FINAL RECOMMENDATIONS

Determination of environmental flow requirements for the Yea River

February 2008

Document history

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1	S. Morath (GBCMA) P. Boon, T. Doeg, R. Hardie, C Arnott (Technical Panel)	Preliminary recommendations for review by Technical Panel and Advisory Group
2	S. Morath (GBCMA) P. Boon, T. Doeg, R. Hardie, C Arnott (Technical Panel)	Final report incorporating comments from Technical Panel and GBCMA and Steering Committee and community stakeholders.

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Abbreviations and glossary of terms

ARI	Average Recurrence Interval
AusRivAS	Australian Rivers Assessment System
Current flows	Long-term flow series simulating 2004-2005 levels of private diversion usage and farm dam development
CFA	Country Fire Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CV	Coefficient of Variation
DNRE	Department of Natural Resources and Environment
DSE	Department of Sustainability and Environment
ECOS	Ecos Consulting Aust Pty Ltd
EPA	Environmental Protection Agency
EPBC Act	Environment Protection and Biodiversity Conservation Act
EVC	Ecological Vegetation Class
FFG	Flora and Fauna Guaranteed Species
FLOWS	FLOWS method for determining environmental water requirements
Fully impacted flows	Long-term flow series simulating demands equal to a fully utilised licence volume
GBCMA	Goulburn Broken Catchment Management Authority
GIS	Geographical Information System
GVW	Goulburn Valley Water
Historic flows	Long-term flow series simulating demands developed from natural conditions to 2004-2005
Hydraulic roughness	Refer to Manning's 'n'
Independence of flow events	Where a flow series is being assessed for the recurrence of a particular flow event that exceeds a threshold magnitude, an independence criteria is applied (in this case 10 days). If the flow drops below the threshold magnitude for less than 10 days, the two peaks above the threshold are not considered to be 'independent' and will only be counted as a single event.
ISC	Index of Stream Condition
Ma	Million years ago
Manning's 'n'	The Manning coefficient of hydraulic roughness, often denoted as *n*, is an empirically derived coefficient, which is dependent on many factors, including river-bottom roughness and sinuosity. Values typically range between 0.02 for smooth and straight rivers, to 0.075 for sinuous rivers and creeks with excess debris on the river bottom or river banks.
MDF	Mean Daily Flow
NTU	Nephelometric Turbidity Units, a unit comparing the amount of light transmitted straight through water with the amount scattered at 90^0

REALM	Resource Allocation Model
SEPP	State Environment Protection Policy
SFMP	Streamflow Management Plan
SIGNAL	Stream Invertebrate Grade Number Average Level
SKM	Sinclair Knight Merz Pty Ltd
Total station and differential GPS	An optical instrument used in surveying. It is a combination of an electronic theodolite (transit), an electronic distance measuring device (EDM) and software running on an external computer. Differential Global Positioning System (DGPS) is an enhancement to Global Positioning System that uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions to provide a higher level of survey accuracy.
Unimpacted flows	Long-term flow series simulating current landuse practices, without man made diversions, demands or impoundments

Flow components used in this Recommendations Report and their definitions are provided below. A graphical representation of flow components is also provided in Figure 1. More detailed explanation of these flow components can be found in the *Victorian River Health Strategy* (2002b)

Cease to flow	No discernible flow in the river, or no measurable flow recorded at a gauge.
Low flow	Flow that generally provides a continuous flow through the channel.
Low flow freshes	Small and short duration peak flow events that exceed the baseflow (low flow) and last for at least several days. Usually in summer and autumn in Victoria.
High flow	Persistent increases in the seasonal baseflow that remain within the channel.
High flow freshes	Small and short duration peak flow events that exceed the baseflow (high flow) and last for at least several days. Usually in winter and spring in Victoria.
Bankfull flow	Completely fill the channel, with little flow spilling onto the floodplain.
Overbank flow	Flows greater than bankfull which result in surface flow on the floodplain habitats.

Figure 1 Illustrative guide to flow components (DSE, 2006).

Note: Generic only, flows in Figure 1 do not relate to actual flows in the Yea River.

