Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Lower Broken Creek

AUGUST 2011 V1.0

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Environmental Water Delivery: Lower Broken Creek

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

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

This document has been prepared to provide information on the environmental assets and potential environmental water use in the Lower Broken Creek system.

The Lower Broken Creek supports significant biodiversity by providing valuable habitat in a highly modified landscape. Biodiversity values associated with Lower Broken Creek include the presence of regionally significant native fish populations and areas of intact riparian vegetation. Potential water use options for the Lower Broken Creek include the provision of water to augment baseflows at Reach 3 to maintain or expand native fish populations through the creek and to support water quality.

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

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

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

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Acronyms

ACRONYM	MEANING
BACI	Before-after-control-impact
BE	Bulk Entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved Oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EVC	Ecological vegetation classes
eWater CRC	eWater Co-operative Research Centre
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
GMID	Goulburn-Murray Irrigation District
G-MW	Goulburn-Murray Water
ISC	In stream condition
IVTs	Inter-valley transfers
MDBA	Murray-Darling Basin Authority
NERWMP	North East Regional Water Monitoring Partnership
NRSWS	The Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
SRA	Sustainable Rivers Audit
TLM	The Living Murray
Tungamah D&S scheme	Tungamah domestic and stock scheme
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VRHS	Victorian River Health Strategy
VWQMN	Victorian Water Quality Monitoring Network

PART 1
Management aims

1. Overview

1.1 Scope and purpose of this document

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

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

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

Information provided focuses on the environmental watering objectives and water use strategy for the Lower Broken Creek in northern Victoria. This includes options for the use of water held in the Goulburn and Murray system storages.

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

1. Existing information for selected environmental assets has been collated to establish asset profiles, which include information on hydrological requirements and the management arrangements necessary to deliver water to meet ecological objectives for individual assets.
2. Water use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible. In the first instance, water use options will provide an "event ready" basis for the allocation of environmental water in the 2011 autumn and spring seasons. These options will be integrated into a five-year water delivery program.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) that are either currently in operation at each asset or methodologies that could be applied for accurate accounting of inflow, return flows and water 'consumption'
   - decision triggers for selecting any combination of water use options
   - approvals and legal mechanisms for delivery and indicative costs for implementation.

1.2 Catchment and river system overview

The catchment area of Broken Creek covers approximately 3,300 square kilometres of the Murray Valley Riverine Plains (SKM 1998), encompassing the western slopes of the Warby Ranges and northern slopes of the foothills around Dookie. The creek lies within the Victorian Riverina and Murray Fans Bioregions. Much of the catchment is cleared for dryland and irrigated agriculture.

Prior to the development of irrigation infrastructure, Broken Creek was an ephemeral system with flows predominantly occurring in winter and early spring. Historically, Broken Creek would have received inflows from the Broken River upstream of the present location of Casey's Weir in approximately one year in five (Reich et al. 2009). However, the regulation of the system for irrigation, stock and domestic supply has significantly modified the hydrologic regime in Broken Creek, turning the system into a largely perennial system dominated by summer flows and permanent weir pools.

The terms Upper Broken Creek and Lower Broken Creek are often used to refer to reaches of the creek upstream and downstream of the Boosey Creek confluence respectively (Water Technology 2010). For the purposes of this report, the Lower Broken Creek is defined as a small section of the Boosey Creek downstream of the Murray Valley 7/3 channel outfall, the Lower Broken Creek and Nine Mile Creek. The Murray Valley Irrigation Area is north of the creeks, while the Shepparton Irrigation Area is to the south.

The Lower Broken Creek and Nine Mile Creek have been regulated for more than 50 years. Under natural conditions, the creeks would have ceased to flow during summer and autumn. Today the creeks are perennial streams with significant flows maintained through summer and autumn to supply water for irrigation, stock and domestic, and urban use. There are a number of weirs downstream of Katamatite that maintain water levels for private pumps. Water quality in the weir pools during summer and autumn is often poor, and in recent years environmental managers have passed increasing volumes of water down the creek to manage threats posed by low dissolved oxygen levels and blooms of the water fern Azolla.

The major sources of regulated inflows to the Lower Broken Creek are discharges from the Shepparton and Murray Valley Irrigation Area channel systems, including from the East Goulburn Main Channel and the Murray Valley 7/3 channel (Figure 1). The major sources of unregulated inflows are the upstream catchments (i.e. the Upper Broken Creek and Boosey Creek), Shepparton Drain 11, Shepparton Drain 12 and Murray Valley Drain 13. In the drought years from 1997 to 2009, unregulated inflows were a very small proportion of total inflows. Altogether, there are currently eleven outfall structures and six drains that connect directly to the Lower Broken Creek from the Murray Valley Irrigation Area, while five outfall structures and six drains connect directly to the Lower Broken Creek and Nine Mile Creek from the Shepparton Irrigation Area. As part of the Northern Victoria Irrigation Renewal Project (NVIRP), seven of the eleven Murray Valley outfall structures connected to the creek will be decommissioned (Water Technology 2010). The outfall structures that will be retained are denoted by an asterisk in Figure 1. Some outfall structures discharging to drains will also be removed.

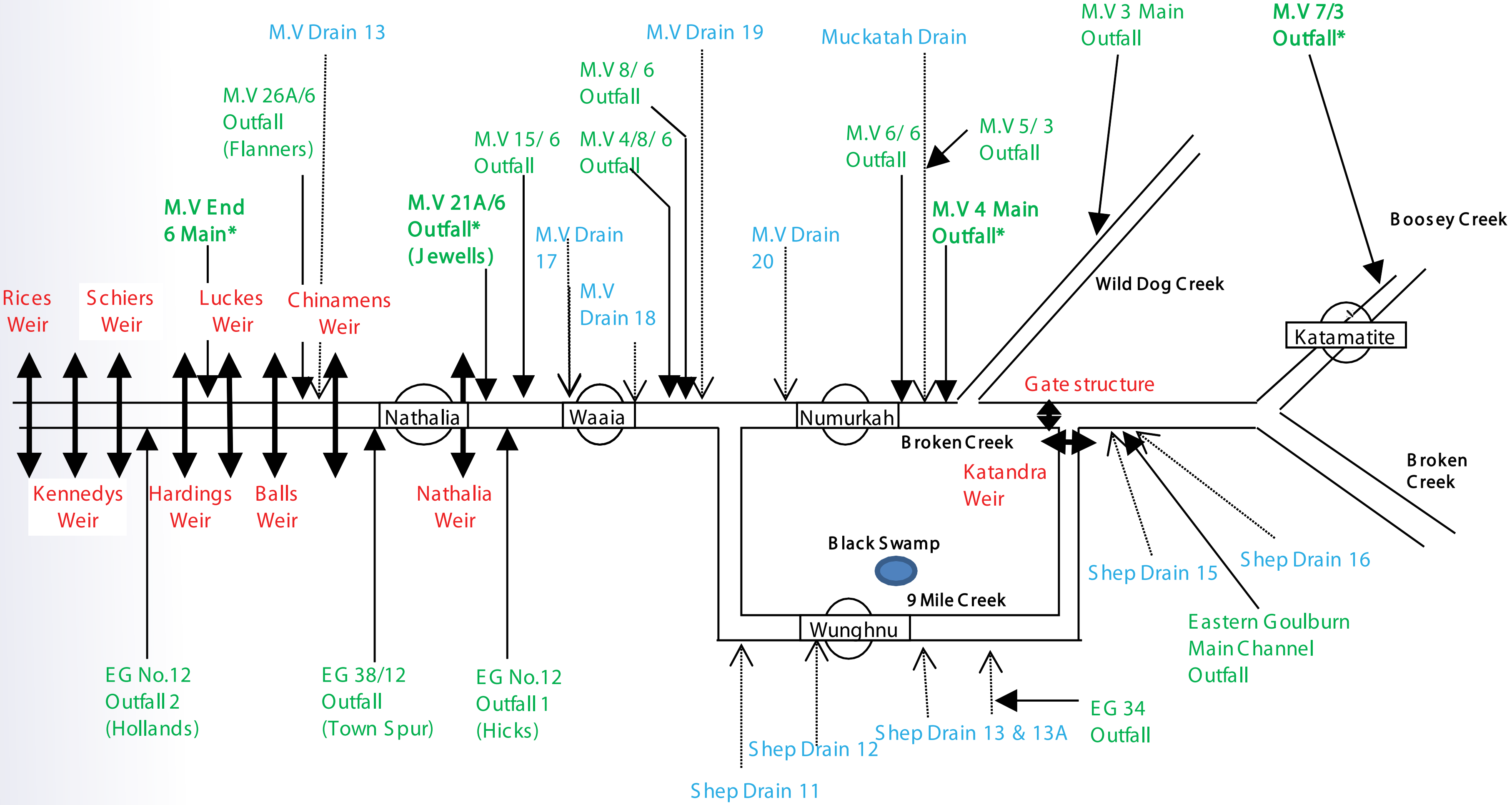

Figure 1: A schematic of the Lower Broken Creek and Nine Mile Creek system (SKM 2003).

The names of regulating structures are in red, the names of drains are in blue and the names of outfalls are in green. Murray Valley outfall structures that will not be removed as part of the NVIRP works are shown by an asterisk. All outfall structures on the Shepparton side of the creeks are being retained (Water Technology 2010).

1.3 Overview of river operating environment

Regulation of flows along the Lower Broken Creek is managed by Goulburn-Murray Water (G-MW). Under the Bulk Entitlement (BE) framework, the Lower Broken Creek (including Nine Mile Creek) is managed as one system, although it is part of both the Murray River and Eildon-Goulburn Weir BEs. About 40,000 ML of regulated water is needed in a normal year to supply the consumptive demands along the Lower Broken Creek system, and to cover transmission and operational losses. This water normally comes from the Goulburn system via the East Goulburn Main Channel (Schedule 3 of the Eildon-Goulburn Weir BE).

Although the majority of water supplied to the Lower Broken Creek is from the Goulburn system, the entitlements of most consumptive users are specified in the Murray River BE. The seasonal allocations that apply are those announced for Victorian water shares in the Murray River system. The remainder of entitlements have Goulburn system allocations.

In low allocation years, the supply of water from the Goulburn system to the Lower Broken Creek is reduced, and the shortfall in supply is met by the Murray system. The contribution from the Goulburn system in gigalitres is generally based on the formula: 5 + 35 x Goulburn allocation (A. Shields, G-MW, pers. comm., 2010). All Murray Valley irrigators pay slightly different water storage and supply charges from the normal Murray River charges, reflecting the fact that some of their water (though only used in the Broken Creek part) comes from the Goulburn system.

Environmental water management, including the Goulburn Water Quality Reserve (30,000 ML), is planned by the Goulburn Broken Catchment Management Authority (GB CMA), in cooperation with G-MW, the Victorian Department of Sustainability and Environment (DSE) and Murray-Darling Basin Authority. Lower Broken Creek is managed as three main reaches (Figure 2):

- Reach 1: Broken Creek from Boosey Creek to Nine-Mile Creek.
- Reach 2: Broken Creek from Nine-Mile Creek to Nathalia.
- Reach 3: Broken Creek from Nathalia to the Murray River.

Nine Mile Creek is excluded from this document, as it is not operated during winter and, as a highly modified channel, has less of the fish habitat that is highly valued in the Lower Broken Creek. The main objectives of environmental water delivered to the Lower Broken Creek relate to the prevention or mitigation of poor water quality that can occur following excessive growth of the water fern Azolla and maintaining habitat and passage for native fish. Environmental releases are generally made to meet the ecosystem needs of Reach 3 in spring and over summer to autumn, when water is delivered to meet irrigation demand along the other reaches. Other assets near Lower Broken Creek, such as Black Swamp and Purdies Swamp, currently receive water in most years. The volume required to fill these wetlands is relatively small (e.g. 100 ML); for these reasons they are not considered in the current version of this document.

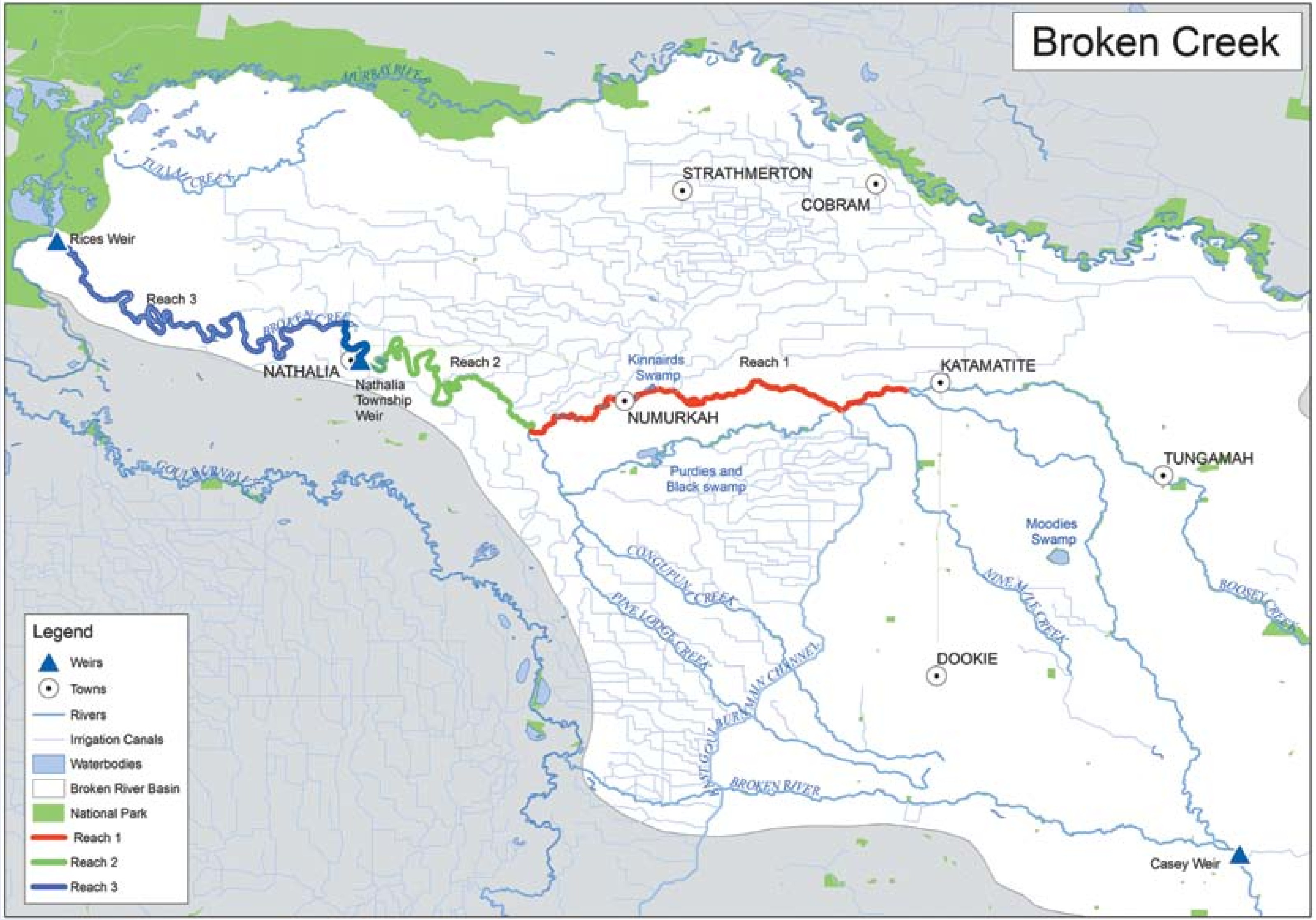

Figure 2: Reaches along Lower Broken Creek (SEWPaC 2011).

