Seasonal Watering Proposal 2022-2023

Lower Broken Creek

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

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Executive Summary

This proposal identifies the environmental water requirements of the lower Broken and Nine Mile Creeks in 2022-23, to maintain or improve their ecological health. The proposal is based on the FLOWS study completed in 2019.

Along with their floodplain and wetland habitats, the lower Broken and Nine Mile Creeks are culturally significant to the Yorta Yorta Traditional Owners. They support a diverse and abundant native fish community, provide water for agriculture and urban centres, and facilitate a variety of recreational activities. The Broken Creek is a priority waterway in the Goulburn Broken Waterway Strategy 2014-2022 and the floodplain of the lower Broken and Nine Mile Creeks is listed in the 'Directory of Important Wetlands in Australia' (Environment Australia 2001). Stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve.

Delivery of environmental water aims to work towards the following long-term environmental objectives:

Table A: Environmental objectives for the lower Broken and Nine Mile Creeks

Ecological value	Long-term environmental objective
Native fish	1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.
Native aquatic fauna	2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.
Native vegetation	3. Avoid excessive build-up of *Azolla*. 4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.
Macroinvertebrates	5. Maintain and promote the diversity and abundance of macroinvertebrates.
Water quality	6. Maintain dissolved oxygen levels suitable for aquatic animals.

Three potential watering actions contribute towards achieving these objectives and include:

- Winter baseflows – to maintain instream habitat and connectivity year-round, as well as reduce stagnation of water in weir pools.
- Spring/summer/autumn baseflows – to increase the availability of instream habitat, provide cues for fish movement/spawning, mobilise *Azolla* accumulations, maintain suitable dissolved oxygen levels and support the growth of native vegetation in the littoral zone.
- Freshes – to cue native fish movement into the system from the Murray River and flush large *Azolla* accumulations.

These watering actions are relevant to each climate scenario, as the environmental flow needs of the creeks is largely independent of annual climatic conditions. Catchment runoff may contribute to winter baseflows and *Azolla* flushing flows in wet periods, but most water is sourced from the Murray and Goulburn Rivers. It is instead the variable flow needs of *Azolla* and dissolved oxygen management throughout the year, that determines how flows are adaptively managed. These watering actions are therefore proposed as follows in 2022-23:

Table B: Potential watering actions 2022-23

Tier	Flow component	Expected watering effects	Climate scenario			
			Extreme dry	Dry	Average	Wet
1	Winter baseflows: 40 ML/d continuously, May to August	Provide year-round habitat and instream refuge areas for native fauna. Improve platypus carrying capacity and reduce predation risk. Minimise exposure of turtles during winter dormancy. Maintain longitudinal connectivity to allow instream fauna to access food and shelter. Maintain inundation of instream aquatic plants, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.	•	•	•	•
1	Spring/summer/autumn baseflows 200-450 ML/d continuously, August to May	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools. Maintain dissolved oxygen levels over summer.	•	•	•	•
1	Freshes: 1 to 3 events of 300-450 ML/d for 1-2 weeks, July-November	As per "spring/summer/autumn baseflow" above. Note: flows over 300 ML/d can flush *Azolla* whilst it is still in single layers or individual plants. Flushes up to 450 ML/d disperse large blooms.	•	•	•	•*

Note: only potential watering actions for reached 3 and 4 are shown in the table. Potential watering actions for all 4 reaches are described in the body of this report. * Freshes are likely to be met by unregulated flows under a wet scenario, but may still be required depending on the timing and extent of unregulated flows and the presence of *Azolla* accumulations.

If delivered in full, this proposal requires approximately 91,100ML of water. It is expected that IVT and Murray Bypass deliveries will occur through the lower Broken and Nine Mile Creeks this coming year and will therefore reduce the volume of environmental water required to meet flow targets. Accounting for expected flows from other water sources (e.g. unregulated inflows) and potential delivery constraints, the volume of environmental water required is likely to be less than 50,000 ML. Prior to 2021-22, annual environmental water deliveries have ranged between 30,000 and 43,000 ML.

The above baseflow watering actions were delivered in 2021-22 to varying degrees, while a spring fresh was not required due to ongoing low *Azolla* levels and a fresh being delivered for native fish the previous year. Maintenance works on the Yarrawonga Main Channel and East Goulburn Main

Channel during the off-irrigation season meant the winter baseflow targets were not consistently achieved over winter and the fish ladders were closed for a period to help retain refuge habitat during the low flow conditions.

Re-commencement of environmental water deliveries to provide baseflows over spring and summer coincided with numerous periods of unregulated inflows, predominantly from Boosey Creek following the wet La Niña conditions. The unregulated inflows contributed blackwater to lower Broken Creek on several occasions. Both the blackwater events and summer heatwaves resulted in instances of low dissolved oxygen levels over summer. Environmental water was used to ensure adequate flows were provided to maintain dissolved oxygen levels during heat waves, as well as dilute any blackwater moving the through system. This helped minimise impacts to aquatic fauna, including large-bodied native fish.

IVT and Murray bypass deliveries had still not commenced at the end of summer, due to ongoing unregulated conditions in the Murray River from the regular rainfall.

The greatest risks to successful delivery of environmental water in the lower Broken and Nine Mile creeks are the ongoing capacity constraints within the irrigation channel network, especially during periods of high irrigation demand, and the need for infrastructure maintenance during the off-irrigation season. Both of these risks have the potential to prevent or reduce the delivery of environmental flows at certain times. The GBCMA and GMW will work closely together to optimise deliveries of environmental water around these constraints.

Once flows are delivered, the ability to fully achieve the environmental outcomes being sought is hindered in part by the highly regulated nature of the system and the poor instream habitat in some locations. Goulburn Broken CMA will continue to identify opportunities for complementary works that improve the health of the creek and enhance the outcomes from environmental water deliveries.

This proposal does not take account of competing needs for environmental water use from other river/creek systems or downstream along the Murray River. However, environmental 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 a very low risk of adverse impacts to private assets from releasing environmental water.

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Glossary and acronyms

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

Baseflow - 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 Office (CEWO) - (part of the Department of the Environment and Energy) holds and manages the water entitlements purchased through the Restoring the Balance water recovery program.

Department of Environment, Land, Water and Planning (DELWP) – Victorian government department responsible for protecting the environment, responding to climate change and supporting sustainable population growth.

DO - dissolved oxygen level of water.

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 waterway or wetland used to inform management decisions 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 license or supply agreement).

Flow - movement downstream of water confined in the waterway channel.

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 provide life cycle cues for fish.

GB CMA - Goulburn Broken Catchment Management Authority.

Geomorphology (fluvial) - 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.

GMW – Goulburn-Murray Rural Water Corporation, trading as Goulburn-Murray Water.

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.

Lotic – flowing or moving water.

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 (includes insects, crustaceans, aquatic worms and aquatic snails).

Macrophytes - aquatic plants that grow in or near water and can be emergent, submergent or floating.

Megalitre (ML) - one million (1,000,000) litres.

MDBA – Murray-Darling Basin Authority.

Overbank flow - flood flows that overtop the river bank 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 (characterised 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 effect 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) – scientific monitoring that 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 Environmental 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.

Introduction

Purpose

This Seasonal Watering Proposal (SWP) outlines the Goulburn Broken Catchment Management Authority's (GB CMA) priorities for the use of environmental water in the lower Broken Creek and Nine Mile Creek in 2022-23, as required under section 192A of the *Water Act 1989*. It aims 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 the environmental values and health of these waterways; and
- inform the development of environmental water priorities in the VEWH's Seasonal Watering Plan for 2022-23.

The SWP is informed by scientific studies and reports that identify the flow regime required to meet the ecological objectives of the creeks. It was prepared in consultation with key stakeholders and partners, and was approved by the GB CMA CEO.

System overview

The lower Broken and Nine Mile Creeks are within the Broken River Basin in northern Victoria.

The Broken Creek is a priority waterway in the Goulburn Broken Waterway Strategy 2014-2022 and the floodplain of the lower Broken and Nine Mile Creeks is listed in the 'Directory of Important Wetlands in Australia' (Environment Australia 2001). 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, including threatened Murray cod (*Macullachella peelii peelii*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*). Along with their floodplain and wetland habitats, the creeks are culturally significant to the Yorta Yorta Traditional Owners, provide water for agriculture and urban centres, and support a variety of recreational activities.

The lower Broken and Nine Mile Creeks form part of the Murray Valley and Shepparton Irrigation Districts, having been regulated for over 100 years. Irrigation water is supplied to the creeks from (Figure 1):

- the Murray Valley 7/3 Main Channel - offtaking from Lake Mulwala on the Murray River and outfalling into lower Broken Creek at Katamatite.
- the East Goulburn Main Channel - offtaking from the Goulburn River (Goulburn Weir at Nagambie) and outfalling into lower Broken Creek at Katandra Weir (downstream of Katamatite).
- over a dozen smaller Murray Valley and East Goulburn channels (and drains) spread along and outfalling into the creeks further downstream.

The most downstream section of the Broken Creek (below Nathalia) is highly regulated, with eight shallow weir pools along the 65km reach. During the irrigation season, these are managed to provide a near-constant water level to facilitate pumping by irrigation diverters and for stock and domestic (S&D) use. Due to the shallow depths and low flow velocities in the weir pools, the lower Broken Creek is prone to low dissolved oxygen levels when temperatures increase in summer, as well as large accumulations of *Azolla* (which can also contribute to low dissolved oxygen levels through blocking light available for photosynthesis by other aquatic plants and algae, and through microbial processes when decaying).

Under natural conditions the creeks would have ceased to flow for extended periods during summer and autumn. Today, the lower Broken and Nine Mile Creeks are largely perennial with significant flows maintained throughout the irrigation season (spring to autumn) to supply consumptive water. However, winter flows have been reduced due to water harvesting and are reliant on environmental water deliveries and catchment induced runoff.

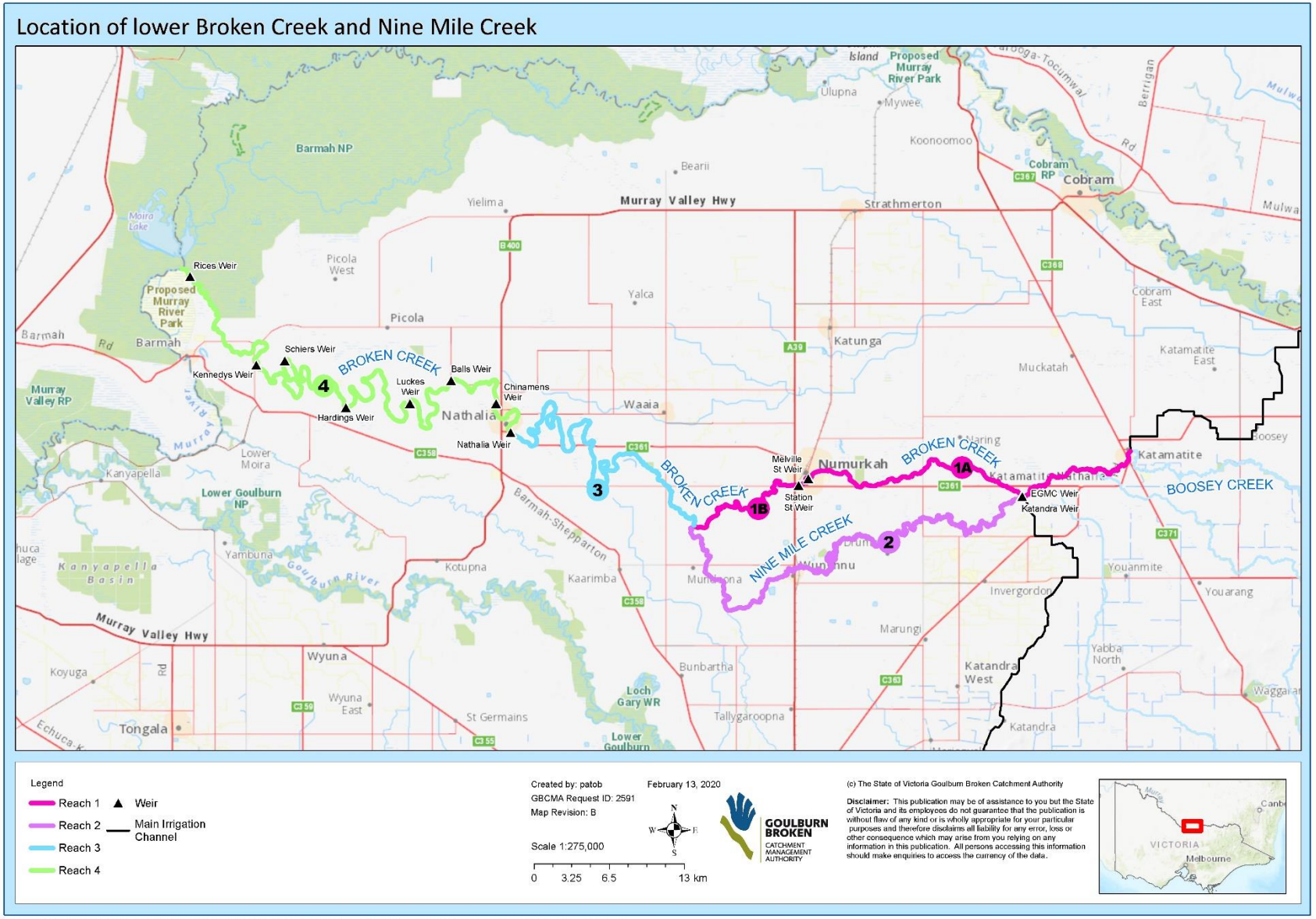

Figure 1: Lower Broken and Nine Mile Creeks

Priority reaches and measuring points

Ecological flow recommendations were developed for the lower Broken and Nine Mile Creeks in 2018 (Jacobs 2019). The environmental flow recommendations were determined using the FLOWS methodology. The creeks were divided into four reaches with similar channel morphology, flow regimes and ecological values (Figure 1). Details of the four reaches are below:

Table 1: The four reaches in the lower Broken and Nine Mile Creek system

Reach	Description
1	Boosey Creek downstream of the Murray Valley 7/3 Channel outfall at Katamatite to Broken Creek confluence (4.1km), Broken Creek downstream of the Boosey Creek confluence to the Nine Mile Creek confluence downstream of Numurkah (38.5km). Total length – 42.6km.
2	Nine Mile Creek from Katandra Weir to the Broken Creek confluence (49.8km).
3	Broken Creek from the Nine Mile Creek confluence to the Nathalia town weir (37.9km).
4	Broken Creek downstream of the Nathalia town weir to the Murray River (65.8km).

While all reaches are important, the delivery of environmental water is targeted to reach 4 over the irrigation period, which supports the most native fish (Howson and Lloyd 2021) and often has poor water quality in summer and autumn. However, water delivered to reach 4 also provides benefits to the other reaches (upstream) during this time. Specific flow recommendations exist for the upstream reaches (1 and 2), which also provides benefits for the downstream reaches (3 and 4). The key environmental flow measurement point for reach 4 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).

Water sources

Environmental flow requirements in the lower Broken Creek system are mostly met from three main water sources – environmental water, Murray bypass flows and Goulburn to Murray Inter-Valley Transfers (IVT). Regarding environmental water, the lower Broken Creek system has no environmental entitlements or water storages. Environmental water must therefore be delivered from the Murray or Goulburn Rivers via the irrigation channel network.

Given the lower Broken Creek flows into the Murray River at Barmah Forest, water-in-transit along the Murray River can be diverted around the Barmah Choke via lower Broken Creek (referred to as Murray bypass flows). Similarly, Goulburn River flows destined for the Murray River can be diverted around the lower Goulburn River via lower Broken Creek (referred to as Inter-Valley Transfers). These water-in-transit deliveries meet a significant proportion of the lower Broken Creek system's environmental flow needs. The availability of these sources is confirmed with the Murray-Darling Basin Authority (MDBA) river operators as seasonal conditions unfold.

Water available for use in the lower Broken and Nine Mile Creeks is detailed in Table 2 and includes:

- a water quality allowance (30GL) established in the Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995 and subsequent amendments;
- environmental entitlements held by the VEWH, the Commonwealth Environmental Water Holder (CEWH) and the MDBA;
- Murray bypass flows;
- Goulburn to Murray Inter-Valley Transfers (IVT); and
- unregulated flows from the Murray River, Boosey Creek and upper Broken Creek.

Table 2: Bulk entitlements and water sources available for meeting environmental requirements in the lower Broken and Nine Mile Creeks

Water Source	Responsible agency	Description	Conditions
Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995			
Goulburn Water Quality Allowance	GMW	30 GL per year	Maintenance of water quality.
Environmental water entitlements and Water-in-Transit			
Murray River flows	MDBA /VEWH MDBA	Unregulated flows Regulated Barmah Choke bypass flows	Available when Murray River flow is unregulated. Regulated conditions when flows at or near Barmah Choke reach capacity.
Goulburn Valley and Murray Valley Irrigation supplies	GMW	Irrigation water	Supply is dictated by demand and channel capacity.
Bulk Entitlement (River Murray - Flora and Fauna) Conservation Order 1999	VEWH	29,782ML high reliability water shares and 3,894 low reliability water shares.	Availability determined by agreement with the VEWH.
NVIRP entitlement	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. Issued to the VEWH as 17,703 ML high reliability water shares.	Availability determined by agreement with the VEWH.
Environmental Entitlement – Living Murray	MDBA	39,625 ML Goulburn high reliability water shares and 156,980 ML low reliability water shares. 9,589 ML Murray high reliability water shares and 101,850 ML low reliability water shares.	Water allocated to this entitlement must be used for the Living Murray 'icon sites'. However, this water can provide environmental benefits in the lower Broken Creek system en-route to the Murray River.
Commonwealth Environmental Water Holdings	CEWO	The 5-year watering schedule between CEWO and VEWH (to 2022-2023) allows up to 50,000 ML to be available for the lower Broken Creek, subject to environmental need and water availability. Additional environmental allocations may be available from CEWH holdings if required.	Approved by the CEWH and sourced from Murray and/or Goulburn holdings. Water use is subject to agreement with the representatives from the CEWO.
Goulburn River Inter-Valley Transfers	MDBA/GMW	Varies (up to 350,000 ML) depending on trade amounts.	Must be called by MDBA Limited to spare channel capacity.
Boosey Creek and upper Broken Creek flows	VEWH	Unregulated flows	Available when Boosey Creek and upper Broken Creek flow is unregulated.

Engagement

Planning

Key community and stakeholder groups have been engaged during the development of this proposal (Table 3). Similar to previous years, these groups include:

- The agencies directly involved in delivering the proposed flow recommendations including Goulburn Murray Water (GMW), the VEWH and the CEWH.
- Yorta Yorta Nation Aboriginal Corporation - the Registered Aboriginal Party under the Aboriginal Heritage Act (2006).
- Taungurung Land and Waters Council – Traditional Owners to the south of the Goulburn Broken CMA region.
- Parks Victoria – the manager of the reserve system adjacent to the creek.
- Individuals or groups potentially affected by or interested in environmental flows and/or the health of the lower Broken and Nine Mile Creeks. This includes water users along the creeks (GMW diversion licence holders), campers and recreational users, local government, environment groups and the general public.

Engagement with these groups primarily occurs through two mechanisms – the Broken Environmental Water Advisory Group (EWAG) and direct engagement e.g. through meetings, email updates and one-on-one informal discussions.