1 Introduction

Alluvium Consulting Pty Ltd (Alluvium) has been engaged by the Goulburn Broken Catchment Management Authority (GBCMA) to undertake the determination of environmental flow requirements for the Yea River using the Statewide FLOWS method (NRE, 2002).

The Yea River was identified by the Victorian Government in *Our Water Our Future* as one of the priority flow-stressed unregulated catchments across Victoria for the development of a Stream Flow Management Plan (SFMP). SFMPs are a key tool in the Victorian water allocation framework that aim to provide a balanced and sustainable sharing of stream flows between all water users in unregulated catchments. The SFMP requires provision of a flow regime sufficient to ensure vital river ecosystems remain viable for the benefit of current and future generations. The FLOWS method has been developed to determine the magnitude and timing of various components in the flow regime.

The FLOWS method comprises 3 key stages:

1. Data Collection – a review of existing literature and identification of study reaches (**Site Paper**)
2. Issues – an assessment of environmental values and threats informs setting environmental objectives for study reaches (**Issues Paper**)
3. Recommendations – determination of minimum environmental flows required to meet the environmental objectives in each reach (**Recommendations Report**)

This Recommendations Report describes the findings of the third stage in the application of the FLOWS method. This Recommendations Report (Part 3) should be read in conjunction with Parts 1 (Site Paper) and Part 2 (Issues Paper) which provide additional catchment context and justification for the recommendations provided in this report.

1.1 Summary findings

Preliminary recommendations for all four reaches of the Yea River catchment are summarise below in Table 1.

Table 1 Preliminary environmental flow recommendations for the Yea River catchment

		ENVIRONMENTAL FLOW RECOMMENDATIONS			
FLOW COMPONENT	**SEASON**	**REACH 1 Lower Yea**	**REACH 2 Mid Yea**	**REACH 3 Upper Yea**	**REACH 4 Murrindindi**
Low flow	Dec - May	50 ML/d or natural	20 ML/d or natural	7 ML/d or natural	20 ML/d or natural
Low flow fresh	Dec - May	180 ML/d 2 / season or natural 3 day duration or natural	90 ML/d 2 / season or natural 3 day duration or natural	20 ML/d 4 / season or natural 3 day duration or natural	90 ML/d 2 / season or natural 3 day duration or natural
				50 ML/d 1 / season or natural 3 day duration or natural	

		ENVIRONMENTAL FLOW RECOMMENDATIONS			
FLOW COMPONENT	**SEASON**	**REACH 1 Lower Yea**	**REACH 2 Mid Yea**	**REACH 3 Upper Yea**	**REACH 4 Murrindindi**
High flow	Jun - Nov	180 ML/d or natural	90 ML/d or natural	20 ML/d or natural	60 ML/d or natural
High flow fresh	Jun - Nov	780 ML/d 2 / season or natural 14 day duration or natural	430 ML/d 2 / season or natural 14 day duration or natural	100 ML/d 2 / season or natural 14 day duration or natural	350 ML/d 2 / season or natural 4 day duration or natural
Bankfull	Any	3460 ML/d 1 / year or natural 1 day duration or natural	1500 ML/d 2 / year or natural 1 day duration or natural	800 ML/d 1 / year or natural 1 day duration or natural	500 ML/d 1 / year or natural 1 day duration or natural
Overbank	Any	4060 ML/d 1 / year or natural 1 day duration or natural	2500 ML/d 1 / year or natural 1 day duration or natural	2000 ML/d 1 / year or natural 1 day duration or natural	700 ML/d 1 / 4 years or natural 1 day duration or natural

Where the recommended base flows could be compared against the current flow regime (Reaches 2, 3, 4), the recommendations were generally being achieved. As can be seen in Table 2, the low flow and high flow recommendations are being met at worst 85% of the time when compared against the current flow regime. Analysis of the 'event' based recommendations such as freshes and bankfull/overbank flows, shows that these generally occur at least as frequently as the recommended recurrence interval, however they tend to have longer durations. This means that there may be opportunities for consumptive water use following provision of the environmental requirements on the receding limb of these flow peaks.

