monitoring is the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP). This program is being undertaken at sites along the Broken Creek from the confluence with the Broken River to the Murray River. The program is monitoring vegetation, fish, macroinvertebrates, channel features, and physical habitat. Not all parameters are measured at each site. These assessments are carried out on a range of timeframes (varying from annually, to when a channel changing event occurs) and are a long-term assessment (5 - 10 years) of the impacts of and changes from environmental flows. The analysis of this data is based on statistical methods rather than before-after style monitoring. Monitoring has been occurring since 2008, however no results have been made available.

The CEWH has funded targeted intervention monitoring in the lower Broken and Nine Mile Creeks in 2012-2013. The project included monitoring of fish, macro-invertebrate, vegetation and geomorphic responses to environmental flow management. The results of the project are expected to be available in May 2013. The project is not continuing in 2013-2014.

Flows are measured in the Broken Creek catchment at four hydrographic gauging stations along the Broken Creek and one on the Boosey Creek. The majority of dryland catchment inflows come from the upper catchment and are measured at the Boosey Creek at Tungamah and the Broken Creek at Katamatite. The key flow monitoring site is at Rices Weir. Goulburn-Murray Water also measure outfalls from channels into the creek, and flows past each of the weirs.

Water quality monitoring on the Broken Creek has been in place for a number of years. Continuous monitoring (i.e. 15 minute intervals) occurs at Rices Weir (2 sites) and monitors temperature, dissolved oxygen, wind direction and speed. In addition, photos upstream of Rices Weir are taken hourly. Goulburn-Murray Water also continuously monitors temperature and dissolved oxygen at Rices Weir as well as at Hardings Weir (3 weirs upstream from Rices Weir). Goulburn-Murray Water also undertakes routine spot readings of dissolved oxygen, temperature and Azolla cover along the reach from Nathalia to Rices Weir. Continuous dissolved oxygen and temperature monitoring occurs at the Boosey Creek at Tungamah and the Broken Creek at Katamatite. Nutrients and turbidity are also measured weekly at Rices Weir.

The GBCMA initiated a re-snagging program in 2012 to improve native fish habitat in the lower Broken Creek. Reach 2 downstream of the Nine Mile Creek was targeted for rehabilitation as it could recruit native fish from established populations moving upstream from reach 3. In early 2013, the ARI was contracted by the GBCMA to survey the newly re-snagged reach for evidence of fish colonisation. The results of this survey have provided baseline data for comparisons with subsequent surveys. Future surveys are planned and it is hoped they will provide evidence of colonisation by native fish.

## 9.2 Monitoring 2013-2014 environmental flow outcomes

In 2013-2014 the VEFMAP will continue to monitor fish, macroinverebrates and vegetation along the Broken Creek. However, as stated above the program generally aims to detect environmental improvement over some years and the frequency and timing does not necessarily coincide with flow events to assess the effect of environmental water in isolation. If funds are available the Goulburn Broken CMA will continue to engage ARI to monitor fish assemblages, movement and recruitment in the lower Broken Creek. Where feasible this will be coordinated to coincide with planned flows to test the hypothesis that they promote migration and recruitment of native fish.

## 9.3 Reporting

The first level of reporting is on use of environmental entitlements. Weekly reporting is planned to advise environmental entitlement holders of progressive water use, and on any adaptive water deployment decisions made. The second level of reporting is on flows occurring in the river system. Weekly reporting is planned to advise environmental entitlement holders of current flows and the effectiveness of environmental water

deployed in achieving desired flows. The third level of reporting is on environmental outcomes achieved. This will tend to more anecdotal in nature and is planned to be reported fortnightly. An annual report will be prepared after the end of the 2013-2014 year to collate all information on the use of environmental water, the river flows achieved, and the environmental outcomes recorded.

## 9.4 Knowledge gaps and limitations

Recent monitoring activity is beginning to yield valuable information on the fish communities within the Broken Creek, with increases in values correlating with improved seasonal conditions and environmental flow management. On-going participation in the state-wide VEFMAP will continue to increase understanding of the relationship of biota and environmental flows. In addition, the GBCMA is involved with researchers looking to improve access to, and use of, evidence-based decision-making in delivery of environmental water.