The Broken EWAG was established by the GB CMA in April 2012 to provide advice on planning environmental water use (including SWPs and Environmental Water Management Plans) and on any environmental health trends occurring in the rivers, creeks and wetlands across the Broken Basin. The EWAG meets 3-4 times per year with the most recent meeting in February 2022. The focus area for the group is the Broken River from Lake Nillahcootie to Shepparton, the Broken Creek from Caseys Weir to the Murray River and wetlands associated with these systems. The group includes community members (from a range of geographic locations along the Broken River and Broken Creek), representatives from Taungurung and key agency partners (the VEWH, the CEWO and GMW). Yorta Yorta Nation have also been invited to join the group. However, to date limited resources has restricted their involvement.

Direct engagement has also occurred with Traditional Owners (Yorta Yorta Nations Aboriginal Corporation and Taungurung Land and Waters Council) and program partners (GMW, the VEWH, the CEWO) through regular meetings and discussions with GB CMA staff. Examples include presentations on planned environmental water deliveries at virtual meetings with Traditional Owner groups and discussions through the Goulburn/Broken Operations Advisory Group.

In addition to the above, communications about the environmental flow program and the specific environmental flows and objectives proposed in the Broken Basin for 2022-23 will occur through a variety of communication materials and products (e.g. media releases, talks and newsletter articles for special interest groups). The communications will help build the general public's awareness and understanding of environmental water in the region, particularly the resulting environmental and shared benefits. Further details are available in the Goulburn Broken Environmental Water Communication Action Plan, which is reviewed and refined throughout the year.

Operations

In relation to the delivery of the proposed flows, an Operational Advisory Group was formally established by the VEWH in early 2016 for the Goulburn and Broken systems. It is comprised of representatives from GMW, MDBA (river operators), the VEWH, the CEWO and the GB CMA. It aims to provide a regular and coordinated forum to discuss and resolve aspects of environmental water management planning, delivery, approvals and facilitate system-scale coordination.

GMW is the key water delivery agency. When the final proposal for 2022-23 is agreed, communications with GMW 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 team in GMW to understand unregulated flows, GMW planned consumptive use releases, and to organise environmental flow releases.

MDBA (river operators) is responsible for requesting Inter-Valley Transfers and use of Barmah Choke bypass flows. Communications (phone, email) will be aimed at initially planning Inter-Valley Transfers and use of Barmah Choke bypass flows to achieve Murray River system operational objectives and lower Broken Creek environmental objectives, and then regularly throughout the season, adjusting the plans to conditions as they unfold.

The VEWH will use this proposal as the basis (in whole or part), in developing their 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.

The CEWO also undertakes annual planning and publishes plans on the CEWO website. Planning by the GB CMA, the CEWO and the VEWH is undertaken in close co-operation with each other to create a shared understanding of the watering priorities and ecological outcomes to be achieved each year. The CEWO is responsible for achieving further benefits from the water at downstream environmental sites. Routine communication will be via the VEWH.

Table 3: Engagement during development of the lower Broken Creek Seasonal Watering Proposal

Who		IAP2 level of engagement	Engagement methods	Engagement purpose
Government agencies	GMW VEWH CEWH Parks Victoria	Collaborate	Broken EWAG meeting 21 February 2022 Direct engagement	Seek input to development of the proposal. Understand any delivery constraints or issues and plan for environmental water delivery in 2022-23.
Traditional Owners	Yorta Yorta Nation Aboriginal Corporation	Involve	Direct engagement – meeting on 2 March 2022	Identify Aboriginal values and uses of the creeks. Seek feedback on environmental water priorities for 2022-23.
	Taungurung Land and Waters Council	Involve	Broken EWAG meeting 21 February 2022 Direct engagement – meeting on 1 March 2022	
Recreational Users	EWAG members	Involve	Broken EWAG meeting 21 February 2022	Confirm recreational and social uses of the creeks. Seek feedback on environmental water priorities for 2022-23.
	Nathalia Angling Club and Numurkah Fishing Club	Inform	Email regarding planned watering actions 21 February 2022	Keep key interest groups informed about planned watering events.

Who		IAP2 level of engagement	Engagement methods	Engagement purpose
Community and Environment Groups	Broken Creek Field Naturalists Club	Inform	Email regarding planned watering actions 21 February 2022	Keep key interest groups informed about planned watering events.
	Broken Boosey Conservation Management Network	Inform	Email regarding planned watering actions 21 February 2022	
	Goulburn Valley Environment Group	Involve	Broken EWAG meeting 21 February 2022	
	Goulburn Murray Landcare Network	Inform	Email regarding planned watering actions 21 February 2022	
Landholders	EWAG members	Involve	Broken EWAG meeting 21 February 2022	Gather observations on creek health and trends. Seek feedback on environmental water priorities for 2022-23.
Local Government	Moira Shire	Inform	Email regarding planned watering actions 21 February 2022	Keep local shire informed about planned watering events.

Aboriginal cultural values and uses of waterways

Traditional Owners value water in the landscape's waterways and wetlands as a way of caring for country, for supporting culturally important plants and providing opportunities to practice culture. Yorta Yorta Nation Aboriginal Corporation is the Registered Aboriginal Party for the lower Broken Creek system, under the Aboriginal Heritage Act (2006).

During consultation with Yorta Yorta, the following cultural values have been identified for the lower Broken Creek:

"The Broken Creek holds many cultural values. Common reed contained within the slack water provides important material for tools whilst also providing refuge for culturally important fish species (large & small bodied). The creek also has significant stands of old growth river red gum containing important habitat and exhibiting scars made from carving out canoes and coolamons" (J. Whittaker, pers. comm. 4 March 2021).

The Yorta Yorta Whole of Country Plan 2021-2030 includes Broken Creek as a priority place with high value including native fish populations, turtles, platypus, rakali, Australiasian bittern and threatened River swamp wallaby grass. Threats around inadequate flow leading to low oxygen levels and overabundant *Azolla* are identified. The Plan outlines Walla (water) actions to "achieve healthier Country and better outcomes for ecosystems and native plants and animals" including improving "volumes, seasonality, timing and depth of river flows" and "the cultural and environmental outcomes from watering operations". This includes protecting "culturally important animal species, especially turtles, through measures to conserve land and water habitat".

The environmental objectives of this SWP were supported by Yorta Yorta and align with their values of caring for Country. Flows have been specifically targeted to support instream vegetation and native fish, along with other aquatic biota. The GB CMA will continue to work with Yorta Yorta Nation to identify how environmental water management can best support cultural values.

In previous meetings to discuss SWPs, Yorta Yorta raised concern about the cultural damage water transfers are having on the lower Goulburn River and the Barmah Choke, this was in addition to the ecological damage being caused. Using the lower Broken and Nine Mile Creeks for delivery of water

(either environmental or consumptive) to the lower Murray River as a bypass mechanism, may help reduce risk of erosion on the Barmah Choke and lower Goulburn River and thus help to protect culturally significant values. Use of lower Broken Creek as an alternative pathway for such deliveries has been identified in the Yorta Yorta Whole-of-Country Plan (2021-2030).

Social, recreational and economic values and uses of waterways

The creeks making up the lower Broken Creek system have a narrow riparian zone with residential and farming properties adjoining or overlooking them. The creek system runs through the Katamatite, Wunghnu, Numurkah and Nathalia townships. Consequently, the communities have a direct connection with their creek, which provides high aesthetic and amenity value, that is particularly important to the mental health and wellbeing of the community during dry periods.

The creeks are also important recreational areas in terms of fishing, canoeing, kayaking and passive recreation. Delivery of water for the environment has helped support these activities e.g. through providing baseflows that keep fishways operational and ensure over-wintering habitat is provided for young-of-year fish, as well as freshes that provide movement and spawning cues for key species such as Murray cod.

The lower Broken Creek system is the source of consumptive water (irrigation and S&D) for over 70 diverters. Lower sections of the creek are prone to poor water quality (high turbidity, low dissolved oxygen levels and elevated concentrations of nutrients and suspended solids) (Sinclair Knight Merz 1996; Cottingham et al. 2001; GHD 2005). Delivery of baseflows and freshes during the warmer months has contributed to improved water quality for local diverters.

The expected shared benefits from delivery of water for the environment in the lower Broken Creek and Nine Mile Creek in 2022-23 are outlined below. These are based on the shared benefits that were realised in previous years and the outcomes of community and stakeholder engagement.

Table 4: Social, recreational and economic shared benefits from environmental water in the lower Broken and Nine Mile Creeks

Shared benefit	Beneficiary	How flows contribute to the shared benefit
Amenity	General community, adjacent landholders, visitors	Baseflows retain (aesthetically pleasing) flowing habitat (almost) year-round. Higher flow in warmer months prevent water quality problems (e.g. algal blooms, large *Azolla* accumulations) and promote visual waterway productivity and biodiversity e.g. vegetation growth on the banks, waterbirds, flowering aquatic plants.
Recreation	Local residents, visitors, anglers, game hunters, kayakers and canoers.	Baseflows retain flowing habitat year-round, keep fishways operational and provide over-wintering habitat for young-of-year fish (when delivered). This ensures water is available (almost) year-round for recreational activities. It also promotes the survival and recruitment of young native fish into the fish community, which supports a sustainable fishing industry. Higher flows prevent water quality problems (e.g. algal blooms, large *Azolla* accumulations) improving access to good quality water for recreational pursuits. High flows also promote waterway productivity and optimal conditions for fish (food and habitat provision), which again supports a productive and sustainable fishing industry.
Economic	Consumptive water users – GMW irrigators and diverters, Goulburn Valley	When delivered, winter baseflows retain flowing habitat (reducing weir pool stagnation in winter) and maintain suitable water levels for S&D pumping out of the irrigation season. Higher flows help improve water quality for all users by:

	Water (GVW) customers.	• breaking up and flushing *Azolla* accumulations, reducing the potential for low dissolved oxygen associated with decaying *Azolla* and keeping the main channel clear to improve pumping access. • reducing stagnation in weir pools and the likelihood of low dissolved oxygen levels over the warmer months. • diluting point source concentrations of nutrients and other potential pollutants from drainage outfalls.

In the past two years, members of the Numurkah community have raised concerns about the visual and ecological impact of the lower Broken Creek being drained over winter (including submitting a letter to the editor at the Numurkah Leader, June 2020). They have requested winter baseflows be provided to maintain the creek habitat, particularly around the Numurkah township. This supports the amenity and recreational value of the creek to the local community. In the last four years, delivery of the winter baseflow has not been possible over the entirety of the irrigation off-season due to GMW maintenance works.

Seasonal review

Historic flow conditions

Prior to 2001, flows in the lower Broken Creek at Rices Weir were relatively high and variable, typically averaging 200 ML/d or more. Flows reduced significantly during the Millennium Drought (2001-2009), especially in 2002/03 and 2006/07. Flows ceased through Rices Weir for most of winter/spring 2002/03, with a major fish death occurring in November 2002, in response to low flows and the decay of large *Azolla* accumulations. Flow events greater than 500 ML/day (generated by catchment runoff) only occurred for short durations in 2003/04 (3 events), 2004/05 (1), and 2005/06 (1). No bank-full events (~2,600 ML/day) eventuated.

In 2010/11, three natural flood events occurred, with flows up to 2,140 ML/day in September, 3,570 ML/day in December, and 1,880 ML/day in February. A blackwater event accompanied the December flood with associated fish deaths. Further flooding eventuated in March 2012 (a major flood event greater than a 1 in 100 year event), with bank-full flows continuing into April. This was again accompanied by a blackwater event with low dissolved oxygen and some fish deaths.

From 2012 to 2016 flow conditions reflected the typical 'flow-inverted' stream pattern, with generally low flows over winter, higher flows during the summer irrigation season and low levels of dissolved oxygen in summer in response to high ambient temperatures. On occasion, local rainfall and catchment runoff resulted in winter freshes e.g. July 2013.

In 2016, two natural flood events occurred (Figure 2), with flows up to 2,200 ML/day at Rices Weir in late August and flooding from September to November resulting in a peak of around 3,000 ML/day (at Harding's Weir). During the second unregulated flow event, the Murray River saw major flooding with a peak discharge of over 196,000ML/day below Yarrawonga Weir. On 7 October, the Murray River backed up over Rices Weir and the lower parts of Broken Creek were essentially part of the Murray until 6 November.

Since the 2016 flood, flows became more typical, except for significant rainfall in December 2017 (and forecast flooding) resulting in flows over 700 ML/day in the lower Broken Creek for a short period. Drier conditions have prevailed from 2018 to 2022 leading to minimal unregulated flows, although it is worth noting that Boosey Creek unregulated flows occurred in late winter/spring 2021 (peaking at 513 ML/d) which was the largest unregulated event from this system since 2016.

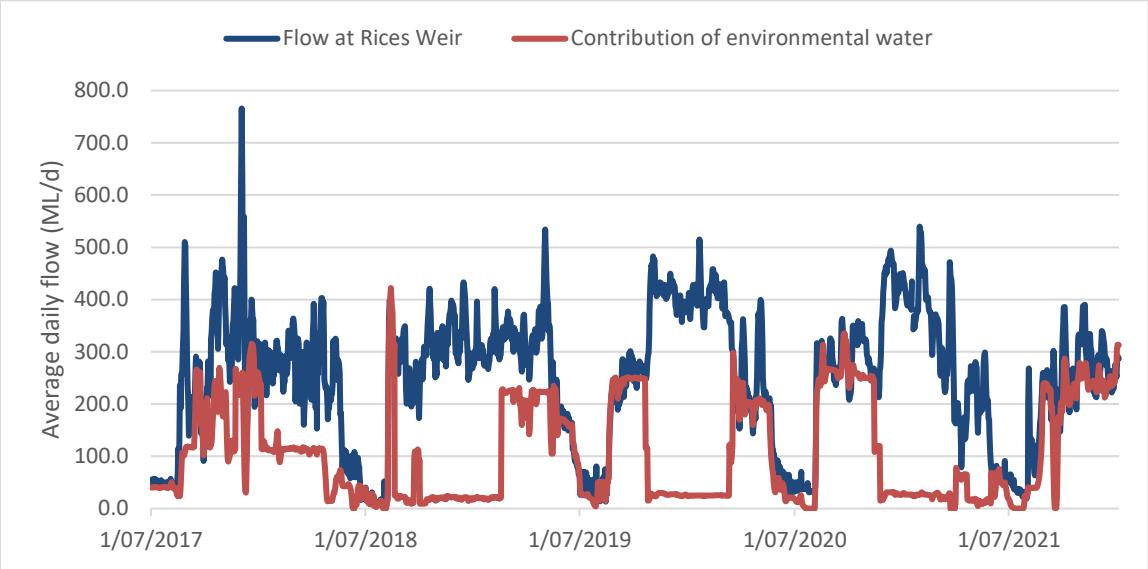

Figure 2: Total flow and the contribution of environmental water in the lower Broken Creek (2017 to January 2022)

Historic flow components delivered

Prior to 2010/11, there was no environmental water available for the lower Broken or Nine Mile Creeks. Flow management was instead provided by redirecting (via lower Broken Creek) Goulburn River and Murray River water passing to the Murray River downstream, and by deployment of the Goulburn River Water Quality Reserve.

In 2010/11, environmental water was used for the first time in the lower Broken Creek system between November and May. Environmental water has since continued to be delivered each year in the lower Broken and Nine Mile Creeks, in line with flow recommendations.

The key flow components for the lower Broken and Nine Mile Creeks include (Table 6):

- winter baseflow (previously referred to as minimum low flows)
- spring/summer/autumn baseflow (previously referred to as extended high flows)
- freshes.

The achievement of these flow components in reach 4 of the lower Broken Creek[1] since 2011/12, as a result of delivering environmental water, unregulated and regulated flows is shown below (Table 7). In summary, since 2011/12:

- Winter baseflow (40 ML/d to provide fish passage through the fish ladders[2] and other environmental benefits) has been completely or partially met over the past decade. The delivery of environmental water in conjunction with unregulated flows has been critical to the provision of this flow component during the irrigation off-season (15 May to 15 August). Typically, flows during the winter period hover around the minimum flow target but may not consistently achieve it. In some years, necessary infrastructure works by GMW mean minimum low flow targets cannot be achieved for a period of time during the irrigation off-season.
- Spring/summer/autumn baseflow (typically 250 ML/d, but ranging from 200-450 ML/d, to mobilise *Azolla*, maintain water quality and improve instream habitat) has been

[1] Based on the Rices Weir compliance point. Achievement of flow targets in the other reaches is described ahead.

[2] Operational since 2002.

partially met in all but one year (where it was fully met). Generally targeted flows occur frequently, but not necessarily consistently over time. They are typically achieved through environmental water deliveries complementing consumptive deliveries and unregulated flows. In recent years, Inter-Valley Transfers (IVT) from the Goulburn River and Murray Bypass flows through the lower Broken and Nine Mile Creeks have contributed significantly to the provision of spring/summer/autumn baseflow.

- Freshes (of 300-450 ML/d to cue fish movement/spawning and mobilise *Azolla*) have been met in most years and partially achieved in others. In winter/spring of 2021, a fresh delivery using environmental water was not required due to low *Azolla* levels and was also not achieved through unregulated or consumptive water deliveries. Environmental water deliveries have contributed significantly to the provision of historic spring freshes. In some years, freshes occur, but later than that recommended in flow studies due to the timing of operational deliveries.

Historic annual environmental water deliveries to the lower Broken and Nine Mile Creeks to achieve these flow components have ranged from 30,000 ML to 43,000 ML.

Table 5: Hydrological achievement over time

Flow component	Hydrological achievement of flow components over time									
	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22*
Winter baseflow (40ML/d)	O/U	U	E/O/U	E/U	U	E/U	E/U	E/U	E/U	E/U
Spring/summer/autumn baseflow (200-450 ML/d)	E/O/U	E/O/U	E/O	E/O/U	E/O/U	E/O/U	E/O/U	E/O/U	E/O/U	E/U
Freshes (1 to 3 events of 300-450 ML/d for 1-2 weeks, Jul-Sep)	E/O/U	E/O/U	E/O	E/O/U	U	E/U	E/U	E/O/U	E/O/U	Not required or achieved through any deliveries

* Described further below

Key:

	No significant part of the flow component achieved
	Flow component partially achieved
	Flow component has been completely achieved, i.e. complete duration, frequency and magnitude was achieved

E	Managed environmental water release
O	Consumptive water en route/other managed flow
U	Unregulated flows
X	Unknown

End of previous season (2020-21) flow conditions and components delivered

Continuation of the La Niña event into 2021 resulted in late January and early February rainfall, which helped increase storage inflows and reduce losses. By mid February, both the Goulburn and Murray systems had an allocation of 100% for High Reliability Water Shares.

Following submission of the previous SWP, IVT and Murray Bypass deliveries continued to dominate flow in the lower Broken Creek system until the end of May 2021. This meant the flow target was mostly exceeded for the remainder of the 2020-21 season (Figure 3).