It is important to note the potential errors associated with accuracy of the hydrology in this catchment. Additional streamflow gauges (as recommended in Section 7) will greatly improve the confidence with this type of analysis and the degree to which environmental recommendations are currently being achieved.

Table 2 Comparison of recommended base flows to current flow regime

BASE FLOW	REACH 1	REACH 2	REACH 3	REACH 4
Low flow	N/A	94%	85%	100%
High flow	N/A	86%	89%	99%

Based upon this analysis, the flow recommendations for the Yea River look achievable, however there is likely to be a need to manage base flows carefully in Reaches 2 and 3. The ultimate environmental flow regime will be determined through the SFMP process.

1.2 Structure of report

This report is separated into the following sections:

Section 1 Introduction
Provides a brief overview of the purpose of the report.

Section 2 Environmental flow determination

Outlines the approach to developing the environmental flow recommendations. This includes discussion of model calibration and sensitivity analyses.

Section 3- 6 Environmental flow recommendations

For each reach, the discussion is presented in the following format:

- Summarises the characteristics, assets, threats and environmental objectives for each study reach.
- Flow parameters and hydraulic criteria
- Environmental flow recommendations
- Notes
- Compliance with unimpacted and current flows

Section 7 Supporting recommendations

Outlines the complementary works required for the environmental objectives to be met.

2 Environmental flow determination

2.1 Approach to determining environmental flows

This project follows the FLOWS method (NRE, 2002) for determining environmental flow requirements. It has been applied to four reaches in the Yea River. Reach breaks are depicted below in Figure 2 (note that one reach includes the Murrundindi River – a tributary of the Yea).