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values

Ecosystem values associated with the Lower Broken Creek include the presence of (Water Technology 2010, URS 2005):

- 20 ecological vegetation classes (EVC, see Appendix 1), including the following threatened and/or regionally significant examples:
  - EVC68 – Creekline Grassy Woodland
  - EVC168 – Drainage Line Aggregate
  - EVC259 – Plains Grassy Woodland / Gilgai Wetland Mosaic
  - EVC803 – Plains Woodland.
- Numerous riparian plant species of conservation significance
- Threatened and regionally significant native fish species, including:
  - Murray cod (*Maccullochella peelii peelii)*
  - Silver perch *(Bidyanus bidyanus)*
  - Golden perch *(Macquaria ambigua)*
  - Unspecked hardyhead *(Craterocephalus stercusmuscarum fulvus)*
  - Crimson-spotted rainbow fish (*Melanotaenia fluviatilis*).

The native fish populations of Lower Broken Creek, particularly Murray cod, are considered to be of regional significance (GB CMA 2005). While a result of water resource development and regulation, the presence of weir pools along the Lower Broken Creek has provided additional habitat for deep-bodied native fish that might not otherwise exist.

Overall, the Lower Broken Creek supports important plant and animal habitat and biodiversity in a region whose landscape has been greatly modified. It also complements the habitat and biodiversity values associated with nearby systems such as the Lower Goulburn River and the Murray River.

2.2 Broad-scale ecosystem objectives

2.2.1 Murray-Darling Basin

The following ecosystem-scale objectives, proposed by the MDBA (2010), are relevant when considering options for the use of environmental water in the Lower Broken Creek:

- Maintain and improve the ecological health of the Basin, and in doing so optimise the social, cultural, and economic well-being of Basin communities.
- Improve the resilience of key environmental assets, water-dependent ecosystems and biodiversity in the face of threats and risks that may arise in a changing environment.
- Maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Basin.

These and flow-related ecological objectives that are the basis for management plans for Lower Broken Creek (Water Technology 2010, GB CMA 2005, GB CMA 2008, URS 2005) are important considerations when allocating environmental water to the Lower Broken Creek.

2.2.2 Goulburn Broken catchment

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

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

3. Watering objectives

3.1 Proposed asset watering objectives

The following environmental watering objectives were identified for the Lower Broken Creek in developing Interim Environmental Flows Recommendations (GB CMA 2008) and are used when considering various existing management plans and the impact of the Northern Victoria Irrigation Renewal Project (Water Technology 2010):

- Native Fish – Improve native fish habitat and passage. Ensure persistence of aquatic habitats during migration and breeding seasons, particularly for Murray cod. Supply sufficient flow to operate the fishways and provide fish access to appropriate habitat all year.
- Wetlands – Restore a more natural flood regime to Black and Purdies Swamps.
- Low Dissolved Oxygen – Maintain dissolved oxygen concentrations above 5 mg/L (based on ANZECC guidelines to maintain suitable conditions for oxygen dependent species).
- Algal and Azolla blooms – Minimise the growth of Azolla and algae.

In effect, the objectives listed above serve as risk mitigation measures to protect or improve the environmental values associated with the Lower Broken Creek.

The objective for wetlands requires a return to a more natural pattern of wetting and drying. Until recently, wetlands such as Black Swamp and Purdies Swamp have a history of being water-logged due to their connection to Nine Mile Creek. Their management requires less frequent inundation from Nine Mile Creek, rather than additional water.

Potential watering options to achieve objectives related to native fish and their habitat, low DO and Azolla are presented in Table 1 and summarised in Table 2. Given that water levels are maintained at high levels due to the influence of weirs and their operation, no objectives have been set for floodplain vegetation, as this would risk the high-value black box communities present along the creek (Water Technology 2010).

Table 1: Proposed flow objectives for reaches along the Lower Broken Creek (Water Technology 2010).

Flow Target	Daily Flow ML/d											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Reach 1												
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Reach 3												
Native Fish Habitat									250	250	250	
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Collective Requirement	40	40	40	40	40			40	250	250	250	40
Reach 4												
Azolla & Dissolved Oxygen (DO)	250	250	250	250						250	250	250
Provisional DO and Azolla flows*	100	100	100	100						100	100	100
Native Fish Habitat									250	250	250	
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Collective Requirement^	350	350	350	350	40			40	250	350	350	350

* Additional flows up to 200 ML/d may be required depending on seasonal conditions.
^ Volumes for native fish passage are not included in the Collective Requirement figures as flows for Azolla and DO will provide the target flows for this objective.

Management is driven by objectives for Reach 3: Nathalia weir pool to the Murray River (highest ecosystem values), given low flows once irrigation demand has been met. Objectives will likely remain relatively constant, irrespective of climatic conditions, as DO and Azolla issues can arise in most years (although Azolla issues are less likely in median and wet years). The recommended flows for January–March are usually met with existing water entitlements and inter-valley transfers.

Table 2: Summary of water use objectives for the Lower Broken Creek.

	Management objectives for specific water availability scenarios			
	Extreme dry	**Dry**	**Median**	**Wet**
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Broken Creek				
Reach 3 objectives	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain a reduced native fish population distribution in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain a reduced native fish population distribution in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain or expand native fish population distributions in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain or expand native fish populations distribution in the creek
Potential use of environmental water	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d is required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September to December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September to December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September–December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat. • Catchment runoff makes the need for water to manage Azolla less likely in median years.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September–December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat. • Catchment runoff makes the need for water to manage Azolla less likely in wet years.

PART 2:
Water use strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

Of total inflows to the Lower Broken Creek and Nine Mile Creek systems, the majority comes through the channel outfall structures (Figure 3). Drought conditions during the 10 years to 2008–09 have reduced the percentage contributions from unregulated sources of water (i.e. the upstream catchments and drains), while the percentage contribution from outfall structures has increased. In 2008–09, inflows from outfall structures contributed approximately 95 per cent of total inflows. At the same time as the percentage contribution to inflows from outfall structures increased, the inflows through outfall structures in excess of orders decreased. In short, the distribution of water through outfall structures to the Lower Broken Creek and Nine Mile Creek has been managed more tightly in recent years (Figure 4).

Interestingly, over the five years to 2008–09, the volume of water ordered through outfall structures by environmental managers (using environmental allocations or inter valley transfers (IVTs)) rapidly increased, while the volumes ordered by diverters decreased (Figure 5). In 2008–09, the volume of water ordered for the environment and IVTs exceeded local diverter orders for the first time. The decrease in diverter orders can be linked with Victorian Murray and Goulburn irrigation allocations (Table 3). As allocations decreased, the volume of water ordered by diverters also decreased. Environmental managers have, therefore, needed to order more water for the Lower Broken Creek system for the purpose of maintaining sufficient water quality in the weir pools.

Inflows to the Lower Broken Creek and Nine Mile Creek systems through drains have also declined significantly over the 10 years to 2008–09. In the late 1990s and early 2000s, drainage inflows to the system were 30–35,000 ML/year. In the mid to late 2000s however, inflows from drains have been a minor component of total inflows. This reduction in drainage inflows is probably attributable to a combination of less rainfall runoff, less runoff from irrigation application, less channel outfalls into drainage systems, increased drainage diversions and a focus on reducing drainage flows.

The contribution of total inflows is weighted to the upstream end of the Lower Broken Creek. This is particularly the case in recent years (eg. 2008–09), when minimal inflows to the system were recorded downstream of where the Lower Broken Creek and Nine Mile Creek split. Of the total inflows to the Lower Broken Creek system, a large portion flows downstream and passes to the Murray River (Figure 6). Over the 10 years to the end of 2008–09, the annual flow past Rice's Weir has only been 25 to 45 per cent lower than total estimated inflows.

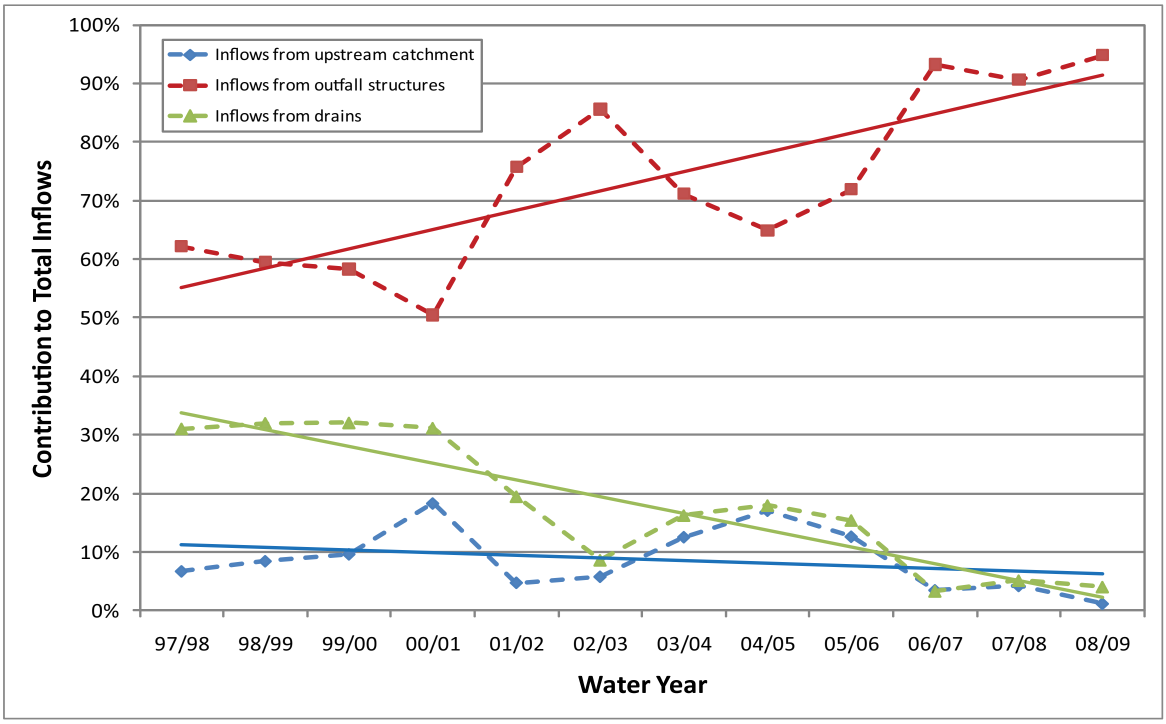

Figure 3: The contribution of inflows from the upstream catchment, outfall structures and drains (SKM 2010).

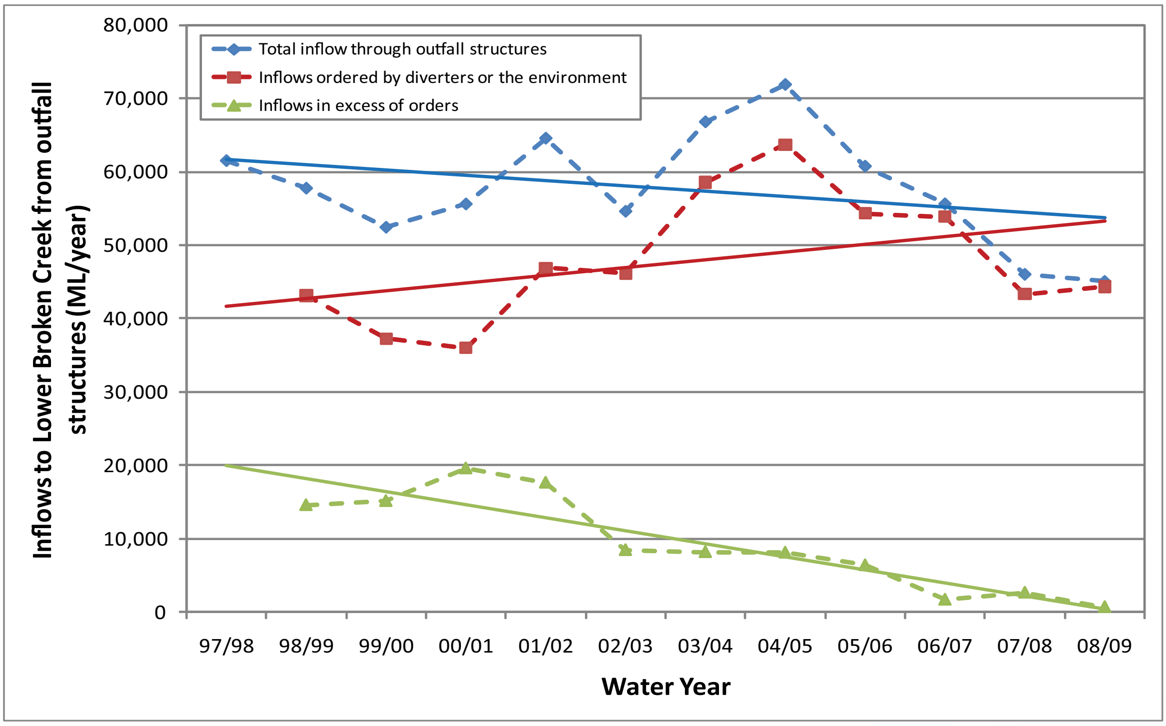

Figure 4: The total inflow through outfall structures, divided into ordered inflows and inflows in excess of orders (SKM 2010).