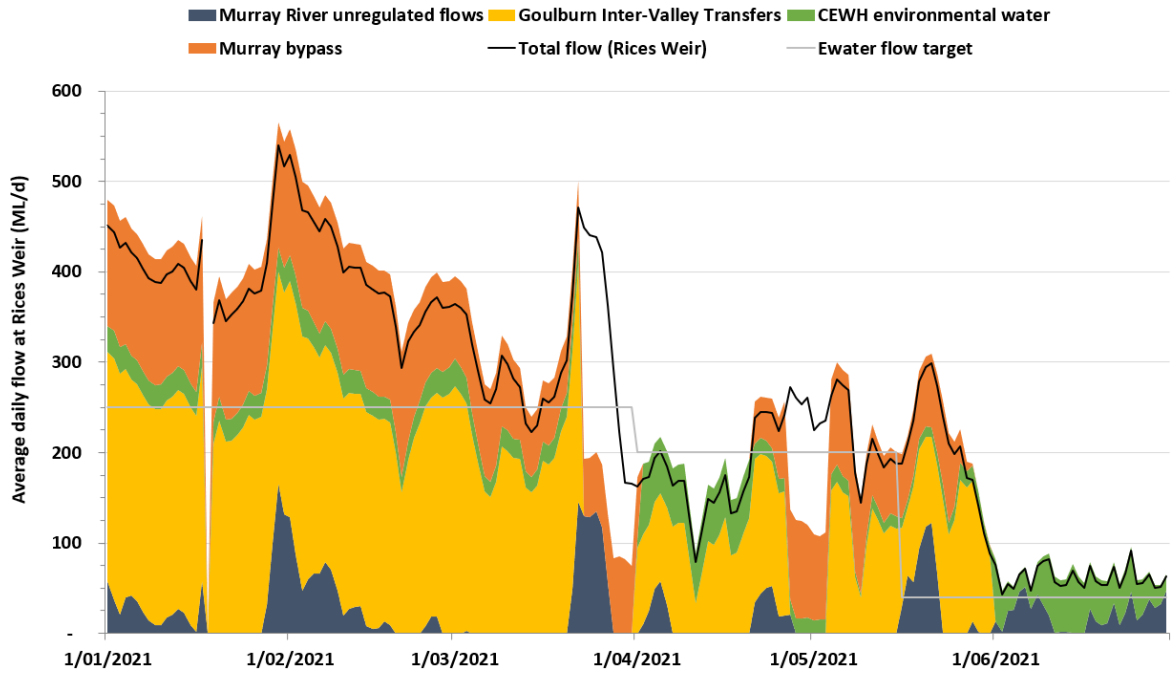

Figure 3: Flow at Rices Weir compared to target flow at the end of last season

The extended period of consistently high flow (over 400 ML/d for 11 weeks from December 2020 to mid February 2021) resulted in backwater build up and very high water levels across the system (Figure 4). Field observations in early March found water levels at the top of the bank in many locations and overbank at one section of Nine Mile Creek (in the vicinity of Kelly's Road Bridge) leading to shallow inundation of riparian wetlands and depressions (Figure 5).

Figure 4: Very high water levels on Nine Mile Creek, March 2021

Figure 5: Inundation of riparian wetlands along Nine Mile Creek, March 2021

In April 2021, the delivery of an autumn fresh in the lower Goulburn River provided an opportunity to reduce IVT deliveries in the lower Broken system by re-diverting the IVT along the lower Goulburn. This resulted in flow reducing to 200-300 ML/d at Rices Weir. The reduced flow corresponded to a reduced water level across most of the system, except for reach 1, which experienced an increase in water level upstream of Numurkah. This was due to the Numurkah Weir pool operating level being increased to help harvest additional water to meet increasing irrigation demand. The increase in water level upstream of the Numurkah Weir resulted in inundation of additional riparian wetlands that had remained dry under the high summer flows (Figure 6).

Figure 6: Inundation of riparian wetlands upstream of Numurkah (left, March vs right, April 2021)

Bank erosion was observed in some locations following the drawdown of water levels from April onwards (Figure 7) and this was confirmed through a 12-month monitoring project over the 2020-21 season. Further details are provided ahead in Table 11.

The long period of higher flow resulted in very low Azolla levels across the system, which substantially reduced the associated water quality risks.

Figure 7: Examples of recent bank erosion on Nine Mile Creek (April 2021)

Over June 2021, the winter baseflow target was met at Rices Weir through dewatering sections of the channel system (EGM and 7/3 channel) in preparation for maintenance works within the Murray Valley and Shepparton Irrigation Districts. Inflows from dewatering the EGM had ceased by 8 June, while inflows from the 7/3 channel had ceased by 23 June. In line with the FLOWS study recommendations, dewatering of the 7/3 channel and EGM channel was prioritised to reach 1 of the lower Broken Creek once flows became inadequate to supply both reach 1 and 2 (Nine Mile Creek). Fish ladders were closed by 23 June to retain as much water (and habitat) as possible in the weir pools. Closing the fishways over winter was expected to have minimal impact on native fish, which have limited movement over the colder months.

From 10 June, unregulated inflows from upper Broken Creek provided 2-3 ML/d to lower Broken Creek following winter rainfall (Figure 8). These flows contributed dissolved organic carbon (blackwater) to the system, which helps support the aquatic foodweb. Due to the cooler winter temperatures, the blackwater did not negatively impact dissolved oxygen levels. Dissolved oxygen levels at Rices Weir over this period remained above 6.5 mg/L.

Figure 8: Blackwater entering lower Broken Creek from upper Broken Creek, winter 2021

The reduced flow (and potential timing of fish ladder closure) resulted in Katandra Weir water level reducing by approximately 50cm on 22 June (see below). This exceeded the recommended drawdown maximum of 30cm in the irrigation off-season. Field observations two weeks later showed water level had recovered to recommended drawdown levels.

Above - 22 June 2021

Above - 6 July 2021 (recommended drawdown level)

Left – December 2020 (example of Full Supply Level)

Figure 9: Katandra Weir pool drawdown levels, winter 2021 compared to Full Supply Level

Current season (2021-22) flow conditions

The La Niña conditions resulted in average to above average rainfall across eastern Victoria for much of winter and spring (BOM 2022) (Figure 10). The wet catchments contributed inflows to Murray and Goulburn storages consistently over winter/spring 2021, with lower irrigation demand over this period frequently met by higher tributary flows and enabling the volume of water in storage to increase (GMW Resource Manager Announcements, July to November 2021). Storages were close to full at the start of 2022 (Table 6).

Available storage volumes resulted in an opening allocation of 33 percent of High Reliability Water Shares (HRWS) in the Goulburn system and 21 percent in the Murray system. The Goulburn increased to 100 percent HRWS at the start of October, while the Murray was at 100 percent by mid October 2021 (Resource Manager Northern Victoria website).

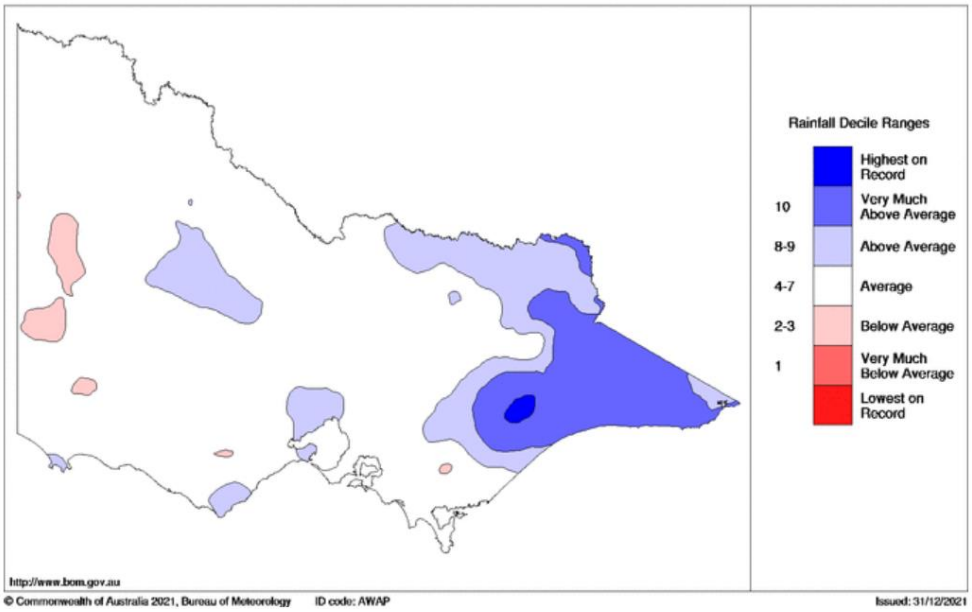

Figure 10: Victorian rainfall deciles 1 July-31 December 2021

Table 6: Water levels at key storages

Storage	September 2021	January 2022
Dartmouth Dam	79%	91%
Hume Dam	97%	99%
Lake Eildon	80%	86%

Source: https://www.g-mwater.com.au/water-resources/catchments/storage-levels

The combination of strong allocations and carry-over of environmental water provided adequate resources for the delivery of priority watering actions. Unlike previous years, the wet conditions resulted in IVT and Murray bypass flows not commencing in the lower Broken system in spring or summer of 2021-2022. Achievement of flow targets this season has therefore relied upon water for the environment and unregulated inflows. However, the ability to use these flows has been inconsistent over the season.

For example, during GMW's winter maintenance period, environmental water could not be delivered from 1-19 July 2021, impacting the provision of winter baseflows and fishway operation. Field observations found many sections of the creek (outside weir pools) had only shallow pools remaining and did not provide functional overwintering habitat (Figure 11). This highlighted the importance of the weir pools as refuge habitat when baseflows are interrupted.

Reach 1 – downstream of Numurkah

Reach 1 – downstream of Katandra Weir

Reach 2 – Central Mundoona Road

Reach 3 – Carlands Bridge (very shallow depth)

Figure 11: Examples of limited instream habitat in the absence of winter baseflows (July 2021)

In terms of unregulated inflows, local winter/spring rainfall was geographically patchy resulting in minimal inflows[3] from the upper Broken Creek catchment (to the south), but the largest inflows since 2016 from the Boosey Creek catchment to the east (Figure 12). Where possible within system constraints, environmental water was delivered in conjunction with these natural inflows to maximise flow variability in the creeks.

[3] 1-8 ML/d from 1 July to 30 November 2021, with flow ceasing at the end of December 2021.

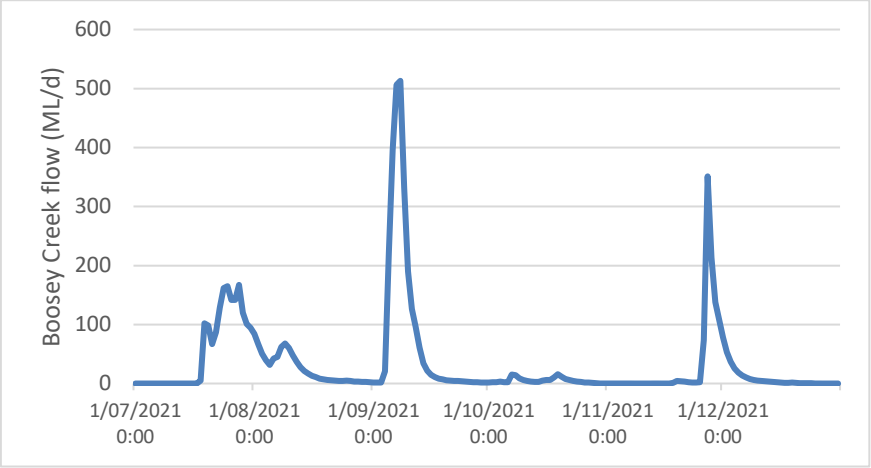

Figure 12: Boosey Creek winter/spring flow 2021

Commencement of environmental water deliveries from the 7/3 channel at Katamatite on the 19th July (once maintenance works were complete) coincided with the start of Boosey Creek unregulated inflows, so that the lower Broken and Nine Mile Creeks had refilled entirely by 3 August (200 ML/d at Rices Weir).

The unusual lack of water-in-transit deliveries heading into summer, posed a potential increased risk of water quality issues (low dissolved oxygen) at Rices Weir. Dissolved oxygen levels at Rices Weir had reduced to less than 4mg/L on four occasions in December 2021 (DO range over these events: 2.95-3.92mg/L) in response to water temperatures of 26 deg C (plus) during the day and persistence of warm water temperatures (24 deg C) at night. Flow rate at Rices Weir during these low DO periods ranged from 207-292 ML/d. Australian native fish and other large aquatic organisms require dissolved oxygen concentrations of at least 2mg/L to survive, but may begin to suffer at levels below 4–5 mg/L. Very low dissolved oxygen conditions may also impact the quality of water within a waterway via the release of sediment bound pollutants such as manganese, iron, phosphorus and ammonium, potentially increasing the concentration of nutrients available to support nuisance and harmful algal blooms.

With higher summer temperatures forecast and the risk of further dissolved oxygen decline at a continuing flow rate of 250 ML/d (in the expected ongoing absence of higher operational deliveries), a decision was made to increase environmental water deliveries as a proactive emergency watering action to reduce the likelihood of very low DO levels at Rices Weir under upcoming hot summer conditions and associated fish deaths (e.g. of threatened Murray cod and golden perch). Increasing the flow rate is the only proactive management action available to reduce the likelihood of low dissolved oxygen under hot summer conditions i.e. the only preventative measure. Travel time to Rices Weir from the EGM is approximately 10 days meaning there is limited ability to respond quickly to water quality decline. The summer baseflow target was therefore increased in advance of any summer heatwaves, to provide the best chance of avoiding very low DO.

A baseflow of 350 ML/d was targeted, which aimed to maintain maximum daytime DO levels above 4 mg/L and minimum DO levels above 2mg/L during the night. Analysis of historic water quality data[4] suggested that during periods of higher water temperatures, this flow rate is adequate for meeting these DO requirements (Figure 13).

Another consideration was the risk of the increased baseflow accelerating bank erosion beyond background levels. A flow target of 350 ML/d is within levels of historic creek operations (around the 90th percentile of summer deliveries prior to the higher flow in recent years from water-in-transit)

[4] 2012/13 to February 2020, excluding the 2016/17 flood year.

(Figure 14) and was not expected to contribute to significant erosion. The potential benefits of the 350 ML/d flow rate (avoiding a fish death event) was therefore considered to outweigh the risk of increased bank erosion under this flow.

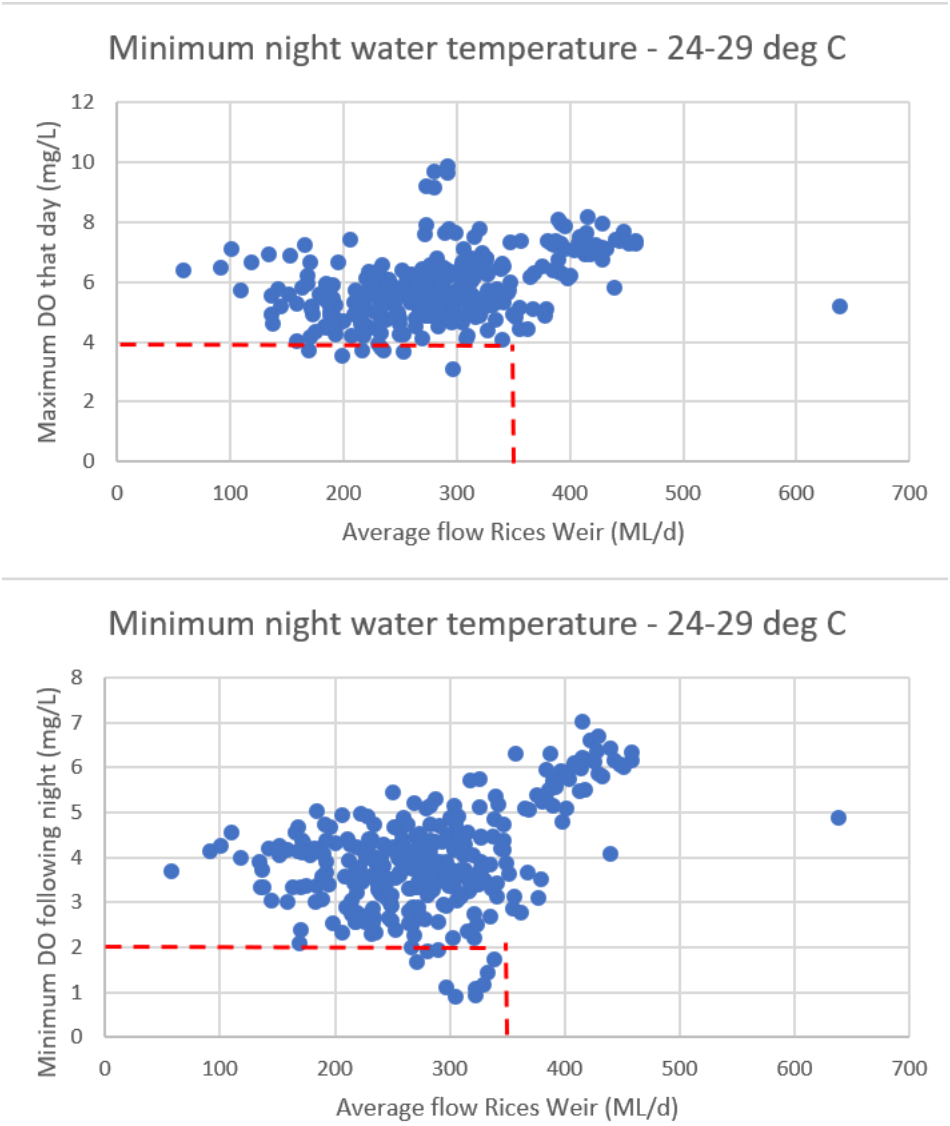

Figure 13: Flow rate providing minimum required DO under higher water temperatures

An emergency watering action therefore commenced on 22 December 2021 following a variation to the Seasonal Watering Plan 2021-22. The water order requested a flow of 350 ML/d at Rices Weir over summer[5], but the amended watering action allowed for an increase up to 450 ML/d to help manage water quality risks if very low DO levels continued at 350 ML/d. Higher deliveries (up to 450 ML/d) would only occur if needed and for short periods to reduce the risk of bank saturation at higher levels and slumping.

[5] This accounted for the unknown timing for commencement of higher operational deliveries (IVT and Murray bypass), so provided availability of the proactive measure over the entirety of the high-risk summer period.

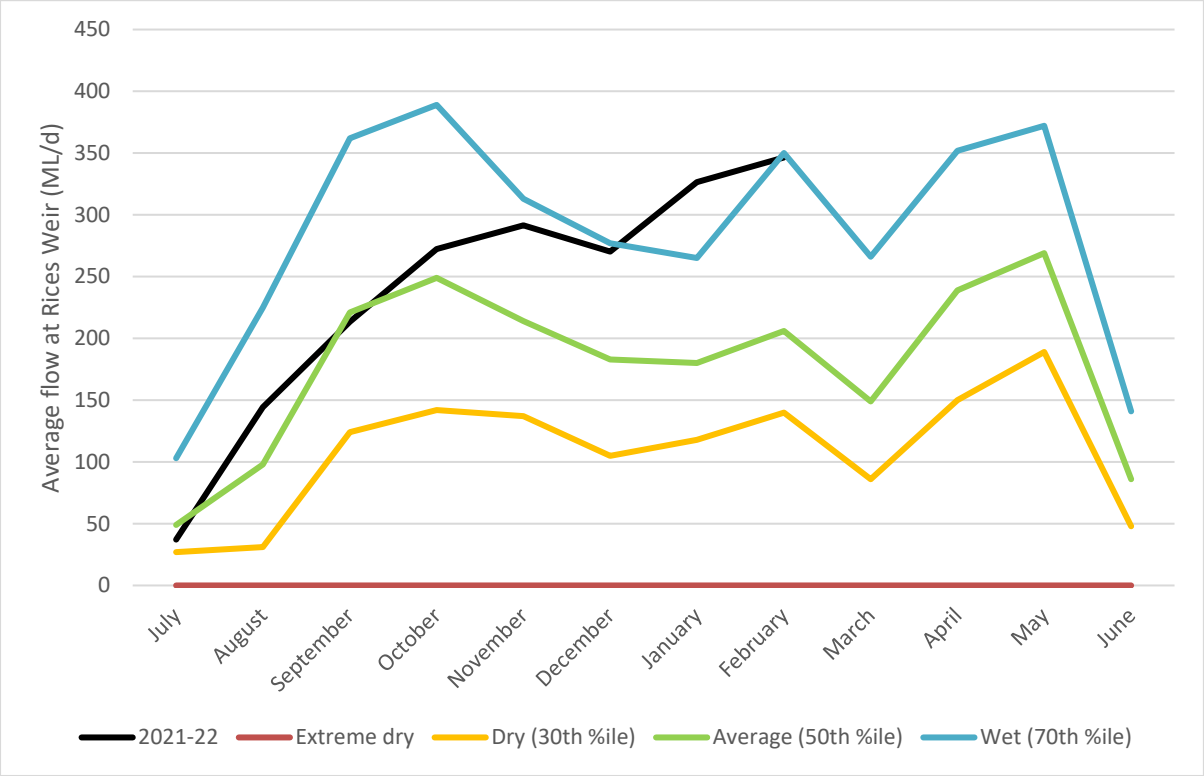

Figure 14: Comparison of average daily flow per month in 2021-22 with historic creek flow record

Note: Flow record from 1965-2009 (Peter Cottingham & Associates and SKM 2011).