The dynamics of Azolla growth and dissolved oxygen levels requires further investigation. There is clear evidence that excess Azolla is problematic for dissolved oxygen and aquatic biota, although recent experience has shown that dissolved oxygen levels can fall below critical thresholds, particularly at depth, in the absence of Azolla. Somewhat fortuitously, critically low levels of DO have not necessarily resulted in substantial fish deaths in the system, with real-time monitoring of parameters used to invoke flow delivery sufficiently quickly to ameliorate low DO in the lower Broken Creek.

Whilst there is a reasonable amount of information and understanding of water flow and quality issues in the lower Broken Creek, further information on the processes by which bed sediments drive low dissolved oxygen levels and higher flows in turn drive higher dissolved oxygen levels. This would allow more predictability of the flows required based on a range of parameters.

The Broken Creek already has low dissolved oxygen levels which fish seem to be surviving. It would be useful to know how they survive (e.g. by moving vertically or horizontally or by 'hibernating') to improve our understanding of their susceptibility to or tolerance of these conditions and the duration of events that can be tolerated.

The flow and water quality issues in the upper reaches (between the Broken River and Katamatite) are not as well known as in the lower reach. It is reasonable to assume that poor water quality issues in this part of the system may be having a substantial impact on problems manifesting in the lower system.
There is likely to have been substantial inputs of nutrients and organic matter (and possibly some toxins) as a result of the unprecedented floods in February / March 2012; the magnitude and longer-term implications of this will require further investigation.

# 10 Communications

In developing the proposal, discussions have been held with Goulburn-Murray water on the seasonal outlook and the deliverability of the proposal.

There are two key audiences for communications under the proposal. The primary audience is the agencies involved in delivering the proposed flow management and include Goulburn-Murray Water, River Murray Water, the Victorian Environmental Water Holder and the Commonwealth Environmental Water Holder.

Goulburn-Murray Water is the key water delivery agency. When the final proposal for 2013-2014 is agreed, communications with Goulburn-Murray Water are aimed at making clear what the intended environmental flow release plans are and their intended purpose. Then, throughout the season, there will be regular communications (phone, email) directly with the water resource management group to understand unregulated flows, Goulburn-Murray Water planned consumptive use releases, and to organise environmental flow releases.

River Murray Water is responsible for calling out Inter-Valley Transfers. Communications (phone, email) will be aimed at initially planning Inter-Valley Transfers to achieve Murray system operational objectives and lower Broken Creek environmental objectives, and then regularly throughout the season, adjusting the plans to conditions as they unfold.

The Victorian Environmental Water Holder will use this proposal as the basis (in whole or part), in developing the Seasonal Watering Plan. Water allocated is to be delivered in accordance with the plan and the plan is used to seek agreement from other water holders for the use of their water. Routine communication (phone, email) will report on deployment of water under the plan, and seek to modify release plans to align with downstream site needs as the year unfolds.

Commonwealth Environmental Water Holder may have allocated water to the Seasonal Watering Plan which is based on this proposal, and are responsible for achieving further benefits from the water at downstream environmental sites. Routine communication will be via the Victorian Environmental Water Holder.

The secondary audience is those potentially affected by or interested in environmental flows and/or the health of the river environment. This includes Parks Victoria and Department of Sustainability and Environment (public land managers), water users along the river (Goulburn-Murray Water diversion licence holders), campers and recreation users, local government, environment groups, and the general public. As the effect of the proposal on these groups is expected to be minimal, the communication objective is to provide information about the decision to provide environmental flows and what it is trying to achieve. A secondary objective is to build a public understanding of the change from past flow regimes to a future one managed to achieve improved river health. These communications will be through media articles of newsworthy actions, and potentially through talks and local newsletters directly with special interest groups.

To assist with the environmental water management program, the Goulburn Broken CMA has established a Broken Environmental Water Advisory Group to provide advice on planning environmental water use (including seasonal watering proposals and water management plans) and on any environmental health trends occurring in the rivers, creeks and wetlands. The focus of the group will be the Broken River from Lake Nillahcooties to Shepparton, the Broken Creek from Caseys Weir to the Murray River and wetlands associated with these systems. The group was established in April 2012 and comprises 6 members (including Chair), who come from a range of geographic locations along the Broken River and Broken Creek. Representatives from key agency partners (such as the Department of Primary Industries, Department of Sustainability and the Environment, and Goulburn-Murray Water) and indigenous groups will be consulted.