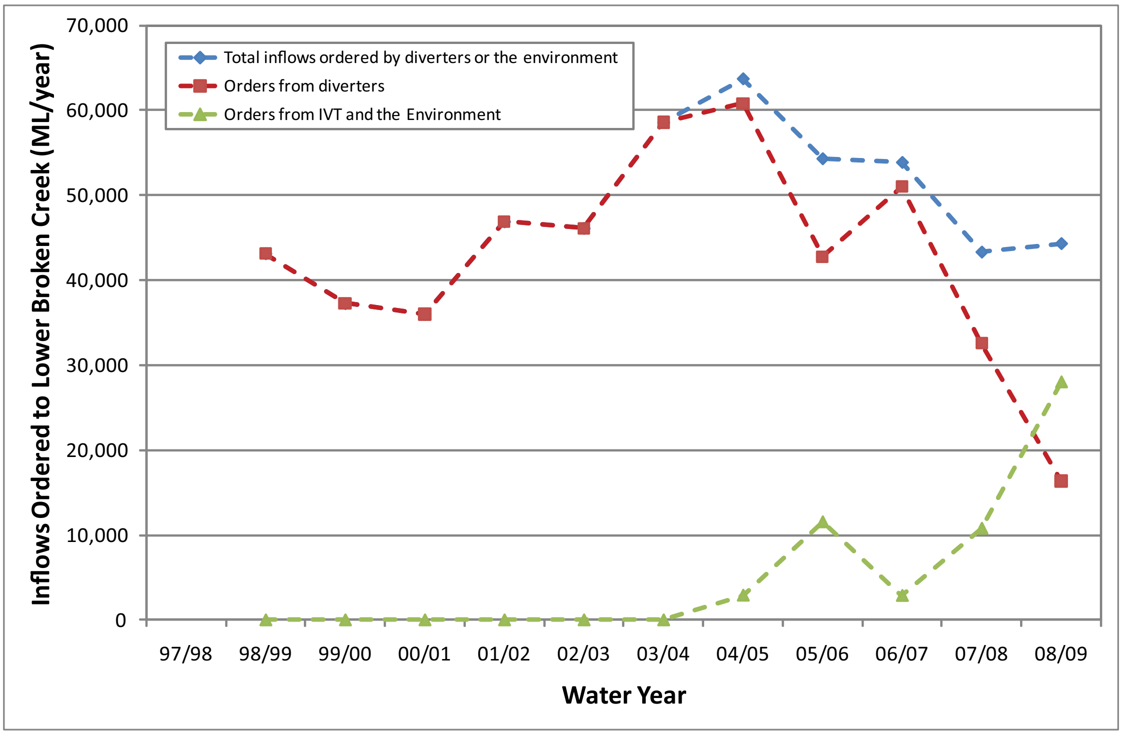

Figure 5: The volume of ordered water for diverters, the environment and inter-valley transfers (SKM 2010).

Table 3: Victorian Murray and Goulburn February irrigation allocations.

Water Year (July–June)	Murray Allocation*	Goulburn Allocation*
1996–97	200%	200%
1997–98	130%	120%
1998–99	200%	100%
1999–00	130%	100%
2000–01	200%	100%
2001–02	200%	100%
2002–03	129%	53%
2003–04	100%	100%
2004–05	100%	100%
2005–06	141%	100%
2006–07	95%	25%
2007–08	42%	53%
2008–09	35%	33%
2009–10	100%	71%

* Note, final allocations did increase after February in 2005–06 and 2007–08 on the Victorian Murray system and 2002–03, 2006–07 and 2007–08 on the Goulburn system.

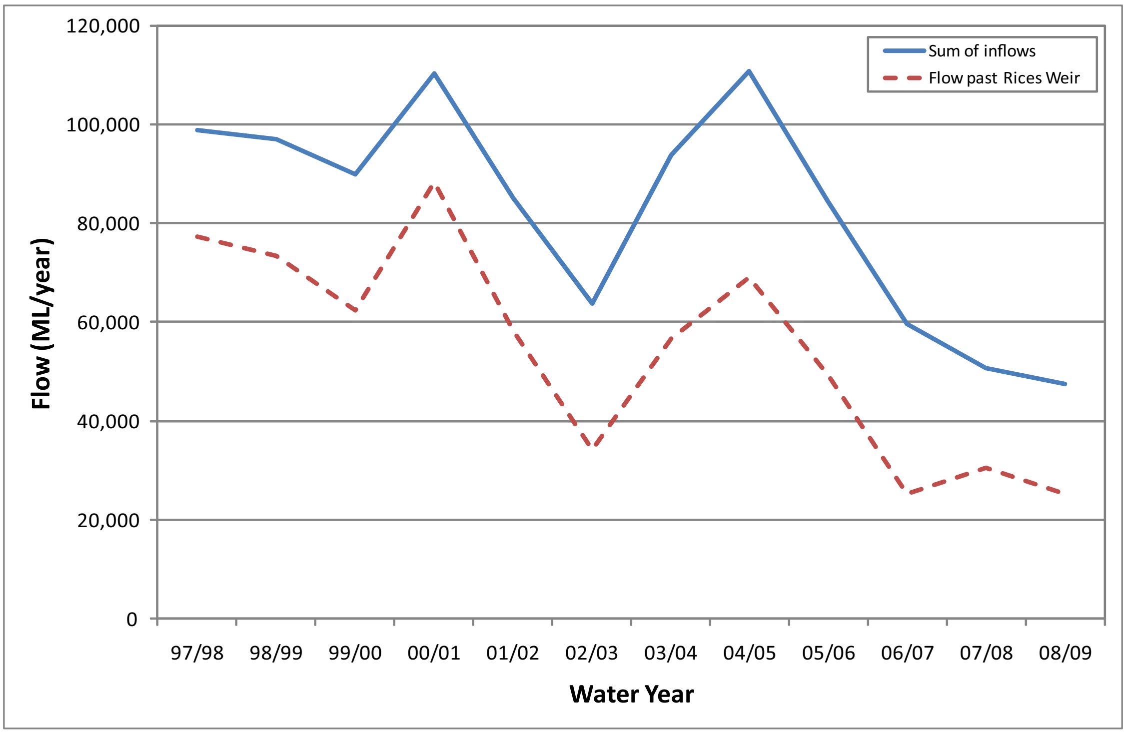

Figure 6: A comparison of annual total inflows (including from the upstream catchments, outfalls and drains) and annual flow past Rice's Weir.

A long term computer model of the Lower Broken Creek has not yet been developed. An existing daily FORTRAN model only covers the period 1 January 1997 to 30 June 2002. The MDBA developed a regression model of Broken Creek flows at Rice's Weir (only) by fitting to gauged flow data from 1965 to 1994 (MDBC 2003). The regression relates flow in the creek to climate variables and a time trend over the period 1965 to 1994, which has been set as a constant at the year 1994 in the current MSM-Bigmod input. The regressions vary by season from 0.26 (poor) to 0.85 (good) and will not represent current (2010) irrigation system operation. Therefore gauged flow data has been used in the information presented below, with the regressed MDBA data at Rice's Weir provided for reference purposes. There is a high degree of uncertainty associated with the relevance of the historical gauged data due to the recent changes in irrigation system operation previously discussed in this section.

This data shows that flow in the Boosey Creek at Tungamah and the Broken Creek at Katamatite ceases for approximately 20 per cent of the time. In contrast, there is flow past Rice's Weir for all but a small portion of time (Figure 7).

Flows past Rice's Weir are elevated in summer and autumn by regulated releases and operational overflows through outfall structures located along the Lower Broken Creek (Figure 8). In winter and spring, the average recorded flow is of similar magnitude to the average flow recorded in summer and spring, but this is because there are significant periods of data missing during winter and spring for 16 of the 45 years of record. In contrast, the MDBA modelled time-series for Rice's Weir, while showing elevated flows in summer and autumn, has the highest average flows occurring in spring. Drought conditions in the 2000s have resulted with flow past Rice's Weir falling below 10 ML/d for extended periods during winter and spring. The flow regime for the Boosey Creek at Tungamah and the Broken Creek at Katamatite follows a more natural pattern, with low flows in summer and higher flows in winter and spring, including occasional flood events.

On average, flows to the Lower Broken Creek from the upstream catchments for the period of record available are 33 ML/d for December to May and 157 ML/d for June to November (Table 4), although it is noted that flow in the Lower Broken Creek is driven by peak flow events rather than more regular flow (indicated by the shape of the flow duration curve). The bulk of these inflows come from the Boosey Creek catchment. Average daily flows past Rice's Weir for December to May and June to November are 300–500 ML/d, depending on whether the recorded or modelled streamflows are analysed.

Note that the pipelining of the Tungamah domestic and stock scheme, which was completed in 2007, is likely to lead to reduced summer flows (particularly baseflows) in the Upper Broken Creek into the future.

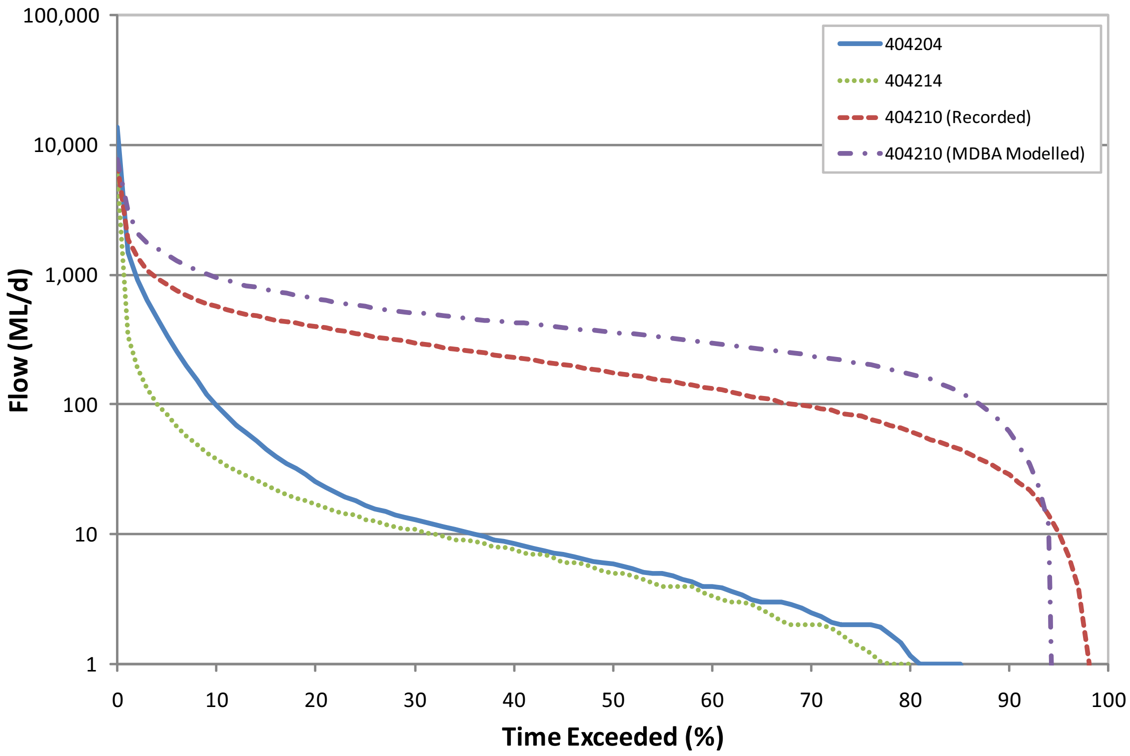

Figure 7: Daily flow duration curve for streamflow gauges at Tungamah (404204), Katamatite (404214) and Rice's Weir (404210).

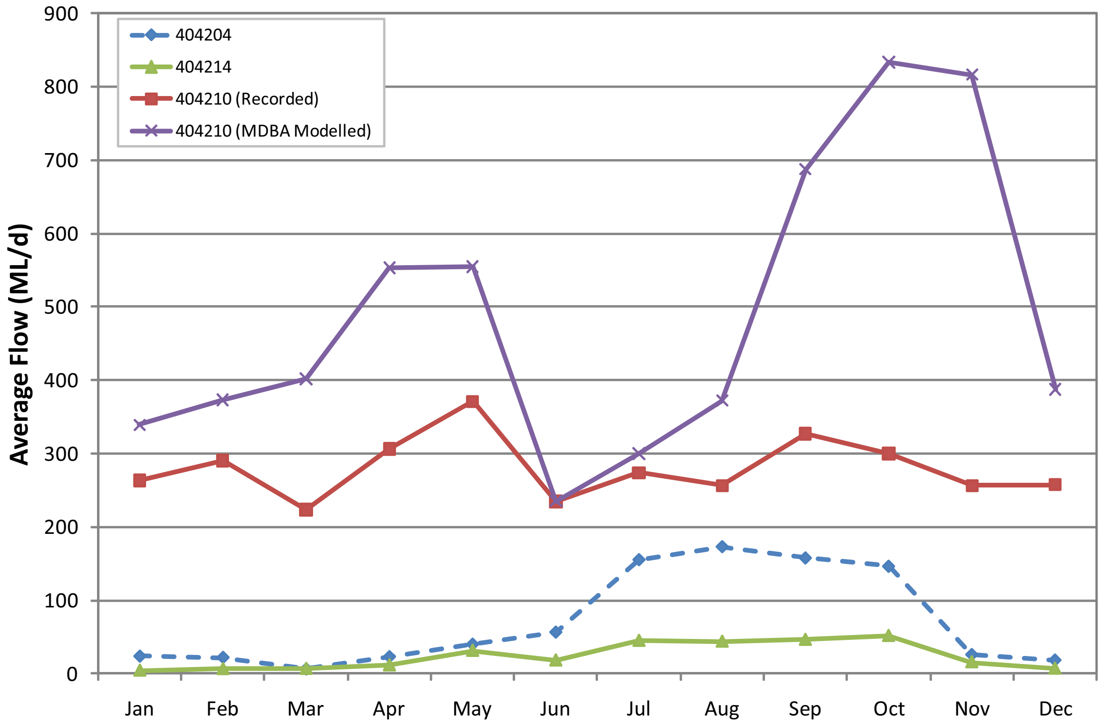

Figure 8: Average daily flow for streamflow gauges at Tungamah (404204), Katamatite (404214) and Rice's Weir (404210).