Towards the end of December 2021 and into January 2022, a heatwave lead to local temperatures in the high 30's for three days. The flow rate at Rices Weir was still around 250-300 ML/d over this period despite deliveries of 350 ML/d upstream (likely due to increased irrigation demand under the higher temperatures). The subsequent increased water temperatures lead to DO reducing to <4mg/L for five days and instances of ≤2mg/L for 12 hours (Figure 15). These DO levels were lower and for a longer duration than those recorded over 9-11 March 2016 (when native fish were electrofished out of Rices Weir pool by ARI in response to the poor water quality). Field observations were conducted on 1 January 2022 in response to the low DO. This found no evidence of a fish death event, with DO spot measurements ranging between 1.5 and 3.5mg/L near Rices Weir, but increasing to 4.3mg/L at the upstream end of Rices Weir pool (Picola Road). Dissolved oxygen was 7mg/L at Schiers Weir pool further upstream (St James Road). Following discussions with GMW, an additional 50 ML/d was delivered through the EGM on 31 December, to help meet the Rices Weir flow target. The flow target was achieved one week later. The DO response and management implications are discussed ahead (see Environmental Outcomes 2021-22 and Lessons and Implications for 2022-23).

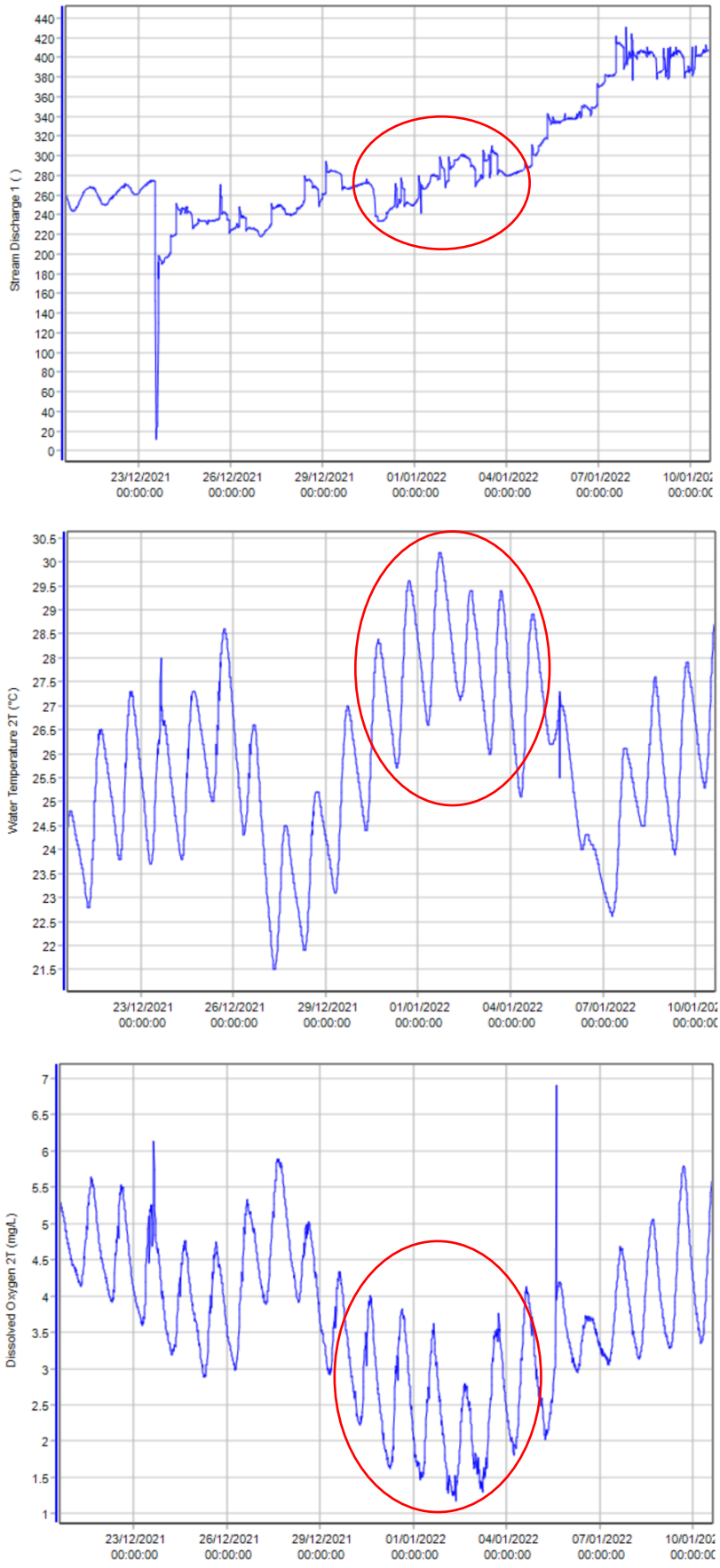

Figure 15: Flow, temperature and DO at Rices Weir (heatwave in red circle)

In late 2021/early 2022, fish ecologists reported large numbers of native fish (threatened silver perch, golden perch and Murray cod) breeding and migrating in the Darling River and mid Murray River. There was evidence that these fish, particularly silver perch, were migrating upstream along the Murray River channel. Fish ecologists proposed that tributaries in the mid Murray reach (including lower Broken Creek) deliver attractant flows to encourage migrating fish to disperse widely throughout the southern connected Basin. The ecologists recommended that delivery of environmental water be maximised from lower Broken Creek to test whether such flows are adequate for cueing silver perch into the creek from the Murray River.

Flow at Rices Weir was planned to be increased to 450 ML/d in early February to provide an attractant flow over one week. An early February date was chosen as discussions with GMW highlighted that increasing flow at Rices Weir from 350 ML/d to 450 ML/d would require all channel outfalls to be running close to maximum capacity, which would require low to medium irrigation demand in the irrigation districts and along the creek itself. Irrigation demand (for subterranean clover) was predicted to peak in late February and through autumn, which would reduce the capacity to deliver environmental water to Rices Weir. They also raised concerns about large volumes of weed in the channel system which had been causing issues with flow delivery that season and may impact the ability to meet the 450 ML/d target flow. The early February date meant the attractant flow was also not competing with March attractant flows planned for the Goulburn River, so would provide the best chance of successful fish migration into lower Broken Creek.

However, another period of high rainfall at the end of January 2022 (Figure 16) resulted in Boosey Creek again increasing in flow, this time peaking at 820 ML/d (Figure 17). Deliveries of environmental water through the 7/3 channel and East Goulburn Main were reduced to allow the natural fresh to pass, before environmental water deliveries were returned to previous levels. Initial expectations that the natural fresh followed by environmental water would be a suitable fish attractant flow (in consultation with fish ecologists), were not met. The natural fresh was associated with hypoxic blackwater (Figure 18/19) and upon attenuation only resulted in a flow peak of around 430 ML/d for two days at Rices Weir. Field observations reported evidence of dead shrimp and stressed small-bodied fish, but no fish deaths along lower Broken Creek. The environmental water delivery on the recession of the natural fresh helped push the poor water quality through the system, while the continued delivery of small volumes of environmental water through the downstream outfalls provided some shandying of the blackwater as it moved through. This meant that dissolved oxygen at Rices Weir experienced only a minor reduction (Figure 20), compared to that experienced further upstream. The fish attractant flow was postponed to late March/early April, subject to capacity constraints from peak autumn irrigation demand.

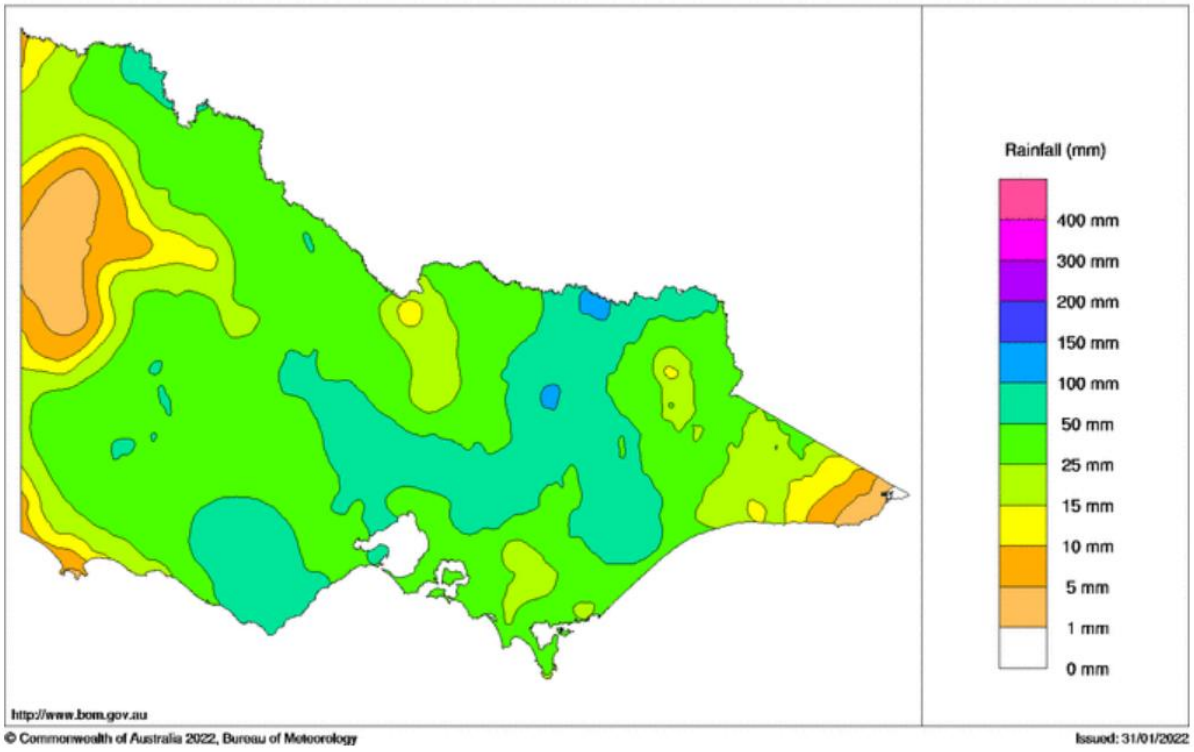

Figure 16: High rainfall in the upper catchment of Boosey Creek in the last week of January 2022

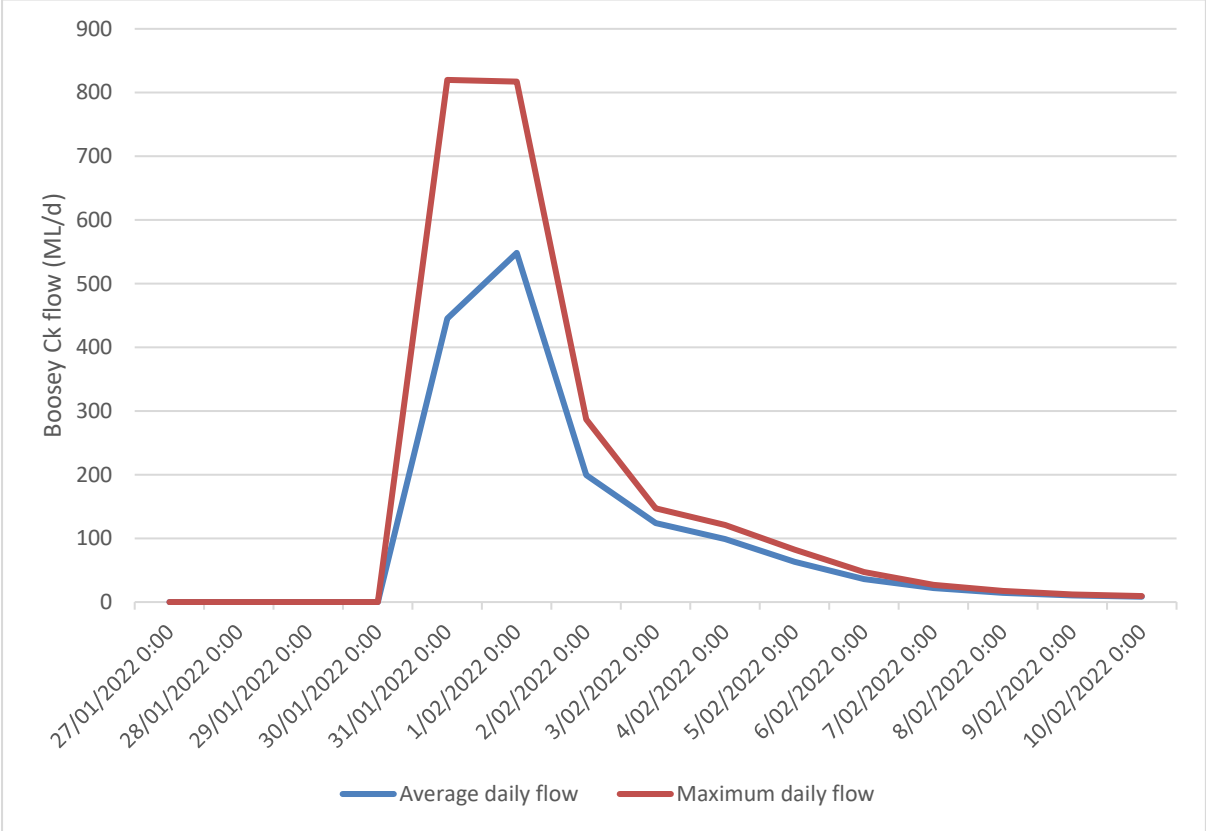

Figure 17: Boosey Creek natural fresh event January/February 2022

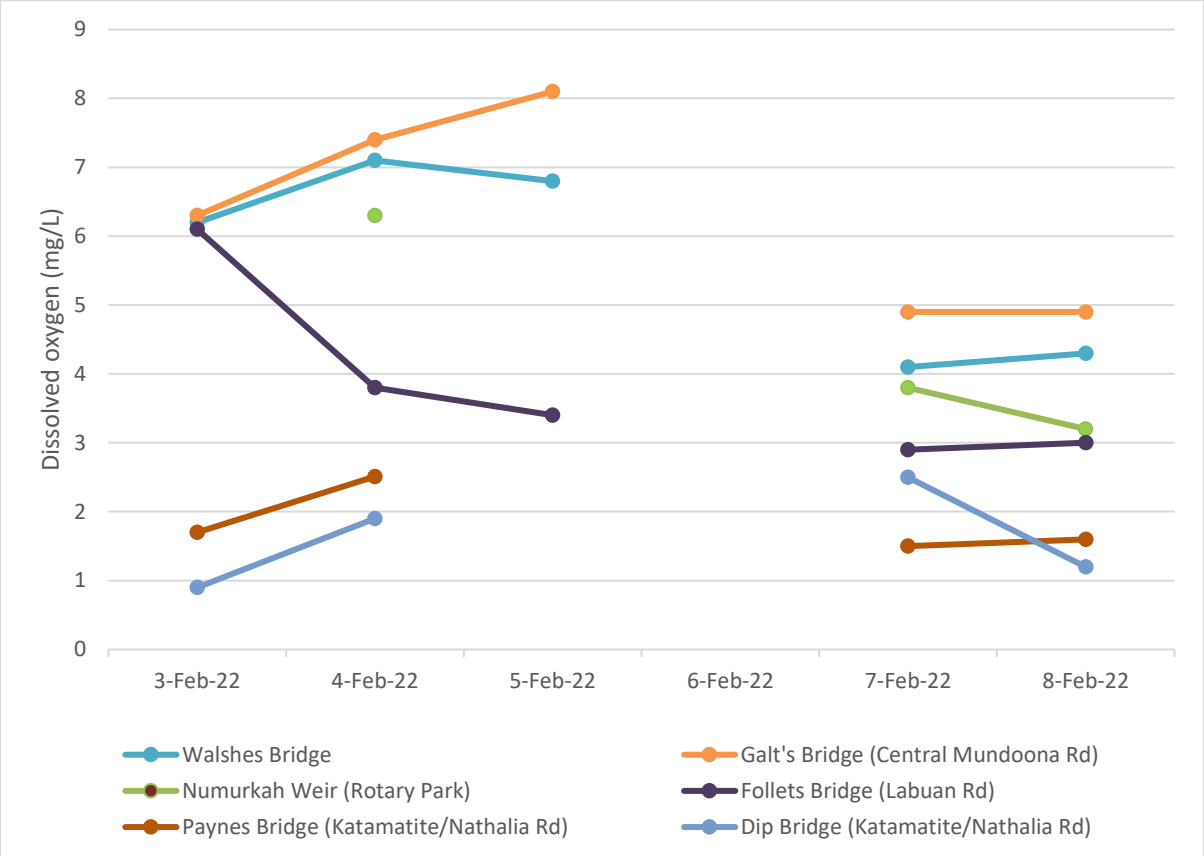

Figure 18: Dissolved oxygen reduction upstream of Nathalia from Boosey Creek blackwater

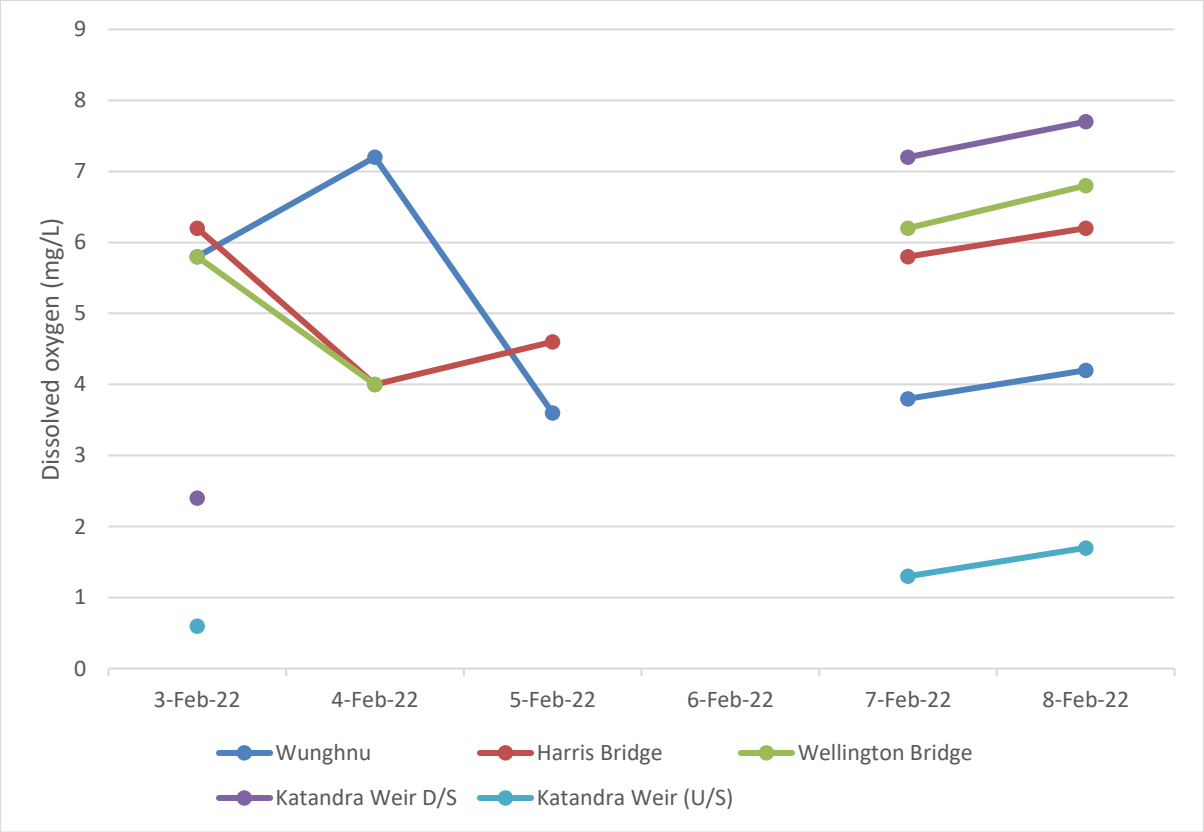

Figure 19: Dissolved oxygen reduction in Nine Mile Creek from Boosey Creek blackwater