Table  outlines the consultation process the Goulburn Broken CMA has undertaken during the development of this seasonal water proposal and the consultation/communication process that will be implemented following its approval.

Table 10: Seasonal watering proposal development and implementation consultation process

| STAKEHOLDER | PURPOSE | ENGAGEMENT TYPE | METHOD | TIMING |
|---|---|---|---|---|
| **Proposal development** | | | | |
| G-MW | Seek information on water system outlooks and river management, and feasibility of proposal | Involve/consult | Personal discussion with key staff | March – April 2013 |
| CMA Board | Approval of the proposal | Approve | Board Meeting Paper/Presentation | 11 April 2013 |
| **Proposal implementation** | | | | |
| Indigenous Groups | Inform Indigenous Groups on the proposal and seek advice on indigenous related issues | Inform/consult | Personal discussion with key staff | May 2013 – April 2014 |
| Broken Environmental Water Advisory Group | Inform the Goulburn Environmental Water Advisory Group on the proposal and seek advice on community and river health related issues | Inform/consult | Meetings | April 2013 – April 2014 |
| VEWH | Report on deployment of water under the plan, and seek to modify release plans to align with downstream site needs as the year unfolds | Inform/consult | Telephone and email | May 2013 – May 2014 |
| River Murray Water | Planning Inter-Valley Transfers to achieve Murray system operational objectives and lower Goulburn River environmental objectives, and adjusting the plans to conditions as they unfold | Inform/consult | Telephone and email | May 2013 – May 2014 |
| G-MW | To understand unregulated flows, planned consumptive use releases, and to organise environmental flow releases | Inform/consult | Telephone and email | May 2013 – May 2014 |
| Interest Groups | Build understanding of environmental flow objectives and changes in flow regime | Inform | Media, possibly newsletters and talks | May 2013 – May 2014 |
| General public | Build understanding of environmental flow objectives and water management to achieve objectives | Inform | Media | May 2013 – May 2014 |

# 11 Execution and endorsement

I, the authorised representative of the agency shown below, approve the Seasonal Watering Proposal for the Goulburn River 2012-13.

**SIGNED FOR AND ON BEHALF OF THE GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY**

Signature of authorised representative

Name of authorised representative

Date:

# 12 References


ARI (2006). Assessment of the Broken Creek Fishways Installation Program. Report to the Goulburn Broken Catchment Management Authority. Arthur Rylah Institute for Environmental Research, department of Sustaainability and Environment, Heidelberg, Victoria.

Cottingham, P., Stewardson, M., Roberts, J., Metzling, L., Humphries, P., Hillman, T., and Hannan, G. (2001). Report of the Broken River Scientific Panel on the environmental condition and flow in the Broken River and Broken Creek. CRC for Freshwater Ecology, Technical Report 10/2001., Canberra.

DSE (2006a). Flora InformationSyatem. Department of Natural Resources and Environment, Melbourne.

DSE (2006b). Atlas of Victorian Wildlife. Department of Natural Resources and Environment, Melbourne.

ECC (2001). Box Ironbark Forests & Woodlands Investigation - Final Report. Environment Conservation Council, Melbourne.

Environment Australia (2001). A Directory of Important Wetlands in Australia (Third Edition). Environment Australia, Canberra.

GHD (2005). Lower Broken Creek Waterway Management Strategy. Report to the Goulburn Broken Catchment Management Authority.

Goulburn Broken Catchment Management Authority (2008). Lower Broken Creek and Nine Mile Creek Interim Environmental Flow Recommendations.

Lintermans, M. (2007). Fishes of the Murray-Darling Basin: An introductory guide. Murray-Darling Basin Commission, Canberra.

NRE (2002). FLOWS - a method determining environmental water requirements in Victoria. Report by Sinclair Knight Merz for the Department of Natural Resources and Environment, Armidale, Victoria.