Table 4: Flow statistics for gauges at Tungamah (404204) and Katamatite (404214), and downstream gauge Rice's Weir (404210), based on the available periods of record.

Statistic (ML/d)	Flow Gauge				
	404204	404214	404204 + 404214	404210 (Recorded)^	404210 (Modelled)*
Minimum daily flow	0	0	0	0	0
Average daily flow	71	24	95	280	490
Maximum daily flow	13,700	5,910	15,800	7,050	7,670
Summer minimum daily flow	0	0	0	0	0
Summer average daily flow	22	11	33	286	435
Summer maximum daily flow	3,390	4,800	6,920	7,020	4,390
Winter minimum daily flow	0	0	0	0	0
Winter average daily flow	120	37	157	273	540
Winter maximum daily flow	13,700	5,910	15,800	7,050	7,670

Note: Summer refers to the months December to May, while Winter refers to the months June to November.
Note:^ Without infilling missing periods in the gauge record.
Note: *Modelled time-series was provided by the MDBA from BigMod for the period 1891–2009.

Table 5 shows that flow in the Lower Broken Creek (measured at Rice's Weir) is elevated in summer and autumn, and reduced in winter and spring. Although zero flows have been observed in nearly all months, these are typically short duration events. The longest periods of zero flow recorded have been 32 days in July–August 1979 and 23 days in August 2002. Note that the values in Table 5 are derived independently for each month. In the very dry year in particular, Table 5 highlights that zero flows can occur in each month of the year, but this does not necessarily mean that zero flows persist for the whole year.

Table 5: Streamflows (ML/d) for the Lower Broken Creek for recorded (1965–2009) and modelled (1895–2009) daily time-series.

Month	Very dry year (minimum on record)		Dry year (30th percentile daily flow)		Median year (50th percentile daily flow)		Wet year (70th percentile daily flow)	
	Record	Model	Record	Model	Record	Model	Record	Model
Jul	0	0	27	75	49	176	103	358
Aug	0	0	31	248	98	340	225	450
Sep	0	0	124	464	221	606	362	836
Oct	0	0	142	159	249	428	389	965
Nov	8	0	137	155	214	417	313	851
Dec	0	0	105	246	183	311	277	416
Jan	0	0	118	220	180	274	265	356
Feb	0	0	140	286	206	343	350	404
Mar	0	0	86	242	149	302	266	406
Apr	0	0	150	396	239	469	352	582
May	0	3	189	426	269	484	372	585
Jun	0	0	48	58	86	133	141	233

4.2 Environmental water demands

The aim for delivering water to the Lower Broken Creek is to provide baseflows of varying magnitudes at Rice's Weir to manage water quality and provide native fish habitat and passage (see Section 2).

Based on gauged data for the Lower Broken Creek at Rice's Weir, Table 6 shows the range of additional volumes required to meet the environmental flow recommendations in very dry, dry, median and wet years. The range of volumes required to meet environmental demand in dry to wet years ranged from 1,000 ML to 55,000 ML. The volume required in the two driest years on record was 42,000 – 47,000 ML. If Bigmod modeled flows are used for the baseline source data (run #20507), the volumes required are lower at around 24,000 – 25,000 ML for the very dry year and up to 36,000 ML for other years. The discrepancy between the modelled and gauged data is in part due to the different timeframes of the source data. With recent changes in system operation, volumes required could be higher (due to improved irrigation delivery system efficiency) or lower (due to IVT and environmental water deliveries by the Goulburn Broken CMA to manage water quality).

Table 6: Range of additional volumes required to achieve desired environmental flows in the Lower Broken Creek, based on modelled Victorian Murray allocations and flows at Rice's Weir.

Desired flow event	Baseline data source	Seasonal volume required to piggyback events	
		Very dry	Dry Median Wet
Baseflow	Modelled flows, 1895–2009	24 – 25 GL	0 – 36 GL
	Gauged data, 1976–2010	42 – 47 GL	1 – 55 GL

5. Operating regimes

5.1 Introduction

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

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

5.2 Identifying target environmental flow recommendations

The same flow requirements are recommended for all climate years (see Table 7).

5.3 Delivery triggers

Triggers for delivering flows to Broken Creek are listed in Table 7. The 40 ML/d baseflow should be provided throughout the nominated season, with environmental water allocations supplementing creek flows as required. G-MW would need to estimate the anticipated shortfall volume and manage deliveries to meet the target flow at Rice's Weir.

The delivery of the higher baseflows from August to December is driven by the need to manage water quality in the creek. Dissolved oxygen in Rice's Weir pool is continuously monitored by the GB CMA. When the dissolved oxygen drops below 5 mg/L the baseflows should be increased to improve water quality and reduce the risk of fish kills and algal blooms. In practice, because of the travel time along the creek through the irrigation system (discussed in the following section), environmental water managers should try and anticipate dissolved oxygen levels reaching this threshold approximately four days in advance by tracking trends in the recorded data. Delivery should cease when dissolved oxygen has increased above 5 mg/L, and the likelihood of it dropping below 5 mg/L with no additional deliveries is low. In practice this may involve throttling back deliveries over a period of days and closely monitoring dissolved oxygen levels.

The 30,000 ML Goulburn Water Quality Reserve has been used in recent years to manage water quality. This reserve is regarded as an emergency supply and may be drawn upon at a time of poor water quality.

Table 7: Summary of proposed operational regime for achievement of environmental objectives.

Climate year	Flow objective in Broken Creek (Reach 3)	Season/ timing	Average return period	Water quality trigger
All	40 ML/d baseflow at Rice's Weir.	Apr–May, Aug–Dec	All years.	Maintain throughout season with deliveries from Goulburn or Murray systems as required.
	80–200 ML/d baseflow at Rice's Weir.	Aug	All years.	Deliver when dissolved oxygen in Rice's Weir pool is expected to drop below 5 mg/L within four days.
	250 ML/d baseflow at Rice's Weir.	Sep–Dec	All years.	Deliver when dissolved oxygen in Rice's Weir pool is expected to drop below 5 mg/L within four days.

5.4 Travel time

Travel time along the Goulburn River between Lake Eildon and Goulburn Weir (the offtake point for the East Goulburn Main Channel) is assumed to be three days in the GBCL daily river system model. G-MW operations work on the basis of two days travel time during the irrigation season. Travel time along the Murray River between Lake Hume and Yarrawonga Weir is estimated to be four days under regulated flow conditions. However, supply can often be made directly at the weirs without waiting for water to arrive from storages.

Travel time from the Goulburn Weir to the Shepparton Irrigation Area outfalls to Broken Creek is less than 24 hours following channel automation. Travel time from Yarrawonga Weir to the Murray Valley Area outfalls is two to four days. This should be reduced to less than 24 hours when the channels are automated over the next few years.

Travel times within the Lower Broken Creek itself are defined in the existing FORTRAN model as:

- Four days from the East Goulburn Main channel outfall to Nathalia Weir.
- Six days from Nathalia Weir to Rice's Weir (and therefore ten days from the East Goulburn Main channel outfall to Rice's Weir).

However, some flow can be provided from Shepparton channel 12 and some Murray Valley outfalls directly to Nathalia Weir pool or further downstream, eliminating the four day travel time. The weir pools themselves can also be manipulated in harmony to reduce the six day travel time to less than one day.

The long travel times from the top to bottom of the Lower Broken Creek system means the peaks of high flow events recorded at the upstream end of the study area are attenuated by the time they reach Rice's Weir (Figure 9).

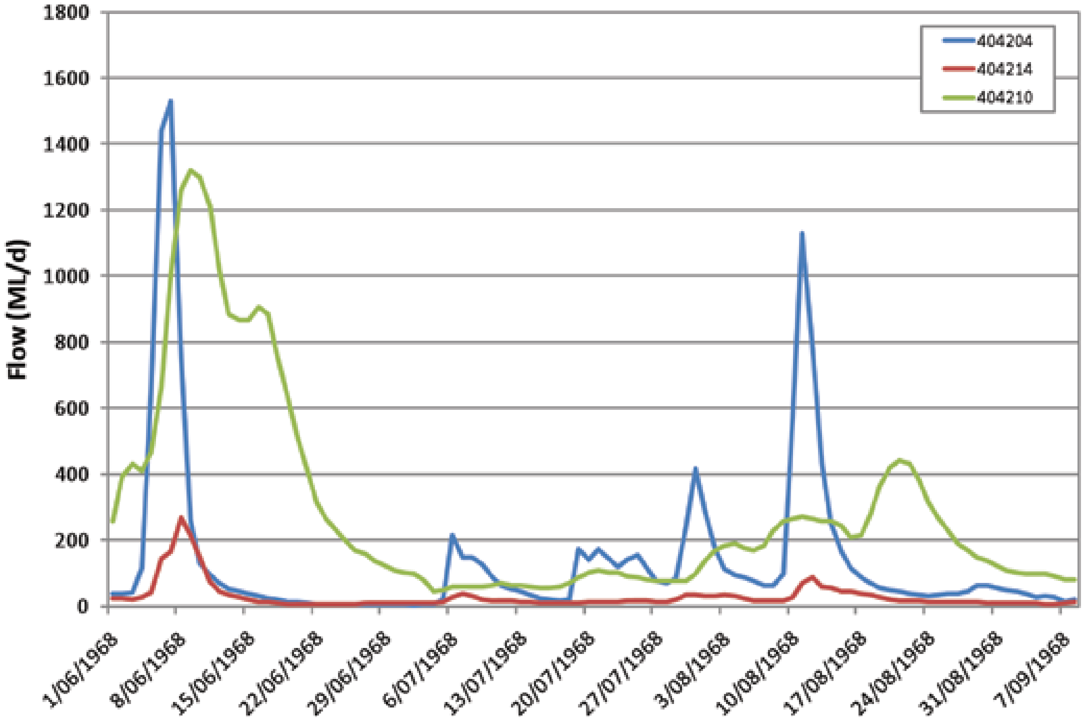

Figure 9: Attenuation of high flow events as they move from the upstream end of the study area (404204 – Boosey Creek at Tungamah and 404214 – Broken Creek at Katamatite) to the downstream end (404210 – Broken Creek at Rice's Weir).

For deliveries using the channel system, G-MW requires an order four days in advance to guarantee the delivery, although flows have been provided in one to two days in response to urgent requests (for example, to address falling levels of dissolved oxygen). If the provision of environmental water was to occur in line with standard ordering procedures, a minimum of four days notice would be required for deliveries.

5.5 Storage releases

The peak thresholds of environmental flow recommendations for the Lower Broken Creek are up to 250 ML/d (Water Technology 2010). Storage release capacities from Murray River and Goulburn headwork storages are not a constraint to delivering these flow magnitudes.

5.6 Channel capacity

Of the regulated inflows to the Lower Broken Creek, the major sources are the East Goulburn Main Channel outfall and the Murray Valley 7/3 channel outfall. The Murray Valley 7/3 channel is a spur channel of the Yarrawonga Main Channel.

Channel capacity constraints can occur seasonally within both the Shepparton and Murray Valley Irrigation Area channel systems. Competition with consumptive (irrigation) demands may pose a significant constraint. Additionally, the channel systems generally do not operate from mid-May to mid-August.

Approximate spare delivery capacities (ML/d) in the Yarrawonga Main channel at the Yarrawonga Weir offtake are shown in Figure 10. Similar plots for the East Goulburn Main Channel offtake from Goulburn Weir and the East Goulburn Main Channel downstream of the siphon are shown in Appendix 2. The data is shown as a range of spare channel capacity over a range of allocations around the defined climate years. Note that there is a difference between low allocation years (with limited irrigation water to deliver and hence spare channel capacity) and dry climate years (where there is low catchment runoff and high environmental demand, but could still be very high allocations from water stored in previous years).

This data highlights, for example, that in a very dry year there is likely to be ample capacity in these main channels to deliver environmental water to the Lower Broken Creek. In dry, median and wet years, the Yarrawonga Main Channel is often at capacity. Along the East Goulburn Main Channel (which has historically delivered the bulk of water to the Lower Broken Creek), there is likely to be limited spare capacity during the irrigation season in median and wet years.

Spare channel capacity in the spur channels and outfalls to the Lower Broken Creek have not been presented because this data was not readily available. However, significant capacity constraints may exist, particularly through the Murray Valley system. A model of the Lower Broken Creek over a long climatic sequence is required to estimate spare outfall capacity. Further analysis of gauged data on the outfalls could be used to identify any recent capacity constraints, which are likely to be representative of spare capacity in dry and very dry years.

The analysis in this section is based on recent past (modelled) conditions, including recent past patterns and volume of demands. More recent changes, including trade out of the Shepparton Irrigation Area and changed patterns of water use from summer pastures to spring and autumn annual pastures due to drought conditions, may affect channel capacity constraints into the future. It is likely that the shift from summer pastures to spring and autumn pastures will reduce capacity constraints (free up capacity) during summer but increase capacity constraints in spring and autumn.

Additionally, channel capacity in Yarrawonga Main Channel and channels through the Murray Valley Irrigation Area may change in the future if there are any changes to Murray River operation around the Barmah Choke. It is likely that this would result in an increase in baseflow to the Lower Broken Creek if the capacity of delivery channels around the choke is increased.

Goulburn-Murray Water should be consulted if the Shepparton or Murray Valley Irrigation Area channel system is to be used to deliver environmental water, to check the likelihood of spare capacity at any given time.

It should be noted that the ability to deliver environmental water via the Murray Valley system is also limited by constraints on water trading. From Zone 7 (Victorian Murray Dartmouth to Barmah) trade is limited to allocation trade up to the volume of back trade to date (no entitlement trade can occur).