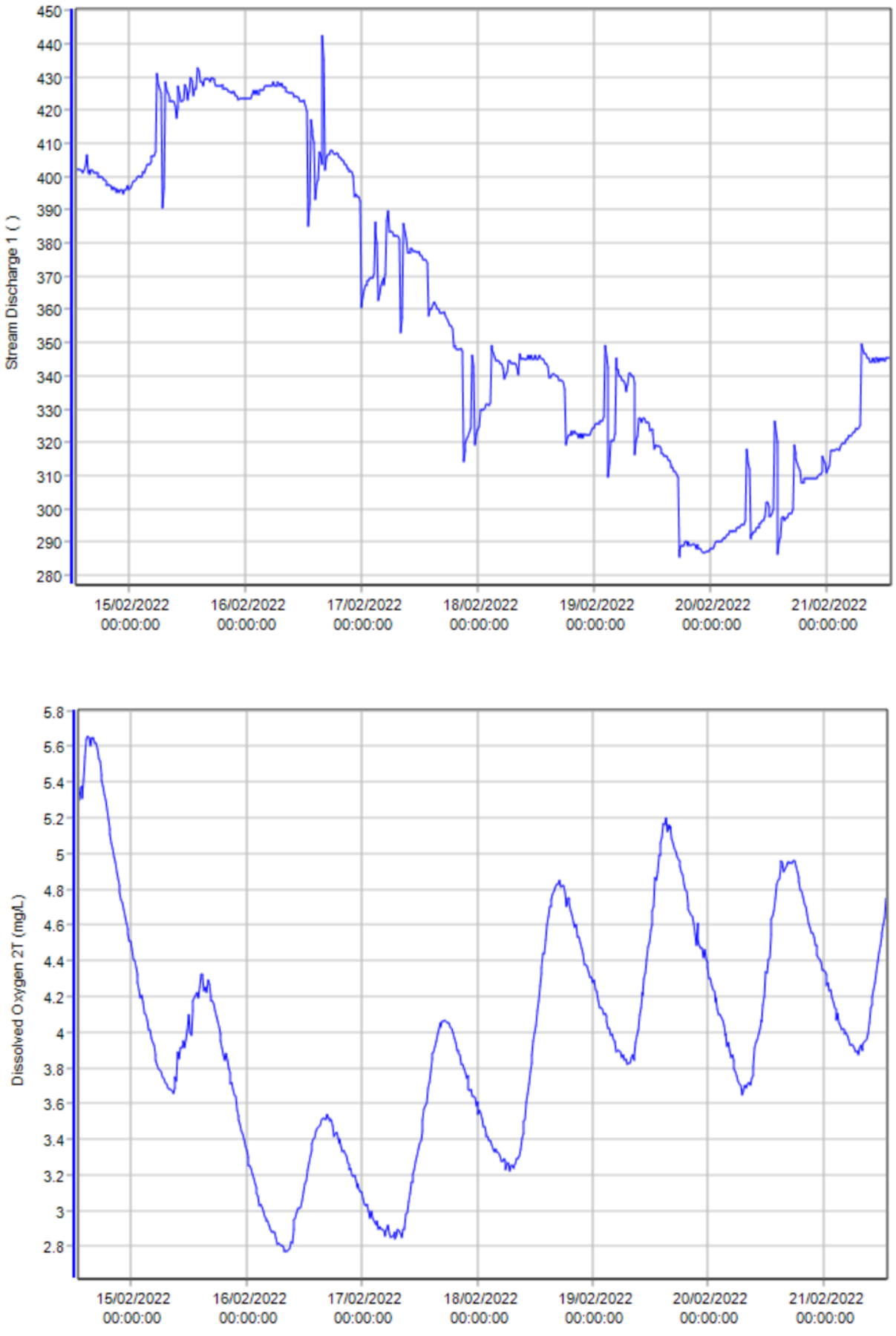

Figure 20: Rices Weir flow and dissolved oxygen in response to Boosey Creek blackwater

Current season (2021-22) flow components delivered

Based on the 2016 FLOWS study, specific flow components have been recommended for each reach of the lower Broken Creek system. An audit against the delivery of the planned flow components in 2021-22 has been conducted for each reach, as shown in the below tables and figures.

The assessment highlights the following:

- Winter baseflow targets were only partially achieved across all reaches for the fourth year in a row due to maintenance works. Opportunities exist around coordinating GMW maintenance works where possible so the 7/3 channel and EGM are not concurrently unavailable.
- A managed spring fresh delivery was not required in September due to ongoing low *Azolla* levels and a fresh having been delivered the year before. This meant a fresh to encourage native fish spawning (of long-lived, large-bodied species) was also not essential this year.
- In reach 1 of lower Broken Creek, there may be opportunities to improve the timing of fish ladder and gate closure at Katandra Weir under low flow conditions to prevent large drawdown of the weir pool as observed in June 2021 (Figure 9).
- Achieving the emergency watering flow target (350 ML/d) at Rices Weir (reach 4) was problematic in late December, possibly due to increased irrigation demand during the hotter weather. Discussions with GMW will identify opportunities to improve achievement of such flow targets e.g. accounting for potential irrigation demand along the system.

Note: some flow components may be better described as operational recommendations e.g. management of weir pool levels and flow diversion splits downstream of weirs. However, these have been included with the other flow components for completeness of the assessment.

Table 7: Audit of flow component delivery in reach 1 of lower Broken Creek (2021-22)

Section of reach	Flow component	Achieved in 2020-21	Explanation
1a – Broken Ck upstream of Katandra Weir pool	Full Supply Level in Katandra Weir (Dec-Mar) for platypus. Drawdown does not exceed 30cm in irrigation off-season.	Partial achievement	Due to Covid restrictions limiting field work, Katandra Weir pool was observed once over the winter period (6 July 2021). This corresponded with the lowest period of water availability to the creek (2-3 ML/d unregulated inflows from upper Broken Ck in the first half of July). The weir pool level had reduced by approx. 30cm on this occasion (Figure 9). Field observations in January revealed Katandra Weir pool was at Full Supply Level. However, this level is expected to have temporarily lowered when deliveries were reduced in preparation for the Boosey Creek natural fresh in February 2022.
1b – Broken Ck downstream of Katandra Weir to Nine Mile Ck confluence	Winter baseflow (20-40 ML/d)	Not achieved in first half of July 2020. Achieved over remainder of year (to date).	During the first half of July 2020, only unregulated inflows from upper Broken Creek were being diverted into reach 1b from Katandra Weir pool. These flows (2-3 ML/d) were substantially less than the target 20 ML/d.
	Fresh in September (100-200 ML/d, for 1-2 weeks at least to connect. But noting 120 ML/d capacity constraint in this reach).*	Not required or achieved in September	A managed fresh was not required this spring due to continuation of very low *Azolla* levels and a fresh being delivered the previous year. Flow data is not available for this reach, however, Boosey Creek unregulated inflows peaked at 500 ML/d in September, which is expected to have provided a fresh in reach 1b as the flow pulse moved through the system. Flow in reach 1b was approximately 100 ML/d over January and February in conjunction with delivery of the emergency watering flow target.
	Avoid constant high flows, especially in summer and autumn	Achieved (assumed)	Flow data is unavailable for this reach, so it is unknown what degree of flow variation has occurred over 2021-22. Water-in-transit deliveries (IVT/Murray bypass) had not occurred at the time of writing, so constant high flows were unlikely to have occurred up until mid-January 2022.
	Split flow between reach 1 and 2 unless flows are too low (<10ML/d), in which case prioritise flows to lower Broken Creek due to higher habitat and submerged vegetation values being present in this reach.	Achieved (to date)	Flows were prioritised to reach 1 in the first half of July when <10 ML/d was available. Once GMW maintenance works were completed, flows were split between reach 1 and 2 from mid-July 2021 onwards.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary) and a follow-up fresh in August/September to inundate littoral vegetation. Monitoring in mid-July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

Table 8: Audit of flow component delivery in reach 2 – Nine Mile Creek (2021-22)

Flow component	Achieved in 2020-21	Explanation
Winter baseflow (20-40 ML/d)	Not achieved in first half of July 2021. Achieved over remainder of year (to date).	When regulated deliveries became too low to adequately supply both lower Broken Ck (reach 1) and Nine Mile Creek (reach 2) downstream of Katandra Weir (due to GMW maintenance works), the Nine Mile Creek regulator and fish ladder was closed. Deliveries and fishway operation re-commenced on Nine Mile Creek on 19 July 2021.
Fresh in September (100-200 ML/d, for 1-2 weeks at least to connect).*	Not required or achieved in September	A managed fresh was not required this spring due to continuation of very low *Azolla* levels and a fresh being delivered the previous year. Flow data is not available for this reach, however, Boosey Creek unregulated inflows peaked at 500 ML/d in September, which is expected to have provided a fresh in reach 2 as the flow pulse moved through the system. Flow in reach 2 was approximately 200 ML/d over January and February in conjunction with delivery of the emergency watering flow target.
Avoid constant high flows, especially in summer and autumn	Achieved (assumed)	Flow data is unavailable for this reach, so it is unknown what degree of flow variation has occurred over 2021-22. Water-in-transit deliveries (IVT/Murray bypass) had not occurred at the time of writing, so constant high flows were unlikely to have occurred up until mid-January 2022, especially given the pulses of unregulated inflows that were passed through the upper reaches over winter and spring.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary) and a follow-up fresh in August/September to inundate littoral vegetation. Monitoring in mid-July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

Table 9: Audit of flow component delivery in reach 3 and 4 of lower Broken Creek (2021-22)

Flow component	Achieved in 2020-21	Explanation
Winter baseflow (40 ML/d)	Partial achievement (achieved 48% of winter period). Achieved over remainder of year (to date).	Environmental water could not be delivered from late June to 19 July 2021 due to GMW maintenance works. Flow at Rices Weir in July was a combination of unregulated inflows and channel dewatering. Consequently, the flow target at Rices Weir was not achieved from 10 July to 2 August 2021. Flow ranged from 18-38 ML/d over this period.
Fresh in September (300-450 ML/d, for 1-2 weeks).*	Not required or achieved in September	A managed fresh was not required this spring due to continuation of very low *Azolla* levels and a fresh being delivered the previous year. Unregulated inflows in early October, early November, early December 2021 and February 2022 provided multiple fresh events.
Spring/summer/autumn baseflow (200-450 ML/d, July to May).	Partial achievement (achieved 68% of spring period, 42% of summer period)	The spring/summer baseflow target has been achieved half of the time through environmental water deliveries and unregulated inflows. Fluctuations have occurred as a result of changes in irrigation demand (pumping) and managing rain rejection events.
Avoid constant high flows, especially in summer and autumn	Achieved (to date)	Flow at Rices Weir has varied considerably since 1 July 2021. This is in response to changing flow targets and variable unregulated inflows. However, the large number of weirs (particularly in reach 4) means flow variability in this part of the system does not equate to variable water levels. Instead, water levels tend to remain relatively constant from mid-August to mid-May.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to flush *Azolla* (if necessary) and a follow-up fresh in August/September/October to trigger fish movement. Monitoring in mid-July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

The contribution of different water sources to the flow in lower Broken Creek at Rices Weir over 2021-22, compared to the flow target, is shown in Figure 21.

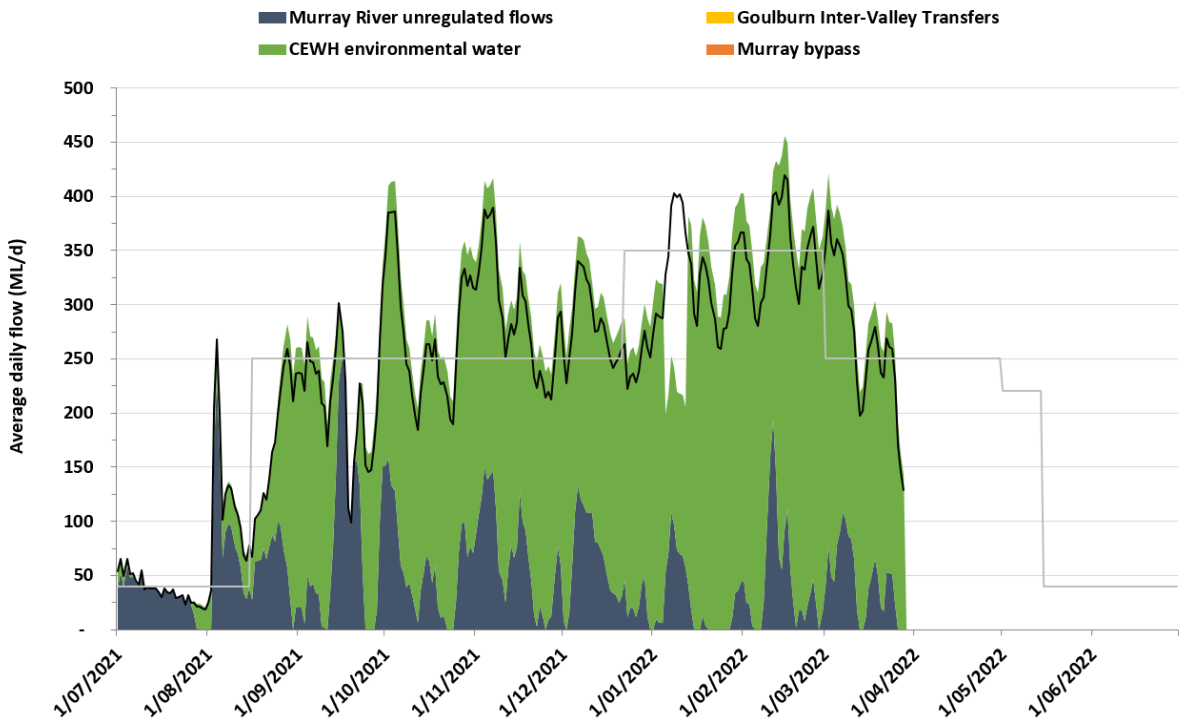

Figure 21: Comparison of planned flow against actual flow at Rices Weir (reach 4)

Environmental outcomes 2021-22

Delivery of environmental water to the lower Broken and Nine Mile Creeks in 2021-22, in conjunction with unregulated inflows, resulted in the following environmental outcomes (Table 10). These have been identified based on field observations in conjunction with scientific, flow and water quality monitoring at several locations.

Table 10: Environmental outcomes from environmental water delivery along the lower Broken and Nine Mile Creeks 2021-22

Ecological value	Environmental outcomes achieved in 2021-22
Native fish and other native aquatic animals	Closing the fish ladders during the GMW maintenance period (when winter baseflows could not be provided) retained as much water and habitat as possible within the weir pools for native fish, platypus, Rakali and turtles. This was very important for survival of aquatic fauna, as elsewhere in the system instream habitat was severely compromised (Figure 11). Outside the maintenance period, fish ladders remained open and provided longitudinal connectivity through the system (especially important during the period of warmer water temperatures and increased fish movement over spring to autumn). Delivery of environmental water in conjunction with unregulated inflows (where possible within system constraints), maximised the instream habitat provision that could be achieved through the environmental water delivery and the size of natural fresh events. This enabled the system to re-fill quicker following maintenance works and provided a greater variety of hydraulic habitat conditions over time (particularly in the flowing sections of the creek). The natural fresh event in late October/early November, coincided with water temperatures increasing over 18 deg C, which would have provided a flow cue to encourage native fish movement and spawning e.g. Murray cod and golden perch.

Ecological value	Environmental outcomes achieved in 2021-22
	Continuation of environmental water deliveries following the fresh events, maximised the availability of instream habitat for native fauna e.g. inundation of large woody debris and littoral vegetation. This is important for successful recruitment of native fish post spawning. A fish survey in autumn 2021 found the native fish community has been stable in recent years (since 2016) (Howson & Lloyd 2021), suggesting environmental water deliveries over this period have been beneficial for supporting native fish species, including threatened Murray cod and golden perch.
Native vegetation	Compared to the previous year, when environmental water could also not be delivered in winter due to maintenance work, the winter flow in 2021 was much lower (Figure 22) and resulted in less coverage of instream aquatic macrophytes such as *Vallisneria* beds. However, in most cases the majority of *Vallisneria* beds observed still had some inundation (Figure 22). Provision of spring baseflows (250 ML/d) maintained the low *Azolla* levels. *Azolla* levels have remained very low across the system since the start of August 2020. The water depth covering instream macrophytes improved, in line with recommendations from the FLOWS study (>50cm). This supported the spring growth of new aquatic plantings (from winter 2021) (Figure 24). The spring fresh events successfully provided soil moisture to developing littoral vegetation and inundated vegetation on instream benches (Figure 25).
Water quality	Delivery of the emergency watering action from late December to the end of February has helped maintain suitable DO levels. A low DO event in late December/early January occurred at Rices Weir following increased water temperatures and flow of 250-300 ML/d (below the intended 350 ML/d target). In contrast, DO had recovered in mid-January once flow had increased (ave. 338 ML/d over the week) despite similar water temperatures (Figure 26). The resultant DO levels (5mg/L during the day and 3mg/L at night) met water quality (DO) targets and reduced the risk of hypoxic stress on native aquatic fauna.