RES (2006). Broken, Boosey and Nine Mile Creeks Wetland Implementation Plan. Report prepared by Regional Ecosystem services for the Goulburn Broken Catchment Management Authority.

Robinson, D., and Mann, S. (1996). Site-specific environmental values and threats of the land along the Broken, Boosey and Nine Mile Creeks. Report prepared by the Goulburn Valley Environment Group for Goulburn-Murray Water and the National Parks Service.

Sinclair Knight Merz (1996). A management strategy for Broken Creek, study report stage 1, volume 2.

SKM (1998). Broken Creek Management Strategy, Final report, Volume 1.Report to the Goulburn Broken Catchment Management Authority.

URS (2011). Report; 2010 VEFMAP Fish monitoring.

Water Technology (2010). Lower Broken Creek and Nine Mile Creek Environmental Watering Plan

Website WWW.nativefish.asn.au.

# Appendix 1: Native fish and water quality

## Native fish

A total of six native and five introduced fish species have been recorded in the lower Broken Creek. The key native fish species recorded are the threatened Murray cod (Macullachella peelii peelii), Golden perch (Macquaria ambigua), Un-specked hardyhead (Craterocephalus stercusmuscarum fluvus) and the Crimson-spotted rainbowfish (Melanotaenis fluviatilis) (Table 11). Boat electrofishing surveys of the lower Broken Creek indicate that:

- the most abundant native fish species are the Crimson-spotted rainbowfish and Murray cod;
- the least abundant native fish species is the Un-specked hardyhead;
- Common carp (Cyprinus carpio) and Goldfish (Carrasius auratus) are the most abundant introduced fish species;
- the least abundant introduced fish species is the Oriental weatherloach (Misgurnus anguillicaudatus); and
- native and introduced fish diversity and abundance decreases substantially upstream of Nathalia township (reaches 1 and 2), with the exception of Katandra Weir pool (located in reach 2) (ARI 2006).

The biology and habitat requirements of the key native fish species recorded in the lower Broken Creek are as follows. Murray Cod prefer deep pool habitats with cover from large rocks, snags, undercut banks and overhanging vegetation. They have a varied diet including other fish, crayfish, yabbies, shrimp, freshwater mussels and frogs. They migrate upstream in late winter early spring to spawn. Migration is triggered by rising water temperatures (when it exceeds about $15^0$c), increased daylight and rising water levels. The species spawns in spring and early summer and then moves downstream again to the same area they occupied before the migration. Eggs are large (3-3.5 mm diameter), adhesive and usually deposited onto a hard surface such as logs. Larvae drift downstream in spring and summer (peaking from mid-November to mid-December) (Lintermans 2007). Evidence also suggests that they will breed with or without spring-floods (www.nativefish.asn.au).

Golden perch like Murray cod prefer deep, slow flowing pool habitats with cover from snags, and overhanging vegetation. They are opportunistic carnivores that feed mainly on yabbies, small fish and benthic aquatic insect larvae. They migrate upstream from spring to summer to spawn. Migration is triggered by rising water temperatures (when it exceeds about $20^0$c), increased daylight and rising water levels. Recent evidence from the Murray River suggests that the species is able to spawn during relative stable, bankfulll irrigation flows and most movement occurs between October and April (Lintermans 2007).

Crimson-spotted rainbowfish prefer slow flowing rivers, wetlands and billabongs. The species is carnivorous, consuming aquatic invertebrates. They breed in spring and summer when water temperatures exceed $20^0$c. The eggs sink and lodge amongst aquatic plants. They have been recorded moving through fishways (www.nativefish.asn.au).
Un-specked hardyhead prefer slow-flowing or still habitats with aquatic vegetation. It spawns from October to February, with a peak in spring when water temperatures are above $24^0$c. The species is carnivorous, consuming small insects such as mosquito larvae and microcrustaceans. They have been recorded moving through fishways (www.nativefish.asn.au).