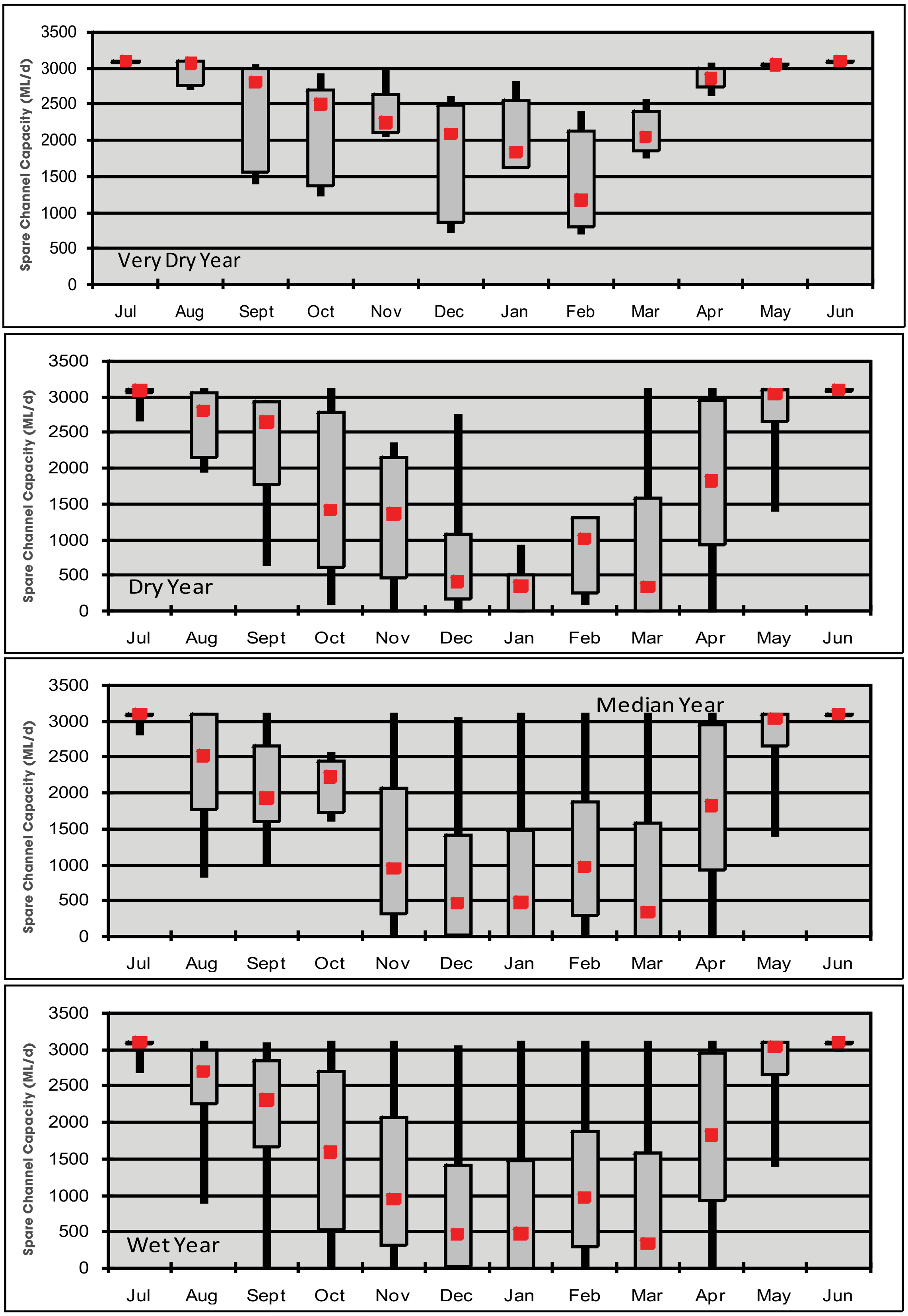

Figure 10: Spare channel capacity in the Yarrawonga Channel offtake, 1895–2009.

The Murray Valley Irrigation Area is being upgraded as part of the Northern Victoria Irrigation Renewal Project (NVIRP). NVIRP plans to reduce the current number of outfall structures that discharge directly from the Murray Valley Irrigation Area to the Lower Broken Creek from 11 to 4, and reduce the volumes supplied above customer requirements by 85 per cent (Water Technology 2010).

Whether the reduction in the number of outfalls from the Murray Valley Irrigation Area to the Lower Broken Creek will reduce or increase the combined outfall capacity, or the ability to deliver environmental water, is unknown at the time of writing. All outfall structures on the Shepparton side of the Lower Broken Creek are being retained.

5.7 Flooding

The baseflow recommended ranges from 40 ML/d up to 250 ML/d. Flows of this magnitude in Lower Broken Creek are delivered via the irrigation channel system and would not be expected to cause any flooding.

5.8 Interaction with other assets

Broken Creek is linked to both the Murray and Goulburn systems via the Yarrawonga Main and East Goulburn Main channels respectively.

Outflows from Broken Creek will contribute to flows in the Murray River downstream of the Barmah Choke. As such, deliveries of water to the Lower Broken Creek can interact with downstream ecological assets on the Murray River, such as Gunbower forest.

Delivering water to the Lower Broken Creek represents an alternative flow path around other ecological assets. Water diverted to the Lower Broken Creek from the Goulburn system may have otherwise flowed through the Lower Goulburn floodplain while water diverted from the Murray system may have otherwise flowed through the Barmah-Millewa forest (depending on river flow rates for both alternative assets). It is noted, however, that environmental water is unlikely to be required for Broken Creek at times when the Lower Goulburn floodplain or the Barmah-Millewa forest are in flood.

5.9 Water delivery costs

5.9.1 Delivery costs

To deliver environmental water to the Lower Broken Creek use of the channel system is required. If environmental water is delivered via the G-MW channel networks, there is an annual service point fee of $200 per service point, plus delivery fees of $11.35 per ML delivered through the Shepparton Irrigation Area and $5.48 per ML delivered through the Murray Valley Irrigation Area. It should be noted that these rates are for interruptible supply, which is only available when there is spare capacity. If guaranteed access is required, the environmental water manager would need to purchase delivery shares which would incur different fees and charges.

Storage charges are also applicable. 2011–12 storage costs for the Goulburn system are $3.54 per ML held in the spillable water account, $6.98 per ML of high reliability water share and $3.54 per ML of low reliability water share. Storage costs for the Victorian Murray system are $4.56 per ML held in the spillable water account, $10.16 per ML of high reliability water share and $4.56 per ML of low reliability water share.

Delivery and storage charges are subject to review on an annual basis, and additional fees and charges may apply. More information is available from http://g-mwater.com.au/customer-services/feesandcharges.

It is assumed that any water sourced from NSW water shares for delivery to the Lower Broken Creek system would first be transferred to a Victorian Murray or Goulburn system account and that Goulburn-Murray Water's delivery costs would apply.

5.9.2 Carryover costs

The 2011–12 fees for transferring water from the spillable water account back to the allocation bank account is $4.52 per ML for the Victorian Murray system and $3.52 per ML for the Goulburn system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more info.

6. Governance

6.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). The NRSWS also presents the community with an agreed level of health target for Victoria's northern rivers. The Victorian Government has agreed to try and meet the health target through various mechanisms, including through the use of environmental water.

Much of the riparian zone is managed by Parks Victoria as part of the Broken-Boosey State Park Management Plan (Parks Victoria 2006). G-MW has responsibility for the planning and delivery of water to the Lower Broken Creek. In doing so, G-MW collaborates with:

- The GB CMA to deliver environmental water, including the Goulburn Water Quality Reserve and inter-valley transfers through Lower Broken Creek. NOTE: while G-MW can make recommendations regarding the delivery of inter-valley transfers to support GB CMA objectives, the actual delivery of inter-valley transfers is governed by the MDBA who are working towards the management of the larger Murray-Darling Basin and are not compelled to follow G-MW's recommendations.
- The Victorian Environmental Water Holder, who is responsible for managing the Victorian government's environmental water entitlements and allocations, and for making decisions on the use of Victorian environmental water.
- The Murray-Darling Basin Authority to manage Murray River rainfall-rejections around the Barmah Choke, by redirecting water from the Murray River at Yarrawonga to the Lower Broken Creek via the Murray Valley Irrigation Area channel system. MDBA may direct water through the Murray Valley Irrigation Area at the request of G-MW to assist with water quality in Broken Creek.

Environmental water holdings in the Murray River and Goulburn systems can be delivered from the Murray River headworks storages (Hume or Dartmouth Reservoirs) or Goulburn headworks storage (Eildon Reservoir, Goulburn Weir).

6.2 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets within the Lower Broken Creek include:

- GB CMA as the manager of the Environmental Water Reserve for the Goulburn system.
- G-MW as the Bulk Entitlement holder and manager of the major reservoirs in the catchment, manager of the Shepparton and Murray-Valley Irrigation Areas and also the licensing authority responsible for groundwater and surface water licensed diversions.
- Goulburn Valley Water is responsible for urban water supply in the catchment.
- VEWH is responsible for making decisions on the use of Victorian environmental water.

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

6.3 Approvals, licences, legal and administrative issues

6.3.1 Water shepherding and return flows

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

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

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

For Broken Creek, water entering the Murray River from Broken Creek is treated as a Victorian tributary inflow under the Murray-Darling Basin Agreement. Credits for this water may be granted if the Murray-Darling Basin Authority determines that the inflows have added to usable resources. If tributary credits are granted, the water is added to Victorian resources and falls under the provisions of the Murray Bulk Entitlement. Environmental water managers would need an agreement with G-MW to have these return flows credited to their allocation bank account for the Murray River downstream of the Barmah Choke. The re-crediting of return flows may require agreement from all three States.

If Murray River water shares were transferred to the VEWH's Flora and Fauna entitlement, then return flows from Broken Creek to the Murray River can more readily be credited under Clause 15 of the entitlement. Specified points for return flows are listed in Schedule 4 to the entitlement, which currently does not include return flows from Broken Creek. If return flows are to be re-credited to the Flora and Fauna entitlement at other locations, then it must be by agreement with the Murray-Darling Basin Authority.

If the point of delivery for environmental water is specified as Rice's Weir, which is at the outlet of Lower Broken Creek, this ensures that the most downstream reaches of Lower Broken Creek receive the required baseflows. However, G-MW could choose to deliver this water through the most downstream outfalls, in which case the upper reaches of Lower Broken Creek would not receive environmental benefit. In practice this is unlikely, because there is generally less spare capacity in these outfalls than further upstream. Alternatively, if the point of delivery for environmental water is specified as the outfall of the East Goulburn Main Channel, which is at the upper end of Lower Broken Creek, this would provide environmental flows in this upper reach. However, there would be no guarantee that the water would be shepherded through the various diversion weirs along Lower Broken Creek. It is recommended that environmental water managers discuss this issue further with G-MW if deliveries are to be made to Lower Broken Creek, to ensure, as best as possible, that the desired baseflows are delivered along the length of the Lower Broken Creek. In the absence of more specific advice from G-MW, ordering water at Rice's Weir is likely to achieve the most environmental benefit.

6.4 Trading rules and system accounting

6.4.1 Water trading

Trading zone boundaries are shown in figure 11.

The Lower Broken Creek system is located in Trading Zone 6B (Lower Broken Creek).

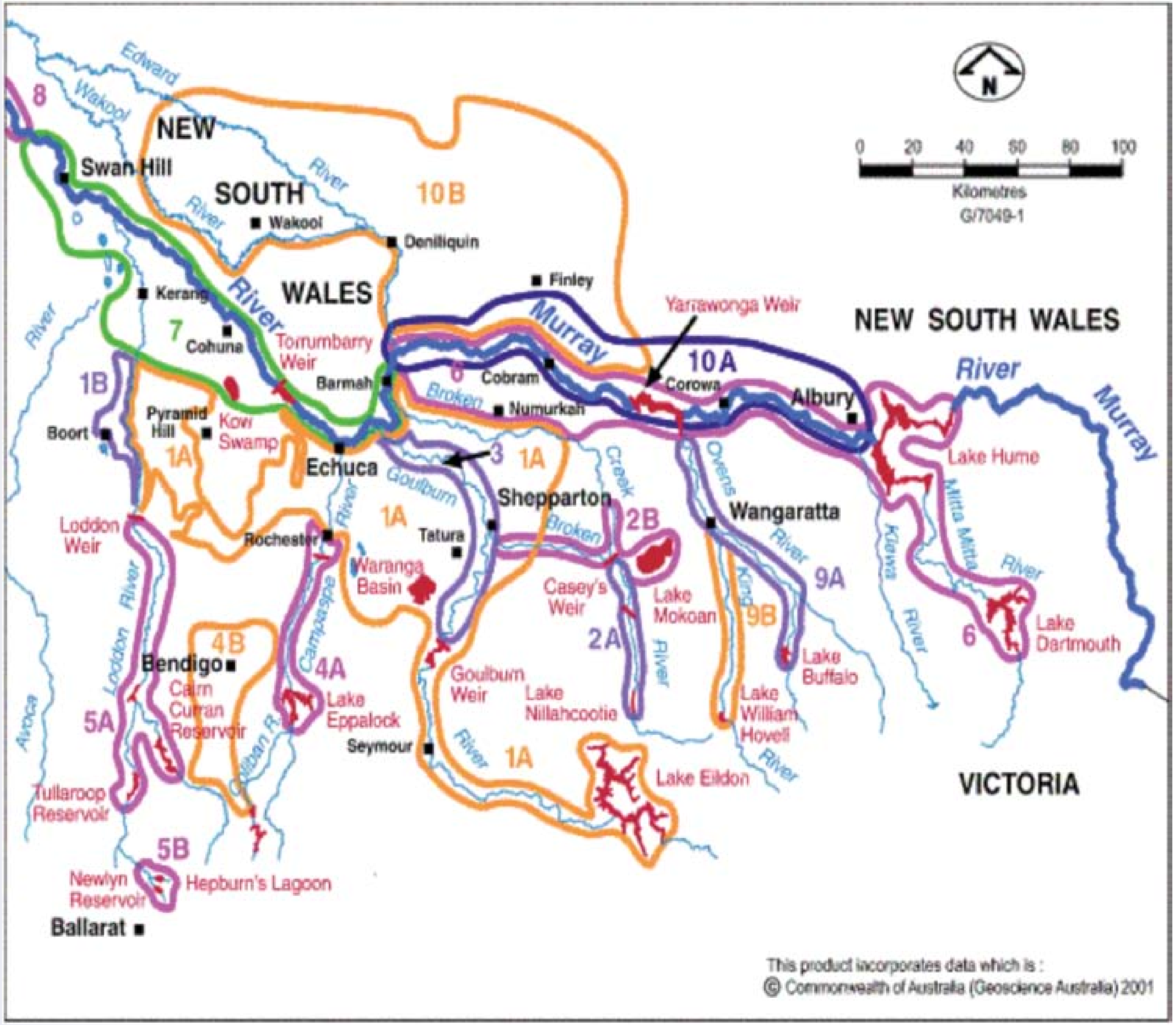

Figure 11: Trading zone boundaries (Source: http://www.watermove.com.au).