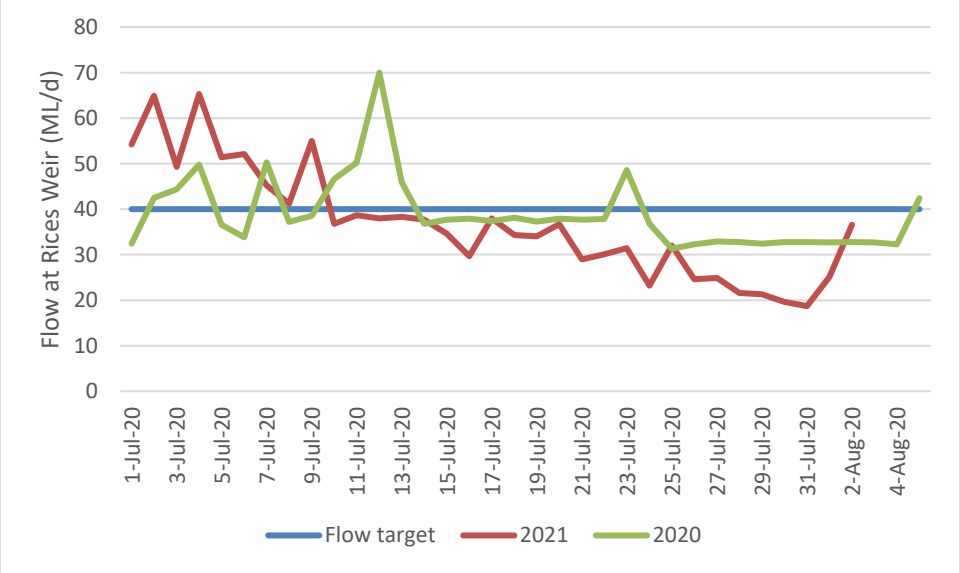

Figure 22: Comparison between winter flow at Rices Weir (reach 4) – 2020 vs 2021

Reach 1 (upstream end) – Larissa Road

Reach 2 – Watters Road

Reach 1 (downstream end) – Walshes Bridge Road

Reach 1 (downstream end) – Walshes Bridge Road

Figure 23: Shallow inundation of Vallisneria beds in remnant pools, July 2021

Figure 24: Growth of recently planted water ribbons (Cycnogeton procerum), November 2021

Reach 2 – Nine Mile Creek

Reach 3 – lower Broken Creek

Figure 25: Residual soil moisture within the littoral zone post spring fresh, November 2021

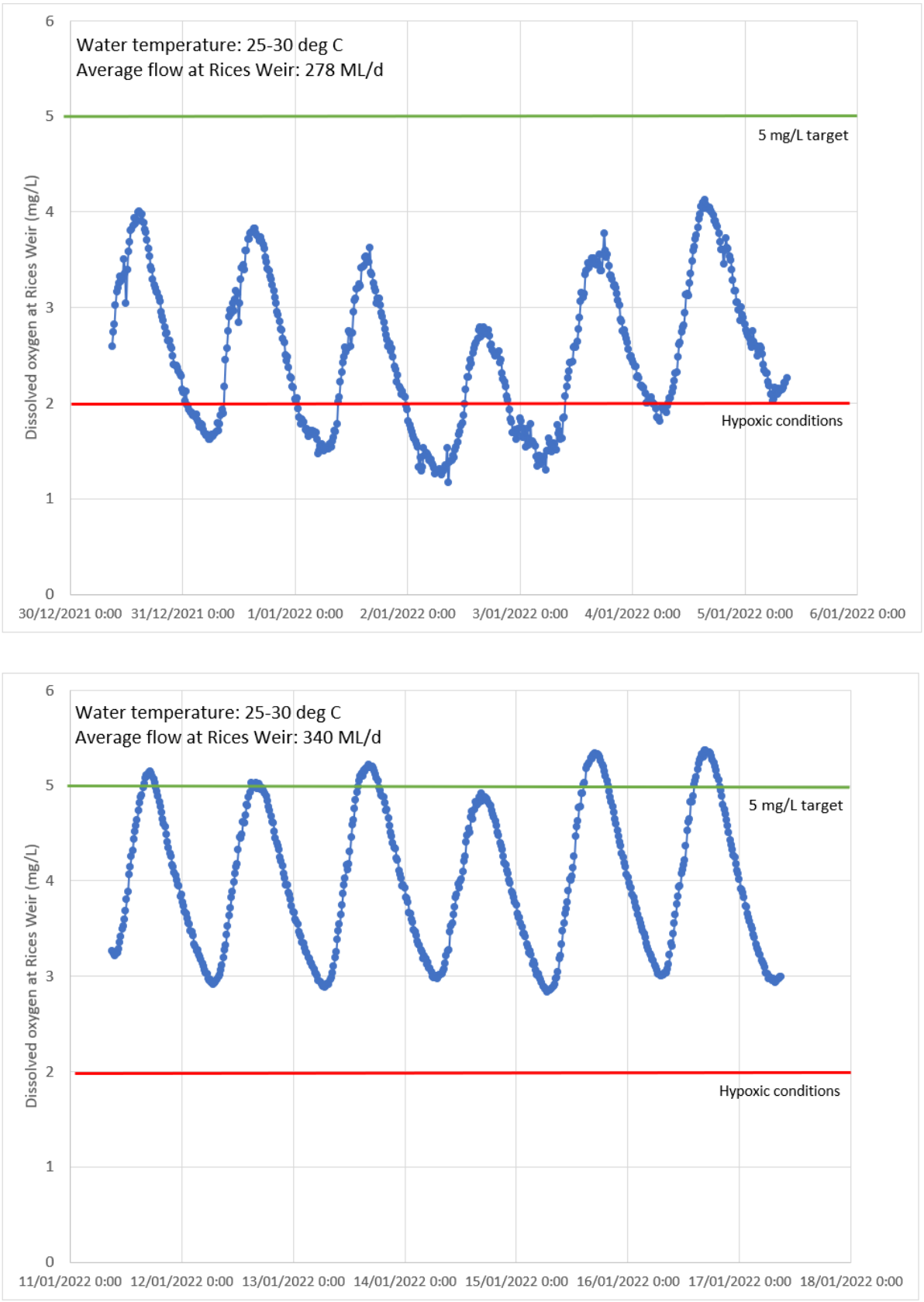

Figure 26: Dissolved oxygen at Rices Weir before (above) and after (below) emergency watering action

Ecological condition

There is limited active monitoring of the lower Broken Creek systems ecological condition. Continual water quality and flow monitoring along various parts of the creek inform operational management and provide information on environmental water delivery and effects on water quality. However, with no dedicated annual ecological monitoring program, knowledge on ecological condition is based on historic studies and a small number of recent investigations. Some monitoring of bank condition changes (erosion, deposition, vegetation) is planned to occur over the next three years under the Goulburn to Murray Trade Rule Review monitoring program. This will commence in winter 2022.

The ecological condition of the system is summarised below.

Table 11: Current ecological condition and trajectory for the lower Broken and Nine Mile Creeks

Ecological value	Condition summary	Expected trajectory
Geomorphology	Highly modified following European settlement through the construction of weirs, floodplain levees, dredging/re-alignments of channels and removal of in-stream habitat including snags (Jacobs 2019). Flow regulation and weirs have contributed to bank erosion, channel widening and shallowing over many decades. The poor condition of the creek banks (i.e. deep notches with overhanging ledges) suggests erosion from historic creek operations is yet to be fully realised. The introduction of consistent high flow during the irrigation season in recent years from increased water-in-transit deliveries (IVT/Murray bypass) may be accelerating the erosion process. While some monitored sites showed little evidence of change, other sites showed extensive, deep areas of erosion over the 12-month period from winter 2020 to winter 2021 (Sutton et al. 2021). Vegetation clearing, the supply of irrigation water combined with irrigated drainage runoff is likely to have increased the supply of fine sediments to the creeks (Jacobs 2019). Large accumulations of silt are evident throughout the system.	With continued management as a conduit for irrigation water, it is expected that the creeks will continue to experience ongoing channel adjustments, with erosion of straighter sections that have historically been dredged and deposition of sediments in dredged pools and weirs (Jacobs 2019).
Vegetation	The 2004 Index of Stream Condition (ISC) assessed the riparian condition as average to good, with a mature overstorey (often regrowth) but degraded understorey (reduced structural complexity, reduced species richness, little or no recruitment and an understorey of non-native species). The degraded understorey is attributed to past and present stock grazing pressures and timber removal for firewood (Jacobs 2019). The littoral zone is restricted to a narrow band of perennial tufted graminoids (e.g. grasses, rushes and sedges) that reflect the constant water level during the irrigation season. Instream vegetation reflects the regulated flow regime – robust perennial species adapted to permanent or near permanent inundation and low flow velocity e.g. *Typha* and *Vallisneria*. Carp are expected to have also degraded instream vegetation.	Assumed to be stable due to ongoing regulation and riparian land uses.
Macroinvertebrates	Macroinvertebrate community dominated by lowland taxa that are generally tolerant of poor water quality conditions. The abundance and diversity of macroinvertebrates is low throughout the system, but especially low downstream of Numurkah. The macroinvertebrate fauna is expected to be adversely affected by poor habitat quality and anthropogenic pollutants (Jacobs 2019).	Assumed to be stable
Fish	In total, nine native and six exotic species have been recorded in lower Broken Creek. Katandra Weir in reach 1	Stable (diversity, distribution and abundance similar between 2016

Ecological value	Condition summary	Expected trajectory
	recorded the highest diversity of native fish in 2021. Most native species tend to be patchily distributed along the creek, with the highest abundance of most species occurring at the most downstream weir pool sites (Reach 4). Murray cod, golden perch, Murray-Darling rainbowfish and Australian smelt are the most common native fish (Howson & Lloyd 2021). However, overall fish populations are dominated by non-native species; common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and gambusia (*Gambusia holbrooki*). Of the larger bodied species, Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua*) are regularly stocked into Broken Creek in large numbers. While there is some evidence of local spawning and recruitment for Murray cod (Jones et al. 2017), stocking is also likely to play a role in maintaining the relatively stable population numbers of these two species. Notably, neither species is detected regularly at sites in Reach 3 (i.e. between Nathalia and Numurkah, including the Numurkah weir pool), suggesting habitat quality in this reach is particularly poor. There have also been a number of fish kills in Broken Creek over the years, the most recent being attributed to a lack of dissolved oxygen during periods of proliferation of the floating macrophyte *Azolla* (Jones et al. 2017).	and 2021) (Howson & Lloyd 2021).
Water quality	Suspended sediment (turbidity) is high, likely to be attributable to carp, catchment and bank erosion. Water quality data shows the creek also has high levels of nutrients. De-oxygenation, especially over the warmer months and in response to decaying *Azolla* accumulations, is a major issue. Sediment chemistry indicates there is input of pollutants from the catchment and there is probably release of accumulated nutrients from the sediment to the water column during low oxygen conditions, that further fuels nutrient enrichment (Jacobs 2019).	Improving for DO/*Azolla* due to environmental water deliveries. Assumed to be stable for other water quality parameters.

Recent observations from the community and local anglers suggests local fish populations have improved:

"I can confidently say it's been the best golden perch fishing I've enjoyed over spring 2021 since I first started fishing the Broken Creek about 20 years ago….including good sized Perch in excess of 6 pound (2.7kg), which are large fish for the creek. At least 1 or 2 good sized fish have been caught each trip. Some bycatch Murray cod have been caught too. I've also managed a couple of silver perch below Nathalia which are few and far between, including one estimated to be 3 pound (1.4kg). Carp have been present in reasonable but not large numbers which is good".

"We've been catching good sized golden perch near Nathalia (around 40cm)".

"I have observed that in the lower sections of the creek (i.e. downstream of Nathalia), there appears to be an increasing Murray cod population, including fish across all class sizes, with fairly low numbers of golden perch (and mainly mature fish). The golden perch seem to be present in higher numbers above Nathalia (e.g. between Kempster's Bridge and Nathalia) and immediately downstream of Nathalia (as far down as Oakes Road). European carp numbers over the last two years also appear to be significantly down on previous years. It's also been good to see the odd good sized silver perch appear the last three years or so".

Dedicated ongoing ecological monitoring is required to determine the effectiveness of environmental water management and complementary works to inform future management of the system.

Shared benefits 2021-22

A review of the shared benefits associated with delivery of water for the environment in the lower Broken Creek and Nine Mile Creek over 2021-22 is provided below.

Table 12: Shared benefits from environmental water delivery along the lower Broken and Nine Mile Creeks 2021-22

Shared benefit	Beneficiary	Shared benefits in 2021-22
Cultural	Yorta Yorta Traditional Owners	During consultation with Yorta Yorta, specific cultural shared benefits were not identified from environmental water deliveries to the lower Broken and Nine Mile Creeks. However, environmental water deliveries align with their values of caring for country.
Amenity	General community, adjacent landholders, visitors	Baseflows prevented water quality problems (e.g. diluting blackwater from unregulated inflows in reach 1, preventing large *Azolla* accumulations and reducing the frequency of stagnant/low DO water in reach 4). The flow promoted visual waterway productivity and biodiversity e.g. flowering aquatic plants, waterbird foraging.
Recreation	Local residents, visitors, anglers, game hunters, kayakers and canoers.	Baseflows ensured water was available almost year-round for recreational activities. Spring and summer baseflows provided optimum conditions for recreation along lower Broken Creek as warmer weather developed, with many observed fishing and camping along the creek, particularly over the holiday periods. The emergency watering action over summer helped maintain suitable water quality to support native fish populations, including popular angling species.
Economic	Consumptive water users – GMW irrigators and diverters, Goulburn Valley Water (GVW) customers.	Environmental water deliveries have continued to promote good water quality for local irrigators and D&S use. *Azolla* levels have remained very low.

Figure 27: A family having fun on lower Broken Creek, Numurkah January 2022

Lessons and implications for 2022-23

Observations and monitoring along the lower Broken Creek system over 2021-22 highlighted the following points that will inform future watering and management actions:

- Many macrophyte beds are located within the main waterway channel and therefore, under very restricted flow conditions (such as that experienced in winter 2021), remain inundated to a large degree. However, winter baseflows are needed to provide deeper and more viable habitat for aquatic biota. Weir pools provide refuge habitat for aquatic fauna over low flow periods and should be the focus of any habitat enhancement works in lower Broken Creek. Where possible, winter baseflows should be provided to both reach 1 and reach 2, in line with recommendations from the FLOWS study. Opportunities to better coordinate maintenance between the Murray Valley and Shepparton Irrigation Districts should continue to be explored, so the 7/3 channel and/or the EGM are available to provide deliveries to upstream reaches.
- Higher summer baseflows (350 ML/d at Rices Weir) are required to reduce the chance of very low DO under high water temperatures. Delivery of the emergency watering action from late December 2021 onwards showed suitable DO levels were maintained at a flow of around 350 ML/d (3-5mg/L) compared to 250-300 ML/d (1.2-4mg/L), under similar water temperatures (Figure 20). Higher summer flows should therefore continue in the system, but in a way that avoids or minimises any negative consequences e.g. impacts to bank condition. Typical summer irrigation demand, particularly during periods of high temperature, should be accounted for to improve the likelihood of the summer flow target at Rices Weir being achieved.
- Consistent, very high flow (400 ML/d plus) associated with water-in-transit deliveries, may be accelerating bank erosion processes along lower Broken and Nine Mile Creek (Sutton et al. 2021). If so, this would exacerbate the channel widening and shallowing that has been occurring for decades under regulation (e.g. stable water levels from weirs creating notching and bank slumping). Further monitoring will be conducted over the coming year to assess and confirm the impact of higher flows on bank and vegetation condition. The results will inform future flow recommendations and creek operations.

Landscape scale considerations

The Lower Broken Creek is a tributary of the mid Murray system, connecting to the main Murray River channel near Barmah. It is one of many waterways (of varying sizes) that form a network of habitats available for migrating aquatic species that can travel large distances within the Murray-Darling Basin, particularly large-bodied native fish such as golden perch, Murray cod and silver perch.

As such, environmental water delivery in the lower Broken Creek considers how best to contribute to system-wide opportunities for native fish movement and breeding. In particular, the creek's discharge can be increased using environmental water during periods of fish migration to encourage a broader distribution of native species across the southern connected Basin by attempting to attract native fish into the creek from the Murray River.

Environmental objectives and scope of environmental watering

Environmental objectives for the lower Broken Creek and Nine Mile Creek have been documented in a variety of formats across multiple strategies and plans since 2001. The current environmental objectives were developed through the recently completed Lower Broken Creek FLOWS study (Jacobs 2019; NRE 2002).

The environmental objectives for the lower Broken and Nine Mile Creeks are summarised below, with further details available in Jacobs (2019).

Table 13: Environmental objectives for the lower Broken Creek and Nine Mile Creek

Ecological value	Long-term environmental objective
Native fish	1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.
Native aquatic fauna	2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.
Native vegetation	3. Reduce excessive build-up of *Azolla*. 4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.
Macroinvertebrates	5. Maintain and promote the diversity and abundance of macroinvertebrates.
Water quality	6. Maintain dissolved oxygen levels suitable for aquatic animals.

The recommended flow components (potential watering actions) to achieve these objectives are shown below and previously in Tables 7-9. These have been developed noting that:

- many of the ecological values in the lower Broken and Nine Mile Creeks are in part or wholly reliant on aspects of the current, regulated water regime.
- delivery of environmental water to the lower Broken and Nine Mile Creeks can only occur via Shepparton and Murray Valley Irrigation District infrastructure, primarily during the irrigation season (approximately mid-August to mid-May) for larger flows, but that smaller deliveries may be made at other times.
- while there is spare channel capacity during the irrigation season to deliver current flow recommendations, this can be reduced during times of peak irrigation demand.

The potential watering actions outlined below are consistent with the FLOWS study (Jacobs 2019) and the Environmental Watering Plan (Water Technology 2010), with the following exceptions:

- The timing of fresh deliveries has been extended from the end of September to the end of November to account for the typical period when water temperatures reach 18 deg C, which is needed to encourage native fish movement (particularly golden perch). Water temperatures typically reach 18 deg C in mid to late October.
- The magnitude of the spring/summer/autumn baseflow rate has been increased in reach 4 from 250 ML/d to 450 ML/d to provide adequate flows to maintain suitable DO levels over the hot summer period. A flow of 250 ML/d at Rices Weir does not appear adequate for preventing very low DO levels under warm water temperatures.
- The magnitude of the spring/summer/autumn baseflow rate has been increased in reach 2 (Nine Mile Creek) from 150 ML/d to 250 ML/d to allow for the increased baseflow rate in reach 4 to better manage low DO risks over the summer months. The additional water is required to be delivered through reach 2, as reach 1 is constrained in capacity (120 ML/d).

Table 14: Potential Watering Actions (reach 1)

Target reach: **Reach 1**	**Reach 1 is a priority to receive environmental water in 2022-23 as it provides different (flowing) habitat compared to downstream reaches, therefore increasing habitat diversity across the system. Reach 1 supports beds of *Vallisneria* and a range of aquatic species including platypus, silver perch, Murray cod, golden perch and river blackfish.** **Compliance point: Broken Creek diversion regulator at Katandra Weir**		
Potential watering action	Winter baseflow (20-40 ML/d continuously, May to August)	Spring/summer/autumn baseflow (70-120 ML/d continuously, August to May)	Freshes (1-3 freshes of 100-120 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Delivery of baseflows to reach 4 (flow rate is subject to water quality risk in downstream reaches and water availability). Delivery of water-in-transit i.e. IVT, Murray bypass.	Delivery of freshes to reach 4 (initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary), follow up freshes to inundate littoral vegetation and encourage fish movement).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates. Maintain dissolved oxygen levels suitable for aquatic species.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna including by providing sufficient water in Katandra Weir pool. Provide and improve habitat for fish species year-round in weir pools and habitats with flowing channels.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.

	Improve platypus carrying capacity and reduce predation risk, especially in Katandra Weir pool. Minimise exposure of turtles during winter dormancy. Maintain longitudinal connectivity to allow instream fauna to access food and shelter through providing sufficient water in flowing reaches. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.		
Rationale for delivery in 2022-23	Reach 1 is predominantly flowing habitat and the limited number of weir structures means flows must continue to maintain instream habitat. In the absence of winter baseflows, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed and there is an overall contraction in available habitat for macroinvertebrates, fish and platypus. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat are provided to prevent impacts on aquatic values in this part of the creek.	The FLOWS study did not provide specific recommendations for spring/summer/autumn baseflows in reach 1, but allowed for them to occur in response to local catchment runoff, climate conditions and in association with delivery of baseflows to reach 4. Such flows are expected to occur in reach 1 in 2022-23 (through the delivery of baseflows to reach 4) and are likely to provide the abovementioned benefits.	A managed spring fresh will be provided in reach 1 in 2022, in association with a managed fresh delivery to reach 4. This is a high priority in 2022-23 to help provide optimum conditions for recovery of aquatic fauna, post the February 2022 blackwater event.