Table 11: The fish species recorded in each reach and their conservation status

| Fish Species | Reach 1 | Reach 2 | Reach 3 | Victorian Status | National Status |
|---|---|---|---|---|---|
| Australian smelt | ✓ | ✓ | ✓ | | |
| carp gudgeon | ✓ | ✓ | ✓ | | |
| Common Carp* | ✓ | ✓ | ✓ | | |
| Crimson-spotted rainbowfish | | | ✓ | DD, L | |
| Gambusia* | ✓ | ✓ | ✓ | | |
| Golden perch | ✓ | ✓ | ✓ | Vul | |
| Goldfish* | ✓ | ✓ | ✓ | | |
| Murray cod | ✓ | ✓ | ✓ | End, L | V |
| Oriental weatherloach* | | ✓ | | | |
| Redfin* | ✓ | ✓ | ✓ | | |
| Un-specked hardyhead | | | ✓ | DD, L | |

In the above table * denotes introduced fish species, DD denotes species with deficient data within Victoria and suspected of being threatened, Vul denotes species considered vulnerable within Victoria, End denotes species considered to be endangered in Victoria, L denotes species listed as threatened under the Victorian Flora and Fauna Guarantee Act 1988 and V denotes species considered to be vulnerable in Australia (listed under the EPBC Act).

## Low dissolved oxygen and Azolla and algal blooms

In the lower Broken Creek water quality has been monitored at Rice's Weir (Reach 3) since 1978. No long term monitoring of water quality has been undertaken on the Nine Mile Creek.

The monitoring results indicate that the water quality in the Broken Creek at Rice's Weir is degraded (Sinclair Knight Merz 1996; CRC Freshwater Ecology 2001). The Creek has high turbidity, low dissolved oxygen levels and elevated concentrations of nutrients and suspended solids, which do not meet the corresponding water quality objectives in the State Environment Protection Policy (SEPP) – Waters of Victoria (WoV) (GHD 2005).

Sediments and nutrients enter the Broken Creek from irrigation and dryland drainage and urban stormwater. The low dissolved oxygen levels in the Broken Creek (reach 3) are principally caused by large algal and Azolla (an aquatic fern that grows on the surface) populations using oxygen within the water column. The growth of algae and Azolla in the Creek is promoted by the high nutrient levels, high water temperatures, reduced competition from macrophytes and slow flow velocities. Low dissolved oxygen levels caused by algal and Azolla growth can also promote nutrient releases from sediments further encouraging their growth. Azolla and algal outbreaks generally occur between July and November.

A major fish death occurred in Rices Weir (reach 3) in November 2002. The deaths were thought to be the result of very low dissolved oxygen concentrations (anoxia) due to excessive algal and Azolla growth (Rees 2006). Since the 2002 event, a response plan has been put in place to prevent future fish deaths. The strategy has been to maintain sufficiently high dissolved oxygen levels through flushing flows of approximately 120 -250 ML/d from July to November, to minimize the growth of algae and Azolla and supply continued oxygen from upstream. In addition, real-time monitoring of oxygen and temperature now occurs at Rices weir to better inform management responses.

# Appendix 2: Summary template

| | |
|---|---|
| **System name** | Lower Broken Creek |
| **Waterway manager** | Goulburn Broken CMA |
| **Storage operator/s** | G-MW |
| **Land manager/s** | Parks Victoria |

| **System summary** |
|---|
| The planning area includes the lower Broken Creek downstream of the Boosey Creek confluence and the Nine Mile Creek. The Broken Creek has been identified as a priority waterway in the Goulburn Broken Regional River Health Strategy is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001) and stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve. The Creeks support a diverse and abundant native fish community, provide water for agriculture and urban centres, and support a variety of recreational activities such as fishing and bushwalking. |

| **Summary of planned environmental water use in 2013-14** |
|---|
| The priority environmental objectives in the Broken system for 2013-14are to: provide native fish passage; provide suitable water quality conditions for native fish; and increase fish habitat during migration and breeding seasons.<br><br>To achieve these objectives, environmental watering will focus on: year-round low flows; winter/spring medium flows; summer/autumn high flows; winter/spring fresh; and spring/summer high flows.<br><br>The priority river reach for environmental watering is reach 3 (from Nathalia Weir Pool to the River Murray), with flows providing benefits to reaches 1 and 2 on the way. |