Table 8: Summary of trading between zones (Source: SEWPaC 2011).

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

■ Entitlement and allocation trade
□ Allocation (no entitlement) trade up to the volume of back-trade to date

Additional Trading Rules

All trade, except trading to unregulated tributaries, is with an exchange rate of 1.00. Trade into unregulated river zones (zone 170) can only be transferred as a winterfill licence, which only becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trade (of allocation or entitlement) into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

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

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

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

This means that any allocation trades must be made well in advance of a targeted runoff event.

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

6.4.2 Water storage accounting

The Lower Broken Creek system does not have any water storages. Water storage accounting for the Victorian Murray system and the Goulburn systems is annual water accounting (July to June) with some carryover.

In the Victorian Murray and Goulburn systems, unlimited storage carryover is allowed, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of spill. Any carryover in the spillable water account cannot be accessed until the risk of spill has passed. If a spill occurs, carryover is the first to spill. Annual deduction for evaporation is 5 per cent of carried over volume.

The fees for transferring water from the spillable water account back to the allocation bank account can be found in section 5.9.2. For more information on carryover, see http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/.

7. Risk assessment and mitigation

The risk assessment outlined in Table 9 provides an indication of the risks associated with the delivery of environmental water in the Lower Broken Creek system. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

Table 9: Flow-related risks to environmental objectives for the Lower Broken Creek system.

Risk type	Description	Likelihood	Consequence	Risk level	Controls
Acid sulphate soils	There is no evidence of acid sulphate soil issues along Broken Creek.	Unlikely	Moderate	Low	Maintenance of continuous flows should minimise this risk.
Salinity	Releases from the Murray and Goulburn Rivers are of good quality and do not pose salinity risks at the volumes proposed.	Unlikely	Minor	Low	Salinity is monitored and the Goulburn Water Quality Reserve could be called upon to reduce (dilute) saline water, if this was necessary (highly unlikely).
Invasive species	Carp breeding can occur, along with that of native fish. The introduced fish weatherloach and gambusia are also present. The aquatic weed *Sagittaria* sp. (arrowhead) has also occurred.	Likely	Moderate	Medium	None for alien fish species. The control and eradication of arrowhead is an ongoing management issue for G-MW and the GB CMA.
Low DO (e.g. from blackwater events)	Fish kills have resulted from low DO, often associated with Azolla outbreaks and low flows in summer. Current management practices are aimed at addressing these contributing factors. Low DO and blackwater events can also arise from overland flooding from the upstream catchment.	Possible	Major	High	Monitor DO at Rice's Weir and track trends in data to ensure a drop in DO levels is noticed in time for action to be taken to prevent negative impacts. Maintain sufficient flow through of water to minimise Azolla build up in winter-spring, and to avoid low DO in summer-autumn.
Limited access to channel capacity	Releases to meet consumptive demand may constrain the capacity available for delivering environmental flows.	Possible/likely	Minor	Medium	Risk may be offset by the delivery of consumptive water.
Reduced discharge to Lower Broken Creek from channel outfalls and Upper Broken Creek due to modernisation and the Tungemah pipeline.	Reduced outfalls may reduce discharge to the creek.	Possible	Moderate	Medium	Adjust releases to account for reduced inflows from channel outfalls and Upper Broken Creek.
Water loss	The magnitude of losses along the Lower Broken Creek system are unknown.	Likely	Minor	Medium	Review losses along Broken Creek. Allow for losses, if necessary, when estimating allocations.
Other considerations	Reliance on modeled flows at Rice's Weir, which may underestimate the volume of water required to meet objectives.	Possible	Moderate	Medium	Develop contingencies for increasing discharge if required.

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Environmental water provisions

G-MW's 'Monitoring and Incident Response Manual' (2004) made note of an agreement between G-MW and the MDBA (then the River Murray Commission) to provide a 40 ML/d allocation to the Lower Broken Creek (via the Murray Valley channel system) to manage water quality (Azolla build up). In 2003–04 the agreement was modified to 80 ML/d. The current status of this agreement is unknown, but it is believed to no longer be active (Water Technology 2010). Excluding the above, there are no planned environmental water provisions for the Lower Broken Creek. However, in recent years significant water deliveries have been made to manage water quality. These provisions have come from a number of sources:

- Water from the Goulburn Water Quality Reserve (Eildon-Goulburn Weir BE 1995) via the Shepparton Irrigation Area channel system.
- Inter-valley transfers from the Goulburn system to the Murray River system through the Shepparton Irrigation Area channel system and Lower Broken Creek (rather than directly down the Goulburn River).
- Water from the Murray Flora and Fauna BE (1999) via the Murray Valley Irrigation Area channel system (which may also be back traded to the Goulburn system and delivered via the Shepparton Irrigation Area channel system).
- Murray River water diverted to bypass the Barmah-Millewa forest.

Table 10 describes how the 30,000 ML Goulburn Water Quality Reserve has been used to manage water quality in the Lower Broken Creek.

Table 10: Goulburn Water Quality Reserve History.

Year	Volumes and purpose of use
2004–05	0
2005–06	513 ML was delivered to the Broken Creek to assist water quality.
2006–07	422 ML was delivered to the Broken Creek. 7,000 ML released onto the Goulburn water market for purchase by local irrigators and urban corporations.
2007–08	1,878 ML was used in the Broken Creek to assist water quality. 10,000 ML supplied to Coliban Water and Central Highlands Water to supplement existing supplies and meet critical water shortages in Bendigo and Ballarat.*
2008–09	2,817 ML was used in the Broken Creek to assist natural break up of a weed infestation (Azolla) and improve dissolved oxygen concentrations. 10,000 ML supplied to Coliban Water and Central Highlands Water to supplement existing supplies and meet critical shortages in Bendigo and Ballarat.*
2009–10	818 ML used to stabilise dissovled oxygen concentrations in the low Broken Creek. 10,000 ML supplied to Melbourne via the Sugarloaf Pipeline (in accordance with Qualification of Rights).

* Coliban Water and Central Highlands Water paid commercial rates for access to additional water, with pricing arrangements agreed by the Minister for Water in accordance with the Qualification of Rights (http://www.g-mwater.com.au/about/reports-and-publications/annualreport/operations-division)

8.1.2 Current water holdings

Commonwealth environmental water holdings (as at October 2010) are summarised in Table 11. Water shares can only be used if sufficient channel capacity to deliver the entitlements is available in the Shepparton or Murray Valley channel systems, because the Australian Government does not hold delivery shares. It should be noted that volumes of Commonwealth environmental water are constantly changing. For the most up to date figures see www.environment.gov.au/ewater.

Figures in Table 11 are based on allocation information from MSM-Bigmod modelling of the Murray River system with The Living Murray deliveries in place (run #22061).

Environmental water currently held by other agencies is summarised in Table 12.

Table 11: Commonwealth environmental water holdings (as at October 2010).

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

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

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

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

Table 12: Environmental water currently held by other agencies.

Water holding	Volume	Comments
Victorian River Murray – **Flora and Fauna** Conversion Order 1999	27,600 ML high reliability water share.	Total available upstream and downstream of the Choke.
Victorian River Murray – Flora and Fauna Conversion Further Amending Order (2009) – **The Living Murray**	40,298 ML low reliability water share. 3,630 ML high reliability water share.	Committed to meet Living Murray objectives but may be useful in transit.
The Living Murray – NSW Murray system	1,887 high security. 134,387 general security. 350,000 ML supplementary. 12,965 ML unregulated.	Unclear how much of this is above or below the Choke. Committed to meet Living Murray objectives, but may be useful in transit.
Environmental Entitlement (Goulburn System – Living Murray) Further Amending Order 2009	141,046 ML of low reliability water shares (sales package). 19,164 ML of high reliability water shares (G-MW recovery package). 20,461 ML of high reliability water shares (Shepparton Irrigation Area modernisation project). 15,780 ML of low reliability water shares (Shepparton Irrigation Area modernisation project).	Committed to meet Living Murray objectives, but may be useful in transit.
Bulk Entitlement (Goulburn System – Snowy Environmental Reserve) Amendment Order 2009	3,900 ML of high reliability water share (pipelining of Normanville waterworks district). 14,812 ML of high reliability water share (Goulburn system improved measurement of small volume supplies to irrigation districts program). 2,000 ML of high reliability water share (Goulburn strategic measurement project).	Generally released along the Goulburn River in summer to supply Murray irrigation demands.
Goulburn River Environmental Entitlement 2010	1,432 ML of high reliability water share (Wimmera-Mallee Pipeline Savings).	Trading zone 1B.
Environmental Entitlement (Goulburn System – Environmental Water Reserve) 2010	Prior to the completion of Stage 1 of the Northern Victoria Irrigation Renewal Project: the volume of water that has been allocated to the environment from the modernisation savings account. After the completion of Stage 1: the volume equivalent to one-third of the total volume saved in the Goulburn component of the Goulburn Murray Irrigation District, with the characteristics of high reliability and low reliability water shares.	Exact volumes to be confirmed after completion of NVIRP works. This entitlement was gazetted but was disallowed in the Victorian Parliament in June 2010.

8.2 Seasonal allocations

Victorian allocations are announced by Goulburn-Murray Water twice monthly and are published at http://www.g-mwater.com.au/news/allocation-announcements/current.asp.

Long-term seasonal allocations are shown for October and April as indicative of spring and autumn in Figures 12 and 13. This information is sourced from the MSM-Bigmod post-TLM run (#22061). These figures indicate that Goulburn system reliability is lower than that of the Victorian Murray system and that the NSW and Victorian Murray systems have slightly different allocation profiles.

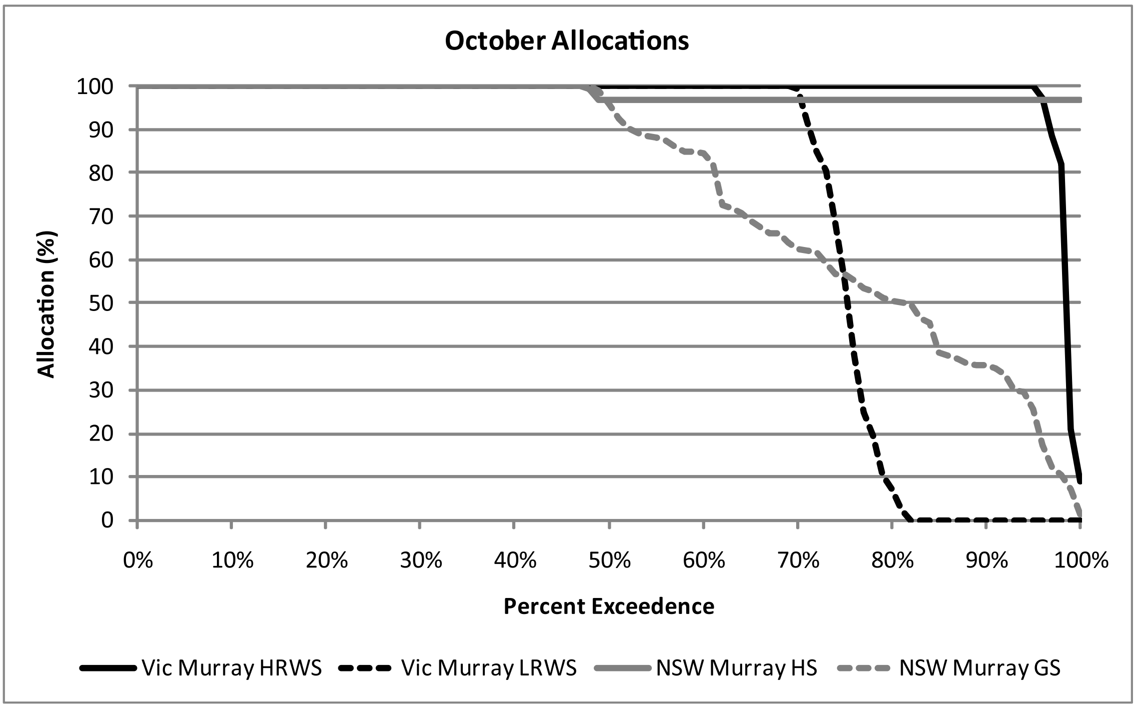

Figure 12: October seasonal allocations for the Murray River and Goulburn systems.

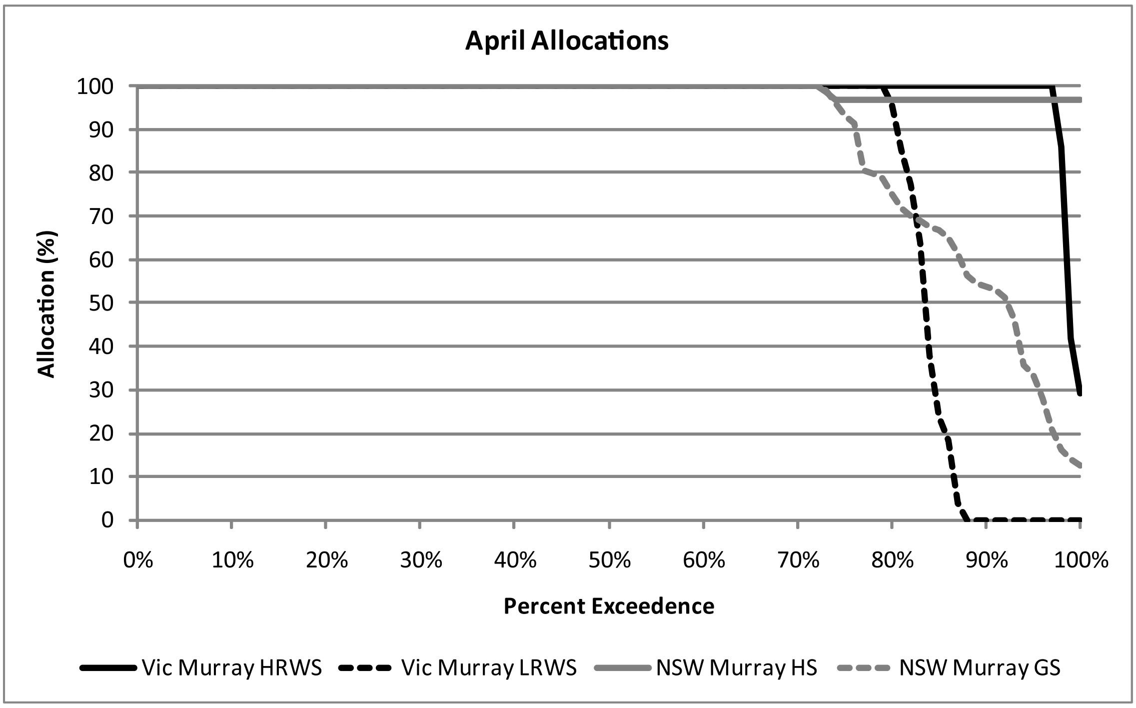

Figure 13: April seasonal allocations for the Murray River, Goulburn and Ovens systems.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 13. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 14.