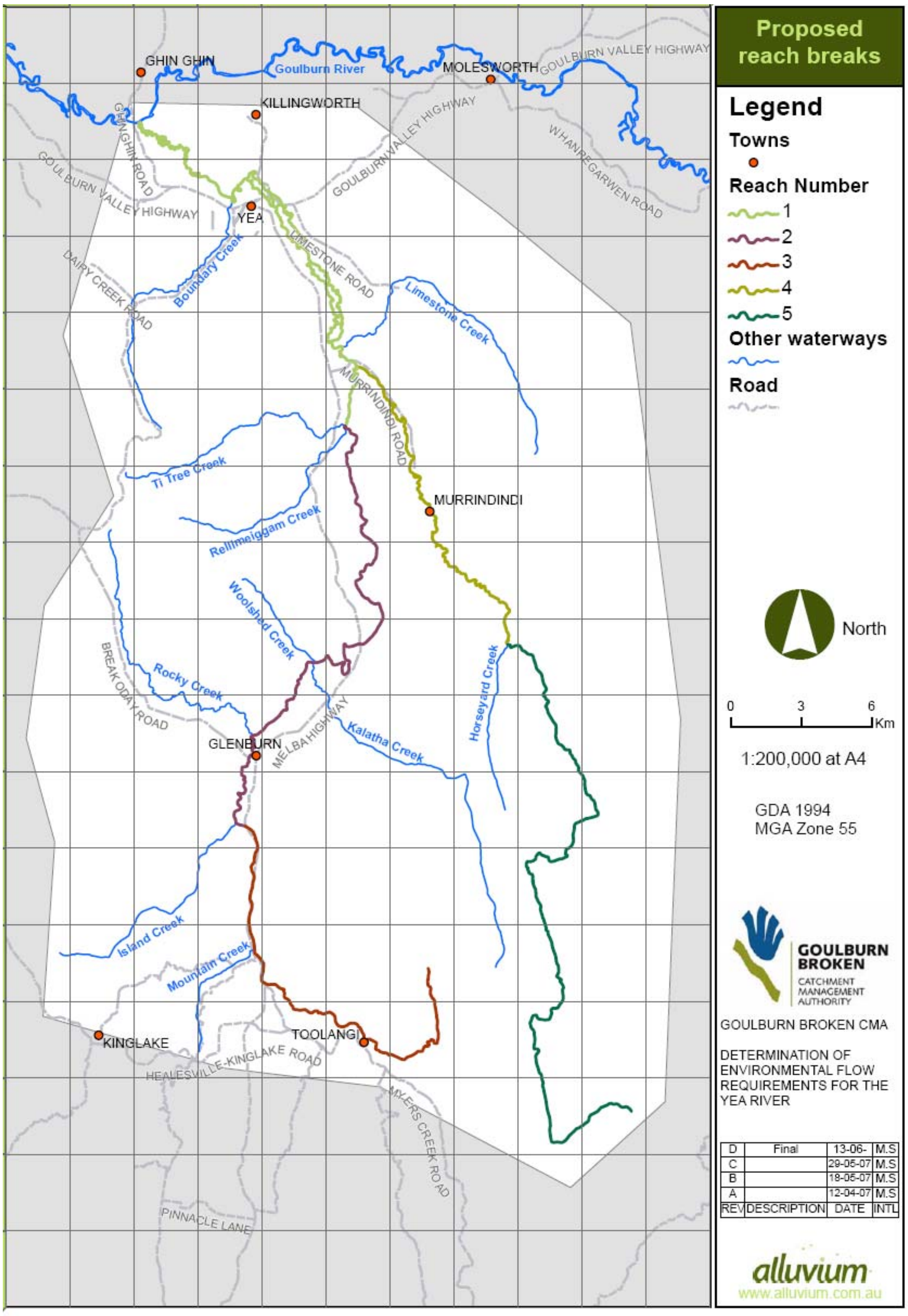


Figure 2 Study reach breaks

More detail on the catchment and the justification for the reach breaks can be found in the Site Paper (Stacey & Wealands, 2007). A fifth reach (Reach 5) shown in Figure 2 covers the upper Murrundindi River. This was not included for detailed flows analysis due to its relatively unimpacted condition. More justification for the exclusion of Reach 5 can be found in the Site Paper (Stacey & Wealands, 2007). Additional detail on the values, threats and general observations about each of the reaches can be found in the Issues Paper (Wealands et al, 2007).

The approach to the survey, hydraulic modelling and environmental flow determination for the reaches are discussed in the following sections.

2.2 Hydraulic modelling

Representative sites in each reach that commonly reflect the reach characteristics were selected by the Technical Panel during field inspections on 21 and 22 June 2007. The sites were chosen because they contained features that were common across the reach and thus reflected characteristics of the reach as a whole. Note that it is common practice in FLOWS determinations to have one representative site per reach. Locations of survey cross sections were then identified by the Technical Panel, pegged and the survey requirements specified. These cross section locations were selected to best represent the features of the channel (pools, runs, riffles, benches etc) in the hydraulic model. Between 6 and 10 cross sections were surveyed at each representative site.

Due to high flows being present during the field inspections in late June 2007, additional inspections were completed and survey postponed until flows had reduced in October 2007.

Cross section survey was undertaken from 2 to 26 October 2007 by Reed and Reed Surveying using a total station and differential GPS. Proportionally more points were surveyed in the low flow channel than in the floodplain (Figure 3) in order to ensure a greater level of confidence in low flow recommendations which are often the most problematic and contentious in FLOWS determinations.