| **System overview** |
|---|
| The planning area includes the lower Broken Creek downstream of the Boosey Creek confluence and the Nine Mile Creek. Water can be released from the Goulburn system through the East Goulburn Main Channel and from the Murray system through the Yarrawonga Main Channel into the lower Broken and Nine Mile Creeks. Water from these channels cannot be released in the upper reaches of the Broken Creek which is largely unregulated and ephemeral in nature.<br><br>The priority river reach for environmental watering is reach 3 (from Nathalia Weir Pool to the River Murray), with flows also providing benefits to reaches 1 and 2 on the way. The measurement point for target flows for reach 3 is at Rices Weir.<br><br>Environmental water releases will be combined with unregulated flows and the delivery of consumptive water en route to maximise environmental outcomes. |

| **Current situation** |
|---|
| The 2012-13 year was been characterised by a dry winter which saw passing flows at Rices Weir fall to zero in August. Early in the season Murray River unregulated flows and Commonwealth environmental water contributed to environmental flow requirements. Local rainfall and subsequent catchment runoff late September 2012 and early October 2012 generated two substantial but short lived freshes. From December to March Commonwealth environmental water and IVTs contributed to environmental flow targets of 250 ML/d (to increase large bodied native fish habitat during migration and breeding seasons) and 200 ML/d (to maintain dissolved oxygen levels above 5 mg/L). Due to channel capacity constraints these targets were not always met and dissolved oxygen levels fell below 5 mg/L for extended periods. There was no significant Azolla growth during the year and therefore no flows to manage Azolla growth were required. |

| **Environmental objectives** |
|---|
| The priority environmental objectives in the Broken system for 2013-14 are to: provide native fish passage; provide suitable water quality conditions for native fish; and increase fish habitat during migration and breeding seasons.<br><br>The flow priorities will improve the social amenity of the lower Broken and Nine Mile Creeks by improving water quality and recreational fishing opportunities. No negative social or economic impacts associated with the flow priorities have been identified. |

**Priority watering actions**

To achieve the environmental objectives the priority watering actions for the Broken system in 2013-14 are as follows:

- low flows (40 ML per day from August to May to provide native fish passage)
- winter/spring medium flows (120 ML per day from August to November to minimize Azolla growth and maintain water quality)
- summer/autumn medium flows (150 - 250 ML per day from October to May to maintain water quality)
- winter/spring fresh (flushing flows of 120- 250 ML per day for up to 14 days from August to November to remove large Azolla blooms impacting on water quality)
- spring/summer high flows (250 ML per day from September to December to increase fish habitat during migration and breeding seasons).

The above priority watering actions meet the recommended water regime under the existing environmental flow study, which does not currently include other flows components such as bankfull flows.

**Risk assessment and management**

The key risks associated with the proposed water delivery of each flow component include: current environmental flow recommendations are inaccurate which may result in ecological objectives not been met; the resource manager cannot deliver the require volumes due to restricted channel capacity; improving conditions for non-native species such as European carp; and unable to provide evidence environmental objectives were met from the environmental water releases. These have been assessed as either a medium or high risk while remaining risks have been assessed as low. The risk the resource manager cannot deliver the required volumes due to restricted channel capacity is higher during summer and autumn. The remaining risks are not influenced by the season.

The table below outlines the mitigation strategies that will be employed by the Goulburn Broken CMA to address the high and medium risks identified above. Importantly risks associated with our current level of knowledge need attention now, but will take time to reduce the associated risks.

| RISK # | RISK TYPE | FLOW COMPONENT | RISK MITIGATION STRATEGY | IMPACT OF RISK MITIGATION |
|---|---|---|---|---|
| 1.1 | Current recommendations on environmental flow inaccurate | 2-5 | Keep focus on monitoring outcomes from flow management and reassess recommendations as necessary | Adaptively improves recommendations and lowers risk over time |
| 1.3 | Resource manager cannot deliver require volume | 2-5 | Have environmental water available from both the Murray and Goulburn systems | Maximises available channel capacity |
| 5.2 | Improved conditions for non-native species (e.g. carp) | 1-5 | None available | NA |
| 7.0 | Unable to provide evidence in meeting environmental objective | 1, 3 and 5 | Seek involvement, contributions and results from monitoring and research programs | Progressively lower risk over time |