The calculation of the volume of water expected to be available to the environment under each climate condition is based on the volume and type of entitlements held and the expected announced allocation for each climate condition (from modelling).

Table 13 and Table 14 were provided by SKM and based on allocation information from a MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #22061).

Table 13: Likely allocation against Commonwealth environmental water holdings, under different climate scenarios.

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

Table 14: Likely volume available to the environment from Commonwealth environmental water holdings (as at October 2010).

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

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

8.3 Water availability forecasts

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

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

Additionally, Goulburn-Murray Water publishes a seasonal allocation outlook prior to the start of each irrigation season (generally in February and May if conditions are likely to be dry) providing a forecast for October and February allocations for the following season. The seasonal allocation outlooks are published on Goulburn-Murray Water's website (see Media Releases). Note that in years with high water availability, only the seasonal allocation outlook may be prepared (i.e. water availability forecasts may not be provided with allocation announcements).

PART 3
Monitoring and future options

9. Monitoring, evaluation, and improvement

9.1 Existing monitoring programs and frameworks

Water quality and quantity is monitored as part of the Victorian Water Quality Monitoring Network. As well as flow monitoring at the three sites listed in Table 15, water quality parameters are measured on a monthly basis at Rice's Weir (site 404210) and Katamatite (site 404214). Parameters measured include: colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidised nitrogen, pH, total phosphorus and turbidity.

In addition, the GB CMA undertakes continuous DO monitoring at Rice's Weir. Two sets of probes, each monitoring surface and bottom DO and temperature, are deployed to provide spatial coverage of conditions in the weir. This allows the GB CMA and G-MW to respond to the onset of low DO conditions by increasing flow delivered to the Lower Broken Creek from the Murray River via the Murray Valley Irrigation Area, or from the Goulburn River via the East Goulburn Main Channel. Wind speed and direction and air temperature are also recorded, along with hourly photographs of Azolla disposition.

Goulburn-Murray Water also has dissolved oxygen and temperature probes at Rice's Weir and Hardings Weir.

Fishways have been established at all weirs along Lower Broken Creek between Nathalia and the Murray River and at the two weirs at Katandra. Fish populations along the creek have been monitored for a number of years to assess the effectiveness of the fishways in allowing movement, as well as the changes to the distribution of fish as a result (O'Connor and Amtstaetter 2008).

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established to evaluate ecosystem response to the delivery of environmental flow components in regulated rivers across northern Victoria. While the Broken River was included in VEFMAP (Chee et al. 2006), Lower Broken Creek was not, as there were no specific environmental flow recommendations for the creek at the time VEFMAP was developed.

9.2 Operational water delivery monitoring

Water delivery monitoring arrangements are summarised in section 9.2.1. In addition, the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has a pro forma Environmental Watering Program Operational Monitoring Report to capture operational information related to releases (included at Appendix 3).

9.2.1 Flow monitoring sites

Three long-term stream flow gauges are located within the Lower Broken Creek area (Table 15). The Boosey Creek at Tungamah (404204) and Broken Creek at Katamatite (404214) gauges are located upstream of the confluence of the Broken Creek and Boosey Creek, while the Broken Creek at Rice's Weir (404210) gauge is located upstream of the confluence with the Murray River.

The flow records for each of the three gauges begin in the mid-1960s (Figure 14; Figure 8). The records for the Boosey Creek at Tungamah and the Broken Creek at Katamatite are generally of good quality. In contrast, there is much data missing from the Broken Creek at Rice's Weir record. Some of these missing periods coincide with floods along the Murray River, when water would have backed up Broken Creek and drowned out the gauging station.

The MDBA can also supply a daily time-series of modelled flows past Rice's Weir, assuming current conditions. The current modelled time-series provided is a combination of gauged and infilled data.

Table 15: Flow monitoring in the Lower Broken Creek system.

Site number	Site name	Relevance
404204	Boosey Creek at Tungamah	Flow from Boosey Creek to Lower Broken Creek
404214	Broken Creek at Katamatite	Flow from Upper to Lower Broken Creek
404210	Broken Creek at Rice's Weir	Flow from Broken Creek to Murray River

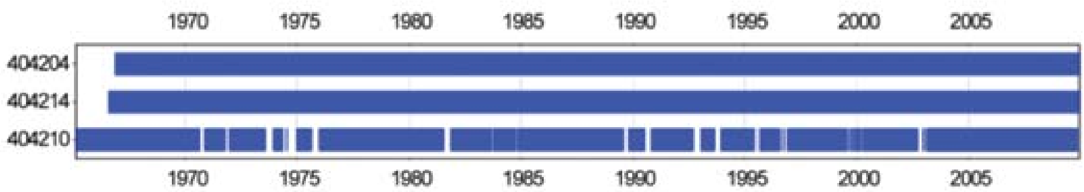

Figure 14: Extent of streamflow data available.

Goulburn-Murray Water have measured flows under regulated conditions passed though each weir on a continuous basis, commencing in the late 1990s to early 2000s.

Data on inflows to the Lower Broken Creek and Nine Mile Creek through outfall structures and drains are available from Goulburn-Murray Water and Thiess (Table 16 and Table 17). For the outfalls, data is only readily available for irrigation seasons from 1997–98 onwards. The 2000–2001 data is missing for the Murray Valley Irrigation Area, and the 1998–99 data is missing for the Shepparton Irrigation Area. For the drains, gauged data is available for the Muckatah drain, Shepparton Drain 12 and Shepparton Drain 11. No data is available for the remaining drains.

Table 16: Outfall structures currently discharging directly to the Lower Broken Creek and Nine Mile Creek. Some structures will be decommissioned as part of NVIRP works (Figure 1).

Asset Code	Asset Name	Data Source
ST066229	7/3	G-MW (Murray Valley)
ST072180	3 Main	G-MW (Murray Valley)
ST041815	4 Main	G-MW (Murray Valley)
ST057773	5/3	G-MW (Murray Valley)
ST056529	6/6	G-MW (Murray Valley)
ST056668	8/6	G-MW (Murray Valley)
ST056597	4/8/6	G-MW (Murray Valley)
ST066584	15/6	G-MW (Murray Valley)
ST058403	Jewells (21A/6)	G-MW (Murray Valley)
ST056428	Flanners (26A/6)	G-MW (Murray Valley)
ST056447	End 6 Main	G-MW (Murray Valley)
ST043762	EGM Outfall	G-MW (Shepparton)
ST018998	EG.34 Union Rd	G-MW (Shepparton)
ST019005	EG.34 End	G-MW (Shepparton)
ST045754	EG.12 No 1 (Hicks)	G-MW (Shepparton)
ST046200	EG.38/12 Town Spur	G-MW (Shepparton)
ST045802	EG.12 No 2 (Hollands)	G-MW (Shepparton)

Table 17: Drains discharging to the Lower Broken Creek and Nine Mile Creek.

Asset Name	Data Source
Muckatah Drain	Thiess (404712)
Murray Valley Drain 20	Not available
Murray Valley Drain 19	Not available
Murray Valley Drain 18	Not available
Murray Valley Drain 17	Not available
Murray Valley Drain 13	Not available
Shepparton Drain 16	Not available
Shepparton Drain 15	Not available
Shepparton Drain 13	Not available
Shepparton Drain 13A	Not available
Shepparton Drain 12	Thiess (405758)
Shepparton Drain 11	Thiess (405757)

9.3 Key parameters for monitoring and evaluating ecosystem response

The environmental management objectives for Lower Broken Creek are to maintain water quality in order to protect native fish populations. Monitoring of Azolla, DO and flow through the system is well established. The information being collected also complements scientific research on the conditions that lead to the onset of stratification and decline in DO along the Lower Broken Creek.

The flow regime proposed for Lower Broken Creek also aims to maintain habitat for native fish and allow fish passage through weirs. Fish populations are currently monitored to assess the extent to which fish are moving through the fishways and colonising different sections of the creek.

9.4 Improved understanding of DO processes

The Murray-Darling Freshwater Research Centre has investigated the growth of Azolla and factors that contribute to dissolved oxygen levels in weir pools along Lower Broken Creek (Rees et al. 2008). This work found that sediment oxygen demand was high in locations such as Rice's Weir and that DO could be reduced close to 0 mg/L at depth. The presence of Azolla exacerbated the DO decline.

It is not clear if the recent (October 2010) high flows have had an effect on the sediments in weir pools along Broken Creek, and if this in turn has affected sediment oxygen demand. Such investigation, along with that of nutrient load and nutrient dynamics, could result in an improved understanding of the factors contributing to low DO in the creek, as well as an understanding of whether managing the flow regime remains the most effective means of managing water quality.

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11. Appendix 1: Key species and communities

Table 18: Key species in the Lower Broken Creek system.

Fauna type	Common name	Scientific name	EPBC Act[1]	Flora and Fauna Guarantee Act[2]	DSE advisory list[3]	Waterway setting[4]
Fish	Bluenose (Trout) cod	*Maccullochella macquariensis*	Endangered	Listed	Critically endangered	-
Fish	Freshwater catfish	*Tandanus tandanus*	-	Listed	Endangered	-
Fish	Golden perch	*Macquaria ambigua*	-	-	Vulnerable	-
Fish	Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	-	Listed	Data deficient	-
Fish	Macquarie perch	*Macquaria australasica*	Endangered	Listed	Endangered	-
Fish	Murray cod	*Maccullochella peelii peelii*	Vulnerable	Listed	Endangered	-
Fish	Silver perch	*Bidyanus bidyanus*	-	Listed	Critically endangered	-
Amphibians	Giant bullfrog	*Limnodynastes interioris*	-	Listed	Critically endangered	-
Amphibians	Growling grass frog	*Litoria raniformis*	Vulnerable	Listed	Endangered	-
Plants	Slender water-milfoil	*Myriophyllum gracile var. lineare*	-	Listed	Endangered	Aquatic
Plants	Ridged water-milfoil	*Myriophyllum porcatum*	Vulnerable	Listed	Vulnerable	Aquatic
Plants	Slender water-ribbons	*Triglochin dubia*	-	-	Rare	Aquatic
Plants	Pale spike-sedge	*Eleocharis pallens*	-	-	Poorly known	Seasonally flooded
Plants	Slender club-sedge	*Isolepis congrua*	-	Listed	Vulnerable	Seasonally flooded
Plants	River swamp wallaby-grass	*Amphibromus fluitans*	Vulnerable	-	-	Waterway margin
Plants	Western water-starwort	*Callitriche cyclocarpa*	Vulnerable	Listed	Vulnerable	Waterway margin
Plants	Winged water-starwort	*Callitriche umbonata*	-	-	Rare	Waterway margin

Fauna type	Common name	Scientific name	EPBC Act[1]	Flora and Fauna Guarantee Act[2]	DSE advisory list[3]	Waterway setting[4]
Plants	Riverina bitter-cress	*Cardamine moirensis*	-	-	Rare	Water way margin
Plants	Long eryngium	*Eryngium paludosum*	-	-	Vulnerable	Waterway margin
Plants	Small-flower mud-mat	*Glossostigma cleistanthum*	-	-	Rare	Waterway margin
Plants	Bluish raspwort	*Haloragis glauca f. glauca*	-	-	Poorly known	Waterway margin
Plants	Swamp star	*Hypoxis exilis*	-	-	Vulnerable	Waterway margin
Plants	Button rush	*Lipocarpha microcephala*	-	-	Vulnerable	Waterway margin
Plants	Leafless bluebush	*Maireana aphylla*	-	-	Poorly known	Waterway margin
Plants	Smooth minuria	*Minuria integerrima*	-	-	Rare	Waterway margin
Plants	Striped water- milfoil	*Myriophyllum striatum*	-	Listed	Vulnerable	Waterway margin
Plants	Large river buttercup	*Ranunculus papulentus*	-	-	Poorly known	Waterway margin
Plants	Annual buttercup	*Ranunculus sessiliflorus var. pilulifer*	-	-	Poorly known	Waterway margin

[1] Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth).
[2] Flora and Fauna Guarantee Act 1988 (Victoria).
[3] Advisory List of Rare or Threatened Plants in Victoria – 2005. This list is maintained by the Victorian Department of Sustainability and Environment to inform land management. This is not a statutory list and there are no legal requirements associated with a species' inclusion on the list (DSE 2005, DSE 2007).
[4] Waterway setting was assigned based on species descriptions from PlantNet (Royal Botanic Gardens and Domain Trust 2011).

Table 19: Ecological vegetation classes in the Lower Broken Creek system.

Vegetation Community	Structural Characteristics
56. Floodplain Riparian Woodland	An open eucalypt woodland or open forest to 20 metres tall over a medium to tall shrub layer with a ground layer consisting of amphibious and aquatic herbs and sedges. Occurs along the banks and floodplains of the larger meandering rivers and major creeks, often in conjunction with one or more floodplain wetland communities. Elevation and rainfall are relatively low and soils are fertile alluviums subject to periodic flooding and inundation.
68. Creekline Grassy Woodland	Grass-dominated eucalypt woodland to 15 metres tall with a range of amphibious herbs. Occurs along banks and adjacent wet flats of smaller intermittent creeks on coarse sands and stony alluvial soils and on the floodplains of larger rivers, in areas where annual rainfall is greater than 500 millimetres per annum.