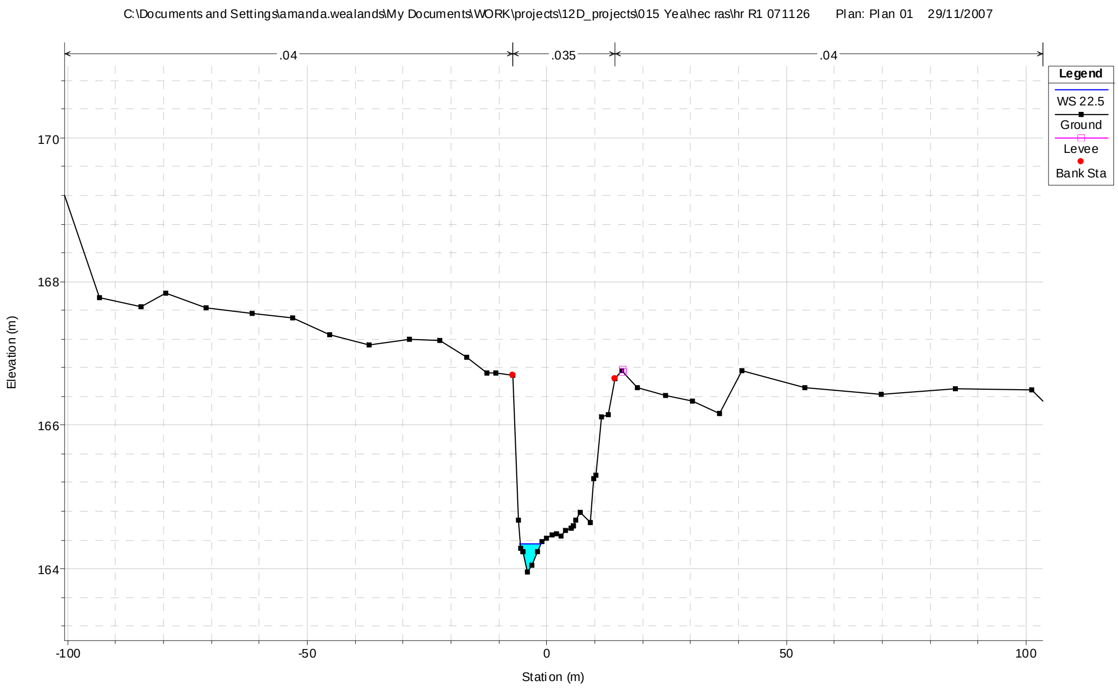


Figure 3 Survey cross section (Reach 1, chainage 2) showing concentration of points in channel

The cross-section survey was then imported into the digital terrain modelling package 12D, which was then used to generate one dimensional hydraulic models (using HEC RAS) of each reach.

There are three primary variables in HEC RAS modelling:

i) channel geometry (from survey data);

ii) downstream boundary condition (rating curve from gauge or downstream slope); and

iii) hydraulic roughness (Manning's *n*).

Table 3 lists the boundary condition and hydraulic roughness adopted for each model. These parameters were adopted on the basis of field observations and results from various model calibration runs.

Table 3 Hydraulic parameters adopted in HEC RAS models

HYDRAULIC PARAMETERS		REACH 1	REACH 2	REACH 3	REACH 4
Manning's roughness	Channel	0.035 – 0.07	0.04 - 0.15	0.1	0.05 – 0.09
	Floodplain	0.04	0.1	0.15	0.03
Downstream slope		0.00078 m/m	0.00067 m/m	0.0117 m/m	0.00045 m/m

2.3 Calibration of the Hydraulic Model

The HEC RAS models were calibrated to the water-surface elevations recorded on the day of survey. In Reaches 1 and 3, which did not have an active streamflow gauge present (Reaches 1 and 3), the flow on the day was estimated by plotting the modelled daily flow (SKM, 2007) at the ungauged reach against the flow at streamflow gauge 405 217 – Yea River @ Devlins Bridge (Figure 4). As shown in Figure 4, there was a good relationship between flows at the two stations, especially at higher flow rates.