Table 15: Potential Watering Actions (reach 2)

Target reach: **Reach 2**	**Reach 2 is a priority to receive environmental water in 2022-23 as it provides different (flowing) habitat compared to downstream reaches, therefore increasing habitat diversity across the system. Reach 2 supports beds of *Vallisneria* and a range of aquatic species including platypus, Murray cod and Murray-Darling rainbowfish. There has been a substantial investment in restoring instream woody habitat to this reach.** **Compliance point: Nine Mile Creek diversion regulator at Katandra Weir**		
Potential watering action	Winter baseflow (20-40 ML/d continuously, May to August)	Spring/summer/autumn baseflow (100-250 ML/d continuously, August to May)	Freshes (1-3 freshes of 100-200 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Delivery of baseflows to reach 4 (flow rate is subject to water quality risk in downstream reaches and water availability). Delivery of water-in-transit i.e. IVT, Murray bypass.	Delivery of freshes to reach 4 (initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary), follow up freshes to inundate littoral vegetation and encourage fish movement).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna. Provide and improve habitat for fish species year-round in habitats with flowing channels. Improve platypus carrying capacity and reduce predation risk. Minimise exposure of turtles during winter dormancy.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.

	Maintain longitudinal connectivity to allow instream fauna to access food and shelter through providing sufficient water in flowing reaches. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna.		
Rationale for delivery in 2022-23	Reach 2 is predominantly flowing habitat and the limited number of weir structures (rock chutes), particularly upstream of Wunghnu, means flows must continue to maintain instream habitat. In the absence of winter baseflows, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed and there is an overall contraction in available habitat for macroinvertebrates, fish and platypus. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat are provided to prevent impacts on aquatic values in this part of the creek. It is particularly important in 2022-23, following the absence of winter baseflows in the previous four winters when low flows were prioritised to reach 1 during GMW maintenance works.	The FLOWS study did not provide specific recommendations for spring/summer/autumn baseflows in reach 2, but allowed for them to occur in response to local catchment runoff, climate conditions and in association with delivery of high flows to reach 4. Such flows are expected to occur in reach 2 in 2022-23 (through the delivery of baseflows to reach 4) and are likely to provide the abovementioned benefits.	A managed spring fresh will be provided in reach 2 in 2022, in association with a managed fresh delivery to reach 4. This is a high priority in 2022-23 to help provide optimum conditions for recovery of aquatic fauna, post the February 2022 blackwater event.

Table 16: Potential Watering Actions (reach 3 and 4)

Target reach: **Reach 3 & 4**	**Reach 4 is a priority to receive environmental water in 2022-23 as it supports a relatively diverse native fish community including Murray cod and golden perch. This reach is shallow over large areas and highly regulated through a series of eight weirs. Consequently it is prone to *Azolla* accumulations[6] and low dissolved oxygen, particularly during hot conditions. Poor water quality has contributed to several past fish death events. Environmental water is critical for maintaining water quality, keeping fish ladders operational on each weir and promoting a robust native fish community.** **Compliance point: Flow gauge at Rices Weir**		
Potential watering action	Winter baseflow (40 ML/d continuously, May to August)	Spring/summer/autumn baseflow (200-450 ML/d continuously, August to May)	Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Flow rate considers water quality risk (*Azolla*, DO levels). A flow of 350 ML/d is targeted during summer and at other times with forecast high temperatures when risk of low DO is greatest. In the event of continued water quality decline at 350 ML/d (e.g. in association with unregulated inflows), higher flows (up to 450 ML/d) may be delivered for short periods to restore water quality.	Initial fresh in July dependent on *Azolla* levels. Follow up freshes consider: 1. the time since and frequency of previous freshes that provided suitable conditions for fish migration, spawning and dispersal. 2. water temperature (min 18 deg C for optimum fish movement – typically 15th October). 3. water quality risk (*Azolla*, DO levels).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates. Maintain dissolved oxygen levels suitable for aquatic animals.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates. Reduce excessive build-up of *Azolla*.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates. Reduce excessive build-up of *Azolla*.

[6] Significant *Azolla* accumulations have occurred in 2002-03, 2007-08, 2008-09, 2015-16 and 2017-18.

		Maintain dissolved oxygen levels suitable for aquatic animals.	Maintain dissolved oxygen levels suitable for aquatic animals.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna (through sufficient water in weir pools). Maintain longitudinal connectivity to allow instream fauna to access food and shelter and escape hypoxic events (through continual fishway operation and sufficient water in flowing sections and weir pools). Improve platypus carrying capacity and reduce predation risk. Provide opportunities for platypus movement between upper reaches and the Murray River. Minimise exposure of turtles during winter dormancy. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools. Note: flows over 300 ML/d can flush *Azolla* whilst it is still in single layers or individual plants. Flushes up to 450 ML/d disperse large blooms.
Rationale for delivery in 2022-23	In the absence of winter baseflow, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed, fishways cease operation and there is an overall contraction in available habitat and connectivity for macroinvertebrates, fish and other aquatic species. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat and connectivity are provided to prevent impacts on aquatic values in this part of the creek. Minimum low flow targets have not been achieved the last four years due to GMW maintenance works. Delivery of winter baseflow targets this year is a very high priority.	Spring/summer/autumn baseflows help mobilise *Azolla* in the main flow path and reduce excessive build up. While *Azolla* levels have remained low since August 2020 onwards, *Azolla* remains in the system and needs continual management through flow manipulation to prevent large accumulations that then require expensive and more difficult mechanical removal. Spring/summer/autumn baseflows are also essential for maintaining suitable DO levels over the warmer months when water temperature increases and dissolved oxygen levels decline in response. This is a very important pro-active management action that reduces the risk of fish death events.	Unregulated inflows in early October, early November and early December 2021 provided three separate fresh events in 2021. These coincided with warmer water temperatures and are likely to have provided a cue to trigger fish migration, spawning and dispersal. However, following the February 2022 blackwater event, a managed spring fresh is a priority to deliver in 2022-23 to help provide optimum conditions for recovery of aquatic fauna in reach 4.

Scenario planning and prioritisation

Water resource outlook for 2022-23

After consecutive years of below-average inflows and depleted storage levels, inflows and storage levels improved over 2020 and 2021 in response to the La Niña conditions. Storage levels are significantly more than at the same time in recent years (Table 17) and were close to capacity by January 2022. Further inflows are possible in autumn as La Niña conditions persist. However, according to the Bureau of Meteorology (climate outlook for 15 February 2022), the seasonal rainfall outlook for March to May does not strongly favour above or below average rainfall across northern Victoria.

Table 17: Murray and Goulburn storage levels in recent years (late summer)

Storage	2019	2020	2021	2022
Lake Eildon	40%	36%	62%	84%
Hume Dam	20%	14%	53%	96%
Dartmouth Dam	-	47%	63%	93%

Source: Storage Levels - Goulburn Murray Water (g-mwater.com.au)

Early forecasts predict strong opening allocations (1 July) for the Goulburn and Murray systems under all scenarios (Table 18), with 100% allocations expected in both systems by mid-February 2022 under all but the extreme dry scenario. This allocation outlook is substantially better than the previous three years.

Table 18: Goulburn and Murray system outlook for seasonal determination of high reliability shares

Inflow Conditions	1 July 2022	15 August 2022	17 October 2022	15 February 2023
Goulburn System				
Wet	100%	100%	100%	100%
Average	65%	100%	100%	100%
Dry	51%	67%	92%	100%
Extreme Dry	49%	52%	59%	67%
Murray System				
Wet	100%	100%	100%	100%
Average	100%	100%	100%	100%
Dry	93%	95%	99%	100%
Extreme Dry	87%	88%	90%	90%

Source: G-MW, 15 February 2021

Carryover is also available in environmental accounts and is estimated at more than 300 GL (Kris Leckie, pers. comm. Broken EWAG meeting 21 February 2022). As a result, even under the extreme dry climate scenario, it is expected that there will be sufficient environmental water available to meet the lower Broken and Nine Mile Creek environmental flow requirements in 2022-23.

Furthermore, delivery of water in transit through the lower Broken Creek is expected (e.g. IVT/Murray Bypass), which will reduce the volume of environmental water required to meet flow targets. Except for 2021-22, approximately 30,000 ML of IVT and over 15,000 ML of Murray bypass flow has been delivered to lower Broken Creek in recent years. Under the Goulburn to Murray Trade Rule Operating Plan, approximately 8 GL/month (~265 ML/d) of IVT is assumed to be delivered

through lower Broken Creek over November to April. Murray bypass flows would be in addition to this volume. The lower Broken Creek system is therefore in a secure water resource position for 2022-23.

Scenario Planning

Typically, scenario planning involves taking account of variations in water availability across climate scenarios (ranging from extreme dry to wet) and differing ecological goals (ranging from protection to enhancement) to identify the most appropriate potential watering actions for each scenario.

However, the lower Broken Creek system differs to many other environmental water locations in that the environmental flow needs are relatively fixed from year to year i.e. are largely independent of annual climatic conditions. This makes the standard scenario planning process less applicable.

Firstly, most of the water in the lower Broken Creek system is sourced from the Murray and Goulburn Rivers through regulating structures. Catchment runoff may contribute short flow peaks in winter and spring, but does not significantly contribute to environment flow needs apart from very wet years such as 2016. However, even in wet years the potential watering actions may not change. E.g. the timing of natural freshes may occur later in the year after managed freshes have already been delivered, or further high flows may be required to restore dissolved oxygen levels in the creeks after flood waters pass. Potential watering actions therefore remain consistent across each scenario, although their timing and purpose may change from year-to-year depending on the conditions.

Secondly, the volume of water expected to be available to lower Broken Creek in 2022-23 far exceeds that required to meet environmental flow requirements, even under an extreme dry scenario (Table 19). This means the potential watering actions don't need to be modified to account for a lack of available water. They are instead delivered through a combination of different water sources including environmental water, IVT, Murray bypass and unregulated inflows.

The lack of constraining factors and therefore consistency in potential watering actions across climate scenarios, means the ecological goal for delivering environmental water in lower Broken Creek has a strong focus on recovery, and where possible, enhancement (while acknowledging the limitations posed by being a regulated, working creek). This includes improving recruitment opportunities and the health and resilience of the system, rather than just maintaining it. For this reason, the lower Broken Creek is also a good candidate for complimentary measures.

Despite the consistency in potential watering actions, 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.

Table 19: Scenario planning summary

Reach 3	Scenario 1 Extreme dry 99% POE	Scenario 2 Dry 90% POE	Scenario 3 Average 50% POE	Scenario 4 Wet 10% POE
Expected climatic and flow conditions	Very low rainfall results in no natural catchment runoff in winter and no unregulated flows at Rices Weir. Water sources available: • Up to 48,000 ML of IVT[7] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 90% Murray and 67% Goulburn high reliability allocations	Some winter rainfall results in flows of 18-20 ML/day past Rices Weir in July generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[7] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations	Average rainfall over the season results in flows of 25 ML/day from July to September past Rices Weir, with a 700-900 ML/day fresh and some 200-300 ML/day freshes. Flows generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[7] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations	High rainfall results in flows of 250+ ML/day from July to October past Rices Weir, with a 2,500-3,000 ML/day high flow and 5,000 ML/day fresh. Flows generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[7] (30,000 ML delivered to lower Broken in recent years) • 30,000 ML Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations
Tier 1 Potential Watering Actions	Winter baseflow (40 ML/d continuously, May to August) Spring/summer/autumn baseflow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter baseflow (40 ML/d continuously, May to August) Spring/summer/autumn baseflow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter baseflow (40 ML/d continuously, May to August) Spring/summer/autumn baseflow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter baseflow (40 ML/d continuously, May to August) Spring/summer/autumn baseflow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).*
Tier 1 Demands	**Total: 91,100 ML** • Winter baseflow – 4,090 ML	**Total: 91,100 ML** • Winter baseflow – 4,090 ML	**Total: 91,100 ML** • Winter baseflow – 4,090 ML	**Total: 91,100 ML** • Winter baseflow – 4,090 ML

[7] Based on 8GL/mth from November to April (Operating Plan for Delivery of Water from the Goulburn IVT Account 2021-22).

Reach 3	Scenario 1 Extreme dry 99% POE	Scenario 2 Dry 90% POE	Scenario 3 Average 50% POE	Scenario 4 Wet 10% POE
	• Spring/summer/autumn baseflow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn baseflow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn baseflow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn baseflow – 76,615 ML • Freshes - 10,400 ML
Estimated ewater required for Tier 1^	< 50,000 ML	< 50,000 ML	< 50,000 ML	< 50,000 ML
Tier 2 Potential Watering Actions	-	-	-	-
Tier 2 Demands (ML)	-	-	-	-
Carryover requirements	86,780 ML to secure the following high priority Potential Watering Actions for 2023/24: • Winter baseflows (40 ML/d mid May-mid August) – 4,000 ML • Spring/summer/autumn baseflows (250 ML/d spring, 350 ML/d summer, 200-250 ML/d autumn) – 82,775 ML Securing baseflow volumes will ensure the health of the creek is maintained (e.g. habitat is not lost, fishways continue to function and poor water quality is avoided), particularly in years when water-in-transit deliveries are limited.			

* Freshes are likely to be met by unregulated flows under a wet scenario, but may still be required depending on the timing and extent of unregulated flows and the presence of *Azolla* accumulations.

^Accounting for other expected flows.

Delivery constraints

Constraints in the irrigation network

The Broken Creek system has no environmental entitlements or water storages. Therefore, all environmental water must be delivered 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 systems, the ecological needs of the creeks are generally not constrained by resource availability. However, they are constrained by the availability of spare channel capacity to deliver environmental water when irrigation demand is high, as the environment does not hold delivery shares in these systems and is therefore subject to interruptible supply (systemic constraint). Outside of the irrigation season, infrastructure maintenance by GMW over winter may also limit the ability to deliver environmental water (temporary constraint).

There are 10 channels that outfall to the lower Broken and Nine Mile Creeks that collectively can supply approximately 570 ML/d (170 ML/d from the Murray Irrigation District and up to 400 ML/d from the Shepparton Irrigation District). However, this is reduced during times of peak irrigation demand (often in spring and autumn). As a result, the estimated volumes (in Table 20) to meet the environmental objectives for the lower Broken and Nine Mile Creeks may not be delivered. Historic annual environmental water deliveries to this system have ranged from 30,000 ML to 43,000 ML.

Given the capacity constraints in the channel network, the proposal aims to have water delivered from both the Goulburn and Murray Rivers at the same time to maximise use of the spare channel capacity for environmental water deliveries. However, Goulburn environmental water entitlement needs to be supplied to the lower Broken Creek from the Goulburn supply system in the months when Goulburn Inter-Valley Transfers are either not occurring or are low (as Goulburn IVT has a limited period in which it can be delivered which depends on seasonal conditions and Murray system supply needs).

In addition, if required to alleviate *Azolla* accumulations, a fresh will be delivered down the lower Broken and Nine Mile Creeks in late winter to flush the *Azolla,* before irrigation demand significantly increases in spring and reduces environmental water delivery opportunities.

Flooding private land

Low lying land in reach one means that flows over 120 ML/day can create minor flooding of private land. GMW manage the Katandra weir and the Broken creek regulator at the top of this section to maintain flows below 120 ML/day by sending most flow down Nine Mile Creek (Reach 2).

Delivery of environmental water is not constrained by the risk of flooding private and public assets as the maximum volume able to be delivered (around 500 ML/day) represents a small proportion of the total capacity of the creeks downstream of the environmental water outfall locations (around 2,000ML/day) and GMW can actively manage flows to prevent out of channel flows.

Farm drains along Nine Mile Creek

Several farm drains exist along Nine Mile Creek to enable private land to drain to the creek under wet conditions. Currently, GMW opens these drains over winter and closes them with stopbanks when the risk of wet conditions passes.

During environmental water deliveries in August 2020 these drains remained open (due to the forecast wet conditions) and they received environmental water from the creek as water levels increased. Some of this water was harvested by the landowners as permitted under their drainage licenses. While the stopbanks had been partially re-instated by the start of September 2020, the flow into Nine Mile Creek during the spring fresh delivery in mid-September was constrained to 150 ML/d

to prevent the drains re-engaging and further loss of water. The drains were fully re-instated in time for higher IVT deliveries in mid-November.

Fortunately, the constraint did not impede the ability to meet the spring fresh flow target (100-200 ML/d) in reach 2. GMW have advised there is a long-term plan to install infrastructure (e.g. one-way stop valves) to eliminate this temporary constraint.

Confounding factors

The lower Broken Creek system is highly modified and has been subject to multiple pressures over many decades. As a result, it was rated as having poor to moderate condition (in the last Index of Stream Condition assessment, 2010). Below are the key confounding factors that continue to hinder achievement of the long-term environmental objectives for the system and what mitigating actions are currently planned.

Table 20: Confounding factors hindering achievement of environmental objectives

Long-term environmental objective	Confounding factors	Mitigating actions planned*
1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of nesting sites (e.g. for Murray cod), shelter and food. The lack of macroinvertebrate food resources for fish, turtles and platypus (related to a lack of instream habitat) is one of four main factors limiting the ecological health of the system (Jacobs 2019).	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Reinstating deep pools through sediment removal (GB CMA). Translocation of threatened freshwater catfish (GB CMA through the MDBA Native Fish Recovery Strategy).
	Weir pools limit hydrodynamic diversity, especially flowing habitat (>0.4m/s) that is important for in-channel, flow-dependent specialists such as golden perch and silver perch to migrate and spawn.	None – the highly regulated nature of lower Broken Creek (particularly reach 4) limits the ability to provide flowing habitat at velocities preferred by large-bodied fish. Velocity measurements indicate maximum flows of 0.3m/s under higher flows and with weir pool drawdown. Velocities in the flowing sections upstream are also low, being limited by the very low gradient.
	Instream barrier at Kokoda Road – the road culvert provides dark and shallow conditions that are not conducive to fish movement (see photo below).	Moira Shire has been notified of the opportunity to improve this structure.
	Functionality of Rices Weir fishway is limited. It relies on an adequate level of backwater being available from the Murray River, which is difficult to achieve under low Murray River flow conditions.	Issue identified in the Mid Murray Floodplain Recovery Reach fish recovery plan (ARI 2021). There are no current plans to upgrade the structure.
2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of shelter and food. The lack of macroinvertebrate food resources for fish, turtles and platypus (related to a lack of instream habitat) is one of four main factors limiting the	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Investigating how to improve flow delivery to minimise bank erosion (GB CMA).