Vegetation Community	Structural Characteristics
74. Wetland Formation	A broad EVC that incorporates a range of freshwater wetlands as listed below in the table. Occurs in topographic depressions associated with standing water ranging from permanent to ephemeral water bodies. Structurally, this EVC can consist of herbland, sedgeland and rushland elements and is characterised by the lack of woody plants (shrubs and trees).
106. Grassy Riverine Forest	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are infrequent, on deposited silts and sands, forming fertile alluvial soils. river red gum forest to 25 metres tall with a groundlayer dominated by graminoids. Occasional tall shrubs present.
125. Plains Grassy Wetland	This EVC is usually treeless, but in some instances can include sparse black box eucalyptus largiflorens or river red gum Eucalyptus camaldulensis. A sparse shrub component may also be present. The characteristic ground cover is dominated by grasses and small sedges and herbs. The vegetation is typically species-rich on the outer verges but is usually species-poor in the wetter central areas.
168. Drainage-line Aggregate	An aggregate of eight EVCs. A detailed description can be found at: http://www.dpi.vic.gov.au/DSE/nrence.nsf/LinkView/47DB7187972C9AD1CA256F1F0022D6DD8062D358172E420C4A256DEA0012F71C#agg
259. Plains Grassy Woodland/Gilgai Wetland Mosaic	N/A
264. Sand Ridge Woodland	Open pine-box woodland to 15 metres tall with a small or medium shrub layer of variable density and including a range of annual herbs, grasses and geophytes, in the dense ground layer. Occupies distinctive sandy rises (or sand mounts) adjacent to major rivers and wetlands. Very sandy, deep, free draining, moderately fertile soil, developed on sand blown up by wind action from a prior stream bed.
292. Red Gum Swamp	Open woodland to 15 metres tall with a diverse understorey dominated by sedgy or grassy-herbaceous aquatics and species tolerant of intermittent to seasonal inundation. Occurs on alluvial plains in the seasonally wet depressions of shallow drainage lines or prior stream meanders, typically associated with heavy paludal soils, sometimes with gilgai development. The annual rainfall across its distribution is generally below 700 millimetres, and the period of inundation may range from two to six months.
803. Plains Woodland	Grassy or sedgy woodland to 15 metres tall (typically dominated by eucalyptus largiflorens in the north-western part of its range) with large inter-tussock spaces potentially supporting a range of annual or geophytic herbs adapted to low summer rainfall, with low overall biomass. Mostly occurs on terrain of low relief in areas receiving <600 millimetres rainfall per annum. Fertile, sometimes seasonally waterlogged, mostly silty, loamy or clay topsoils, with heavy subsoils, derived largely from recent (ie Quaternary) fluvial or alluvial deposits.
814. Riverine Swamp Forest	Open eucalypt forest to 25 metres tall with understorey dominated by obligate wetland species (or opportunistic annuals during sustained dry periods) and can range from closed sedgeland or herbland to grassy-herbaceous or extremely sparse and with cover primarily leaf-litter, blackwater or exposed alluvium. Occupies low-lying areas subject to reasonably regular flooding, typically flood-prone lower river terraces and low-lying areas adjacent to floodways through or within riverine forest.
816. Sedgy Riverine Forest	Eucalypt forest to 25 metres tall with understorey dominated by larger sedges. Understorey composition indicative of at least occasional shallow flooding and a tolerance of gaps between floods of several years. Typically on heavy soils which can become wet in winter. Sedgy Riverine Forest has some floristic affinities to Red Gum Swamp. It is considered to occupy areas infrequently flooded and in which flood duration may be short, for example, higher ground surrounding the box ridges or occurring along the river levee in a position remote from the channels from which the forest first floods. These areas are therefore the last to flood and the first from which floods quickly recede. Soils are typically heavy clays. The major understorey species *Carex tereticaulis* is intolerant of total immersion (at least in turbid water).

Vegetation Community	Structural Characteristics
817. Sedgy Riverine Forest/Riverine Swamp Forest Complex	Eucalypt forest to 25 metres tall with understorey dominated by larger sedges. Understorey composition indicative of at least occasional shallow flooding and a tolerance of gaps between floods of several years. Typically on heavy soils which can become wet in winter. Sedgy Riverine Forest has some floristic affinities to Red Gum Swamp. It is considered to occupy areas infrequently flooded and in which flood duration may be short, for example, higher ground surrounding the box ridges or occurring along the river levee in a position remote from the channels from which the forest first floods. These areas are therefore the last to flood and the first from which floods quickly recede. Soils are typically heavy clays. The major understorey species *Carex tereticaulis* is intolerant of total immersion (at least in turbid water).
867. Shallow Sands Woodland/Plains Woodland Mosaic	Woodland or open-forest to 15 metres tall, with a sparse shrub layer of heathy, ericoid shrubs and a species-rich ground cover dominated by grasses and annual herbs. Typically it occurs between the heavier soils of the plains and the deep-sand aeolian dunefields which overlay these plains, but also occurs on broader areas of plains covered by shallow fluvial, outwash or aeolian sands overlaying drainage-impeding clays.
869. Creekline Grassy Woodland/ Red Gum Swamp Mosaic	Grass-dominated eucalypt woodland to 15 metres tall with a range of amphibious herbs. Occurs along banks and adjacent wet flats of smaller intermittent creeks on coarse sands and stony alluvial soils and on the floodplains of larger rivers, in areas where annual rainfall is greater than 500 millimetres per annum.
873. Riverine Grassy Woodland/ Riverine Chenopod Woodland/ Wetland Mosaic	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. River red gum woodland to 20 metres tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs.
882. Shallow Sands Woodland	Woodland or open-forest to 15 metres tall, with a sparse shrub layer of heathy, ericoid shrubs and a species-rich ground cover dominated by grasses and annual herbs. Typically it occurs between the heavier soils of the plains and the deep-sand aeolian dunefields which overlay these plains, but also occurs on broader areas of plains covered by shallow fluvial, outwash or aeolian sands overlaying drainage-impeding clays.
1040. Riverine Grassy Woodland/ Riverine Swampy Woodland Mosaic	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. RIver red gum woodland to 20 metres tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs.
1050. Mosaic of Floodplain Grassy Wetland/Grassy Riverine Forest-Riverine Swamp Forest Complex	Wetland dominated by floating aquatic grasses (which persist to some extent as turf during drier periods), occurring in the most flood-prone riverine areas. Typically treeless, but sometimes with thickets of saplings or scattered more mature specimens of *Eucalyptus camaldulensis*. Occupies temporary shallow lakes in the most flood-prone riverine areas, also occurs as a narrow intermediate band around some floodway ponds.
1068. Riverine Swamp Forest/Sedgy Riverine Forest Mosaic	Open eucalypt forest to 25 metres tall with understorey dominated by obligate wetland species (or opportunistic annuals during sustained dry periods) and can range from closed sedgeland or herbland to grassy-herbaceous or extremely sparse and with cover primarily leaf-litter, black water or exposed alluvium. Occupies low-lying areas subject to reasonably regular flooding, typically flood-prone lower river terraces and low-lying areas adjacent to floodways through or within riverine forest.

12. Appendix 2: Spare channel capacity

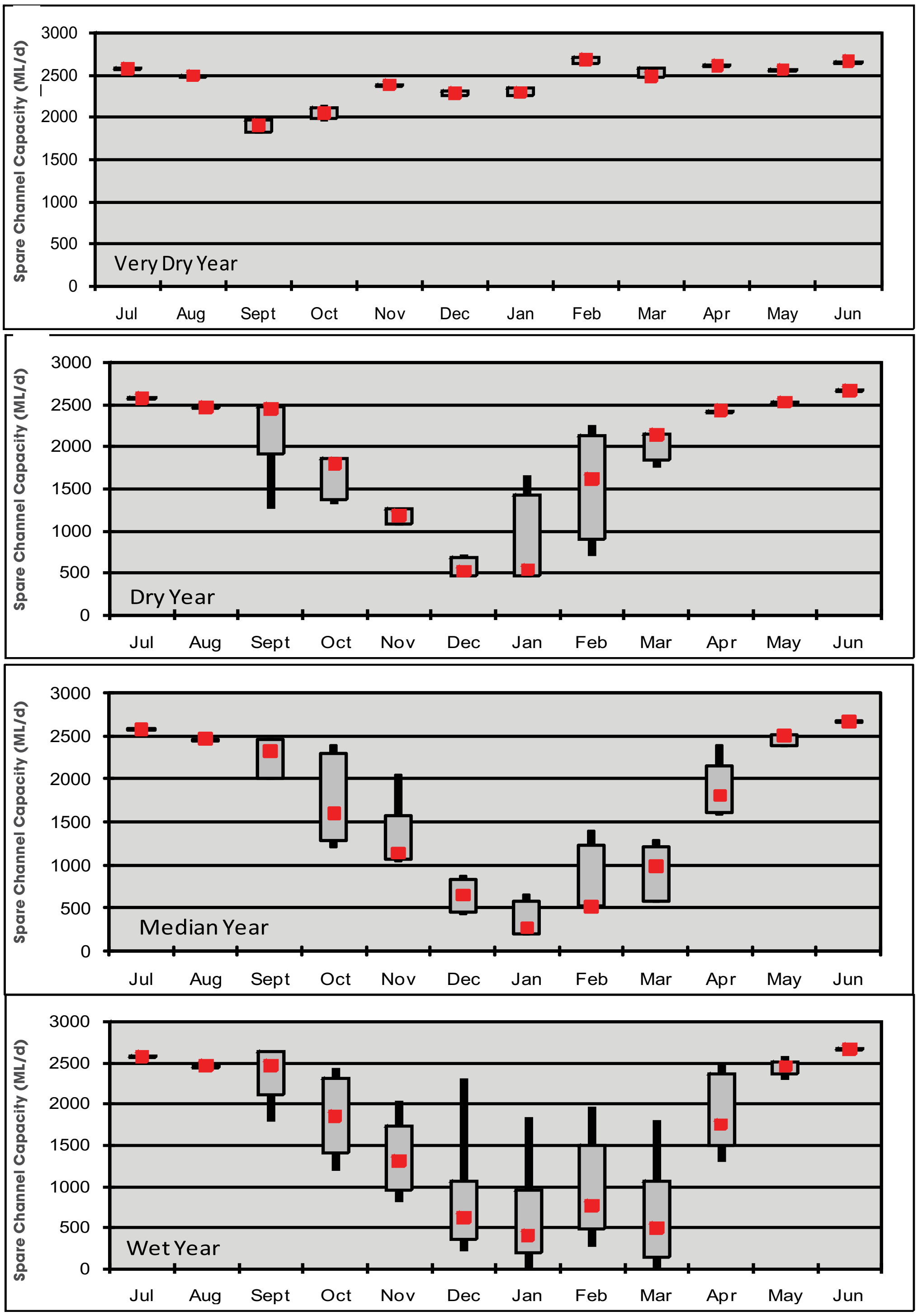

Figure 15: Spare channel capacity in the East Goulburn Main offtake, 1891–2009.

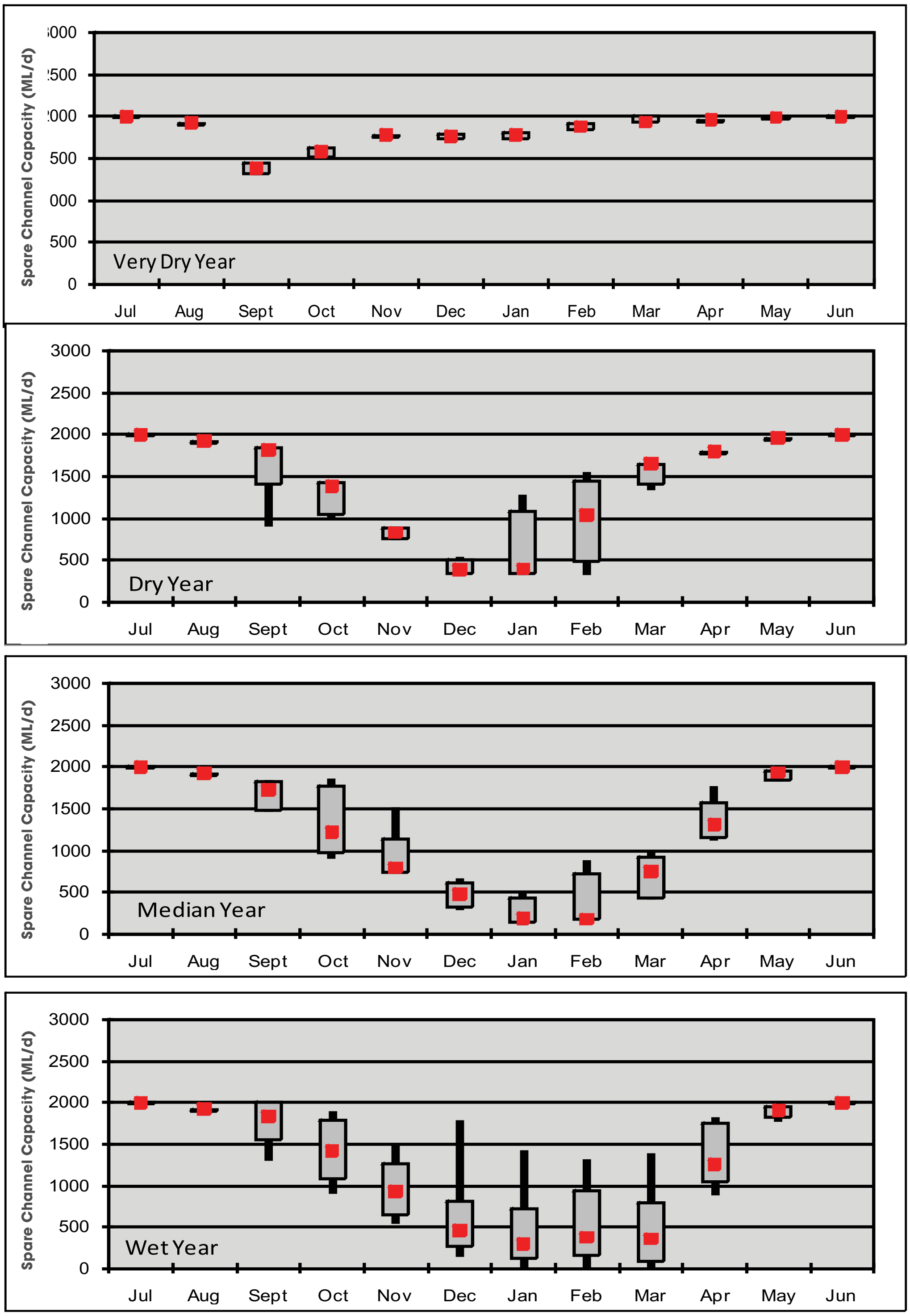

Figure 16: Spare channel capacity in the East Goulburn Main Syphon, 1891–2009.

13. Appendix 3: Operational Monitoring Report

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

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

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

14. Appendix 4: Risk assessment framework

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

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