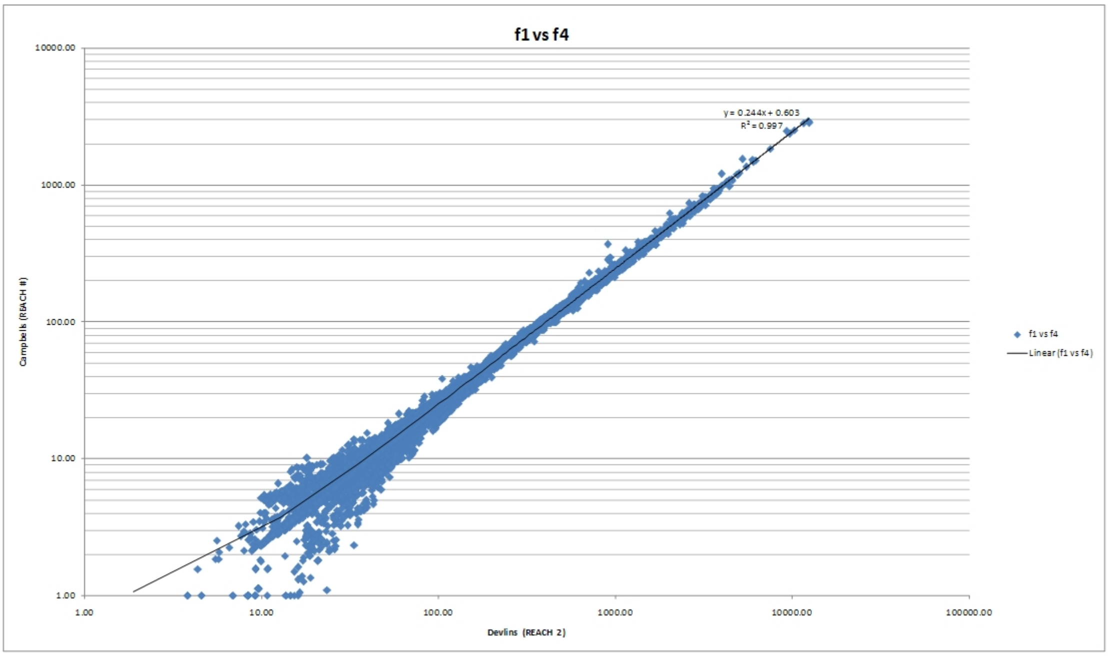


Figure 4 Regression plot of daily flow at Devlins Bridge against the modelled flow in Reach 3 – Upper Yea River

Increases in hydraulic roughness in a stream resulting from the presence of instream timber, riparian vegetation such as willows and instream vegetation such as emergent and submerged plants. The effect of these various factors was modelled in three different ways:

i) by increasing the Manning's n roughness value used in the HEC RAS model simulation;

ii) using blocked obstructions; and

iii) identifying ineffective flow areas.

A combination of these approaches was adopted to permit the best calibration over the full range of flows.

2.4 Sensitivity analysis

A sensitivity analysis was undertaken to assess the potential error in hydraulic parameters adopted in the HEC RAS models (Table 2). The upper-error limit is based on decreasing the roughness by 25% and increasing the downstream slope by 25% (i.e. a smoother and steeper model). The lower-error limit is determined by increasing the roughness by 25% and decreasing the downstream slope by 25% (i.e. a rougher and flatter model).

Table 4 Error limits on recommended low and high flows determined through hydraulic modelling.

FLOW COMPONENT		REACH 1		REACH 2		REACH 3		REACH 4	
Low flow	**Recommendation**	**50 ML/d**		**20 ML/d**		**7 ML/d**		**20 ML/d**	
	Upper limit	70 ML/d	+ 40%	28 ML/d	+ 40%	9 ML/d	+ 29%	28 ML/d	+ 40%
	Lower limit	38 ML/d	- 24%	14 ML/d	- 30%	6 ML/d	- 14%	15 ML/d	- 25%
High flow	**Recommendation**	**180 ML/d**		**90 ML/d**		**20 ML/d**		**60 ML/d**	
	Upper limit	225 ML/d	+ 25%	120 ML/d	+ 33%	24 ML/d	+ 20%	86 ML/d	+ 43%
	Lower limit	138 ML/d	- 23%	60 ML/d	- 33%	16 ML/d	- 20%	43 ML/d	- 28%

As the models have been calibrated to observed water levels on the day of survey, it is not anticipated that a 25% variation in hydraulic parameters is likely. This sensitivity assessment aims to set extreme error bounds on the modelling that was undertaken.

2.5 Rates of rise and fall

The rate of rise and fall relates to the increase and decrease, respectively, of flow between days. These fluctuations in the flow rate serve important ecological and geomorphic functions in a river system. For example, excessive rates of water-level fall can result in fish being stranded by falling waters or bank slumping (Earth Tech, 2006). It is therefore important that the rate of rise and fall is not significantly altered from the unimpacted flow scenario.

The maximum rate of rise has been defined as the 90^{th} percentile of all rates of rise. Correspondingly the maximum rate of fall has been defined as the 10^{th} percentile of all rates of fall (Table 5