Long-term environmental objective	Confounding factors	Mitigating actions planned*
	ecological health of the system (Jacobs 2019). For platypus, some of the other factors limiting the distribution and abundance include (Jacobs 2019): - dredged and re-aligned channels. - lack of instream woody habitat. - increased bank and bed erosion. - increased sedimentation of deep pools. - the low-lying nature of the banks, which means high flows in late spring and summer may inundate nests and drown young.	
3. Reduce excessive build-up of *Azolla*.	None identified – currently being achieved through ongoing flow management.	-
4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.	Regulated flows continue to transport fine sediment through the water column, contributing to high levels of turbidity, which may be impacting on the health of macrophytes by limiting light penetration (Jacobs 2019). The diversity of instream vegetation is limited in most parts of the system. Stable water levels (especially during the irrigation season) limit the cover and health of littoral vegetation.	Instream planting of aquatic native species (GB CMA). Investigating opportunities to increase water level variability to improve the recruitment and growth of littoral vegetation (GB CMA). Monitoring is planned to commence in 2022 under the Goulburn to Murray Trade Rule review.
5. Maintain and promote the diversity and abundance of macroinvertebrates.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of shelter and food. A lack of habitat (i.e. large woody habitat) is likely to be the most limiting factor effecting freshwater prawn abundance in the system (Jacobs 2019).	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Investigating opportunities to increase water level variability to improve the recruitment and growth of littoral vegetation.
6. Maintain dissolved oxygen levels suitable for aquatic animals.	Large areas of shallow water in the weir pools are more inclined to heat up under high ambient temperatures and therefore have reduced dissolved oxygen. Lentic conditions (<0.4m/s) provide little opportunity for oxygenation through turbulence. Limited aquatic plants reduce the opportunity for oxygenation through photosynthesis.	Instream planting of aquatic native species (GB CMA). Continued delivery of higher baseflows, especially during high temperatures.
Various objectives	Erosion from regulation and weirs leading to channel widening and shallowing (potentially accelerated through consistently high water-in-transit deliveries). This reduces the	Investigating opportunities to reduce the rate of erosion(GB CMA). Monitoring is planned to commence in 2022 under the Goulburn to Murray Trade Rule review.

Long-term environmental objective	Confounding factors	Mitigating actions planned*
	quality of instream habitat (physical form, water quality) for native aquatic fauna.	

* Subject to funding

Figure 28: The culvert under Kokoda Road (reach 1 of lower Broken Creek) is expected to be a barrier to fish passage

Increasing knowledge

There is limited ecological monitoring on the lower Broken and Nine Mile Creeks. This makes it difficult to quantify the effects of environmental watering actions on the health and ecology of the creeks, or the underlying condition trajectory.

The key knowledge gaps related to each environmental objective are outlined below.

While a long-term geomorphological objective has not been established for the creek, a potential risk to bank condition was raised in early 2020 (through the Broken EWAG) from delivery of consistently high flows associated with IVT and Murray bypass flows. Monitoring commenced in June 2020 to identify changes in bank condition over the 2020-21 water year. This found some locations with little change and others with extensive, deep areas of erosion (up to 40cm in depth). Monitoring is planned to continue in 2022, to confirm the extent of bank condition changes and better understand the role of various flows in contributing to these changes (through water level gauging). The findings will inform future operational decisions and watering actions.

Table 21: Key knowledge gaps for lower Broken Creek and Nine Mile Creek

Long-term environmental objective	Knowledge gap	Implications and planned monitoring
1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.	Evidence of migration, spawning events and recruitment following specific flows. How carp respond to different flow components. Fish movement patterns in the absence of winter baseflows i.e. refuge locations.	Regular fish surveys are required to enable adaptive management of watering actions and identify whether progress is being made towards the long-term environmental objective. An autumn fish survey was conducted in 2021. Annual fish surveys are planned under the Trade Rule Review monitoring program, commencing in 2022.
2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.	Current status of platypus, Rakali and turtles – abundance and distribution.	In the absence of surveys, it is unknown whether populations are stable and whether over-wintering habitat provided through current winter baseflows is adequate for these species. No surveys are planned in the near future.
3. Reduce excessive build-up of *Azolla*.	None identified.	Regular monitoring of *Azolla* levels (particularly in reach 4) will continue (GB CMA, GMW).
4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.	If and how the cover and condition of native instream and littoral vegetation is changing. What flows provide optimum conditions for native vegetation, particularly in the littoral zone. Whether consistent high flows associated with water-in-transit deliveries are impacting littoral vegetation.	Regular vegetation monitoring is needed to determine progress against the long-term objective and enable adaptive management of watering actions, particularly any risks associated with consistently higher flows. GB CMA have commenced monitoring of instream vegetation (*Vallisneria*) to measure retention over time. Bank vegetation impacts associated with consistently high flows are also being monitored as part of the Trade Rule Review monitoring program, commencing in 2022.
5. Maintain and promote the diversity and abundance of macroinvertebrates.	If and how the diversity and abundance of macroinvertebrates is changing.	In the absence of surveys, it is unknown whether the macroinvertebrate community is being maintained. Given this is a key food resource for fish, turtles and platypus, it is also unknown whether the macroinvertebrate community is limiting the ecological health of the system. The last survey was completed in 2015-16. No surveys are planned in the near future.
6. Maintain dissolved oxygen levels suitable for aquatic animals.	Why Rices Weir pool is prone to lower DO levels compared to other weir pools in reach 4.	Regular monitoring of dissolved oxygen levels (particularly in reach 4) will continue (GB CMA, GMW).

Risk Management

Each year the environmental water holders facilitate a risk workshop and develop a table of risks associated with environmental water delivery in northern Victoria. Risks associated with the proposed water delivery in the lower Broken Creek and Nine Mile Creek are shown in Table 22. Risks identified for other systems not relevant to this proposal have been removed and so the risk numbering is not sequential. Mitigation strategies that will be employed by the GB CMA to address the high and medium risks are identified.

Legend for Table 23:

1. Risk category abbreviations are: Env. – environment/sustainability; BC – business cost; People – safety/wellbeing and people/culture; Rep – political/reputation; Legal – legal consequence; Service – service delivery; CH – cultural heritage
2. L refers to the Likelihood of a risk occurring. Abbreviations for consequence ratings are: AC – almost certain; L – likely; P – possible; U – unlikely
3. C refers to the Consequence if the risk occurs. Abbreviations for consequence ratings are: Min – minor; Mod – moderate; Maj – major; Ext - extreme

Table 22: Risk assessment of proposed water delivery

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
1	Env	Specified flow rates are insufficient to achieve the intended extent of wetland inundation or magnitude and duration of river flows, resulting in a failure to achieve planned environmental outcomes.	P	Maj	Medium	Include contingency allowance in estimated watering requirements, based on previous event data, and consider a contingency in the duration of the event to achieve desired wetland inundation.	CMA
						Monitor event (especially for deliveries to new sites or for previously untested events) and adjust flows as necessary, or terminate event if it becomes clear that insufficient water is available.	CMA
						Identify and address constraints that may limit the flow rates for environmental deliveries.	CMA/GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
2	Rep	Specified flow rates are insufficient to achieve the intended extent of wetland inundation or magnitude and duration of river flows, resulting in a failure to achieve planned environmental outcomes and loss of community support.	P	Maj	Medium	Communications on the environmental benefits of watering actions. Monitor event (especially for deliveries to new sites or for previously untested events) and adjust flows as necessary, or terminate event if it becomes clear that insufficient water is available. Communicate the need for complimentary measures to optimise the benefits of environmental watering actions.	CMA CMA CMA
3	Env	Overestimates of environmental water demand prevents planning for supplying demands at other locations. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	P	Min	Low	CMAs review demand estimates and targets met by unregulated flows throughout the delivery cycle and regularly advise VEWH of any changes so unused water can be reallocated. CMAs review demand estimates at the conclusion of the watering year, prior to the development of the following seasonal watering proposal, so estimates of future requirements are more accurate. River operators provide regular updates on flows, including through OAG meetings. Manage Water Holdings to maximise supply opportunities for all sites.	CMA CMA MDBA/GMW VEWH
4	Env	Inaccurate accounting and measurement or operational error results in target flows either not being achieved or being exceeded, leading to a failure to achieve planned environmental outcomes.	U	Mod	Low	Review accounting and measurement processes to be used to ensure that techniques are agreed and monitoring/measurement sites are operational.	GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
5	BC	Volumes of environmental water delivered or released exceed volumes approved for use in the event, leading to potential overdrawing of accounts or preventing other planned actions being undertaken. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	U	Maj	Low	Ensure that deliveries are reported progressively throughout the event and are monitored against ordered volume. Ensure ordering and delivery procedures are kept up-to-date and adhered to. Ensure metering and reporting processes for temporary pump operations are suitable and effective.	CMA GMW GMW/CMA VEWH CMA
6	Env	Environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions and environmental benefits not being achieved. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	U	Maj	Low	Monitor ABA balances and undertake regular communications with CMA and RWC as part of portfolio management activities. Ensure that deliveries are reported progressively throughout the event and are monitored against ordered volume.	VEWH CMA/GMW
7	Env	Planned maintenance of water delivery infrastructure results in planned/specified flows not being achieved, leading to a failure to achieve planned environmental outcomes.	L	Min	Low	Undertake early planning and communications between the CMA and storage operator to minimise likelihood of constraints, enable scheduling of maintenance outside of high demand periods or identify alternative environmental water delivery windows to avoid scheduled maintenance activities. Consider adding time contingencies to planned maintenance schedules to ensure works are completed prior to commencement of watering actions.	CMA/GMW CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
8	Env	Failure of poorly maintained environmental delivery infrastructure results in planned/specified flows not being achieved, reducing the ability to achieve planned environmental outcomes.	L	Mod	Medium	Asset ownership is clarified and the asset owners perform regular maintenance, and pre-event asset inspections, on delivery infrastructure. **Note that insufficient resources are likely to limit the asset owner's ability to regularly inspect and maintain infrastructure. Increased resources for these activities may further reduce the likelihood and risk ratings.* Report vandalism to police. Review asset design to minimise opportunities for interference or damage. For privately owned assets, arrange approvals to use/operate assets and undertake pre-delivery inspections. Communicate failures to the CMA. Initiate documentation of asset ownership and management arrangements in national parks.	Asset owner Asset owner Asset owner CMA Asset owner PV
9	Env	Poor condition of delivery infrastructure results in the asset owner being unable to operate the structure due to OH&S risks, leading to failure to deliver environmental flows and to achieve environmental objectives. Note: This issue may affect multiple sites. GMW to confirm OH&S status and likelihood rating.	L	Mod	Medium	Asset owner to undertake regular maintenance and pre-event asset inspections on delivery infrastructure. **Note that insufficient resources are likely to limit the asset owner's ability to regularly inspect and maintain infrastructure. Increased resources for these activities may further reduce the likelihood and risk ratings.* Communicate failures to the CMA	Asset owner Asset owner

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						Develop design for new regulating structure and seek funding to implement necessary upgrades in conjunction with asset owner. Note: PV proposing to issue operating licences for BMF regulators.	CMA (MDBA in Barmah Forest)
10	Env	High operational and consumptive water demands lead to reduced access for environmental deliveries, with the result that target flows/volumes cannot be achieved, impacting on environmental outcomes.	L	Min	Low	Event planning will seek to avoid peak demand periods, and events will be monitored and adjusted as necessary. System operators to provide longer term forecasts for future consumptive demands as an input to planning watering proposals Develop longer term agreements on river capacity access for environmental deliveries. Investigate opportunities to undertake deliveries outside the irrigation season with consideration of appropriate delivery costs	CMA/GMW GMW/MDBA VEWH CMA/VEWH
11	Env	High downstream demands may lead to flows that exceed local environmental requirements and targets (including rates of river rise and fall), leading to negative environmental outcomes, including negating previous environmental improvements.	AC	Maj	Extreme	Seek to negotiate and formalise acceptable seasonal flow limits for river systems, with annual negotiation and management of release plans and reviews during the season as required. Monitor impacts of new trade limits and revised operating rules and review as necessary. Note: This risk may still be rated as extreme after mitigation actions.	VEWH/ DELWP DELWP/ GBCMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
12	Legal	Environmental releases, either on their own or potentially in combination with unexpected tributary inflows, cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets.	P	Maj	Medium	Ensure currency of any landholder agreements for inundation of private land. Release plans designed to avoid overbank flows or unauthorised flooding. Monitor events and adjust releases to avoid overbank flows. This may include limiting deliveries to daylight hours only. Monitor forecast rainfall and tributary inflows and adjust releases to avoid overbank flows. Monitor deliveries to new locations to build an understanding of flow patterns and inundation thresholds and adjust releases accordingly.	CMA CMA GMW/MDBA GMW/MDBA CMA
18	Env	Environmental water deliveries result in low dissolved oxygen (DO) levels, with adverse environmental impacts. Note: Advice is that annual leaf litter accumulation is sufficient to cause risk, even if previously inundated.	U	Mod	Low	Where possible implement a full annual suite of flow components in river systems, including those designed to control build of organic matter (such as winter flushes). Plan deliveries with consideration of high temperature periods where appropriate. Develop monitoring and response plans and reserve contingency volumes in delivery plans for dilution flows if DO concentrations drop to levels of concern. Monitor leaf litter loads and avoid exceeding any flow thresholds likely to create hypoxic black water events, where possible and considering temperature drivers. Assess new/proposed actions for DO impact potential and adjust watering plans as needed.	CMA CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
19	Rep	Environmental water deliveries result in low DO levels, with adverse environmental impact and loss of community support.	U	Maj	Low	Communicate benefits of environmental water management to the broader community and engage with recreational user peak bodies and management agencies. Communicate the benefits of environmental water management and inform the local community of environmental water management activities and the underlying rationale, including blackwater mitigations. Inform communities of black water vs hypoxic black water issues, to build understanding and support.	VEWH CMA VEWH/CEWO
20	Env	Environmental water deliveries may generate or mobilise BGA blooms, with adverse water quality and/or health impacts (including to people, livestock and pets), resulting in cessation of releases and environmental impacts.	P	Maj	Medium	Consider likelihood of initiating BGA blooms in event planning and amend as required to manage risk. Land managers or water corporation implement a monitoring program during environmental watering events, and where issues are identified, activate BGA response processes. *Note: Parks Victoria's BGA risk management plan for Northern Victoria Region that considers the potential risk of environmental water events is currently awaiting final approval. This plan outlines proactive and reactive monitoring and management responsibilities that Parks Victoria commits to as a Local Waterway Manager for BGA. Adequate BGA resourcing is considered as part of this plan. Regional monitoring and advice on BGA status.	CMA/ GMW Land mgr. GMW GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
22	BC	Insufficient resources available (including staff, funding for maintenance of roads, regulators etc.) across partner organisations to deliver all planned environmental watering actions, leading to cancellation or interruptions of deliveries.	P	Maj	Medium	Partners notify the CMA and VEWH of resource constraints in advance of deliveries and VEWH convene OAG meetings to consider implications and potential solutions. Continue to actively prioritise actions to match available resources and ensure key actions are delivered. Reallocate tasks and available funds to ensure highest priority watering actions are delivered.	VEWH CMA CMA
23	Env	Insufficient information and knowledge available to inform environmental water deliveries.	U	Mod	Low	Identify important knowledge gaps and secure funding to improve scientific understanding. Consider deferring deliveries until sufficient information is available to mitigate unacceptable risks. Implement adaptive management processes and undertake trials to collect data.	CMA CMA CMA
24	Legal	Failure to recognise cultural heritage issues at a site targeted for watering may result in necessary permits and approvals not being obtained, leading to prosecution and fines.	P	Mod	Medium	Undertake desktop reviews and site assessments with archaeologists, traditional owners and land managers, to identify approval needs and contingency measures. Obtain any necessary formal approvals/permits and implement required actions.	CMA CMA
25	Legal	Environmental watering causes harm to identified cultural heritage.	U	TBC*	TBC*	Work with Traditional Owners to ensure that the potential impact of environmental water deliveries	CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						on cultural heritage is understood and avoided, minimised and/or acceptable. Consider opportunities for additional resourcing for TO groups to engage in risk assessments.	DELWP/ VEWH
26	Rep	Inability to demonstrate outcomes achieved through environmental watering activities may lead to a loss of public/political support for activities.	P	Maj	Medium	Rationalise and refocus current monitoring programs (e.g. Wetmap) to better identifying outcomes. Seek additional funds to address gaps in monitoring programs and knowledge. Communicate the benefits of environmental watering and monitoring results. Note: It may not be possible/affordable to address all monitoring gaps, so this risk may still be rated as medium after mitigation actions.	DELWP VEWH CMA
27	Env	Environmental deliveries improve conditions for non-native species (e.g. carp, invasive species, feral horses) leading to adverse environmental impacts. Or pest plants and animals prevent environmental water outcomes being achieved.	L	Mod	Medium	Study/understand life history of species and develop high level management strategies. Develop and implement site specific management strategies aimed at eradication/control of existing populations (e.g. carp management strategy, willow removal program, water-lily spraying program, feral animal programs). (*Note: This risk is still rated as medium after mitigation actions.*)	DELWP CMA/Land Mgr.

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
28	Env	Environmental watering actions trigger non-targeted environmental responses (e.g. bird breeding) causing unintended consequences (or lost opportunities) for other environmental values.	L	Mod	Medium	Undertake monitoring and communicate these issues as they arise and apply adaptive management and review of delivery plans. Consider including contingency allowance in delivery plan water volumes to complete breeding events.	CMA CMA
29	Env	Ineffective planning results in administrative obstacles that prevent watering opportunities.	U	Mod	Low	Enable the full range of watering actions possible in seasonal watering proposals and the seasonal watering plan (as per SWP guidelines).	CMA/VEWH
30	BC	River operators release water for flood mitigation which causes downstream flooding and debits those releases to environmental water accounts. **Note that debits of releases to environmental accounts is specific to Lake Hume and pre-releases from other storages could not be debited to environmental accounts.*	U	Mod	Low	Resolve appropriate water accounting treatment as part of the development of the Enhanced Environmental Water Deliveries SDL Adjustment Measures project (aka Hydrocues project). Refer to MDBA Environmental Water Management Group for development of suitable accounting arrangements.	VEWH/ DELWP MDBA
31	Rep	River operators release water for flood mitigation which causes downstream flooding and public perceive the releases are for environmental purposes.	U	Mod	Low	River operators to clearly communicate to customers and the broader community when large releases are for operational purposes.	MDBA/GMW
32	Rep	Sections of the community perceives (incorrectly) that high river flows are due to environmental releases in dry conditions, leading to a loss of support for watering activities.	P	Mod	Medium	Communications to inform the community on the drivers/reasons for high flows in river systems, especially under dry scenarios.	GMW/CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
33	Rep	Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering actions.	U	Mod	Low	Communicate benefits of environmental watering to the community, especially in relation to strategic watering in dry periods. Enhance community understanding of water system operations and entitlement frameworks (water literacy).	CMA VEWH
34	Rep	Under dry conditions, community expectations of the extent of environmental watering that can be achieved are not met, leading to a loss of support for environmental watering actions. Note: environmental water deliveries may be constrained in 22-23 due to high consumptive water availability and release.	P	Mod	Medium	Communications to inform the community on the limits of environmental water holdings and the extent of actions possible under dry conditions. *Note that public concern in this regard may still be heightened as a result of the Menindee fish death events.*	CMA
35	Env	Limited environmental deliveries may reduce opportunities to test ecological responses to environmental flows, impacting on effectiveness of research projects.	U	Min	Low	Review monitoring program and adjust if possible. Reprioritise future flow targets.	CMA
36	People	Environmental releases create rapid or unexpected changes in flow conditions, resulting in injury to river users.	U	Mod	Low	Include consideration of ramp-ups and ramp-down phases in release plans to reduce rapid water level changes. Appropriate notification actions to alert general river users, especially for high use sites and high use periods.	CMA CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						Provide information on proposed changes to PV for inclusion in Change of Conditions Section of their website. Implement communications plan about environmental water releases. Undertake notifications to water users with assets potentially at risk due to changing river levels	CMA GMW

* In consultation with Traditional Owners

Approval and Endorsement

Approval

I, Chris Cumming, the authorised representative of the agency shown below, approve the Seasonal Watering Proposal for the Lower Broken Creek system 2022-23.

SIGNED FOR AND ON BEHALF OF Goulburn Broken Catchment Management Authority

Signature of authorised representative

Name of authorised representative

Chris Cumming (CEO)

Date: 13 April 2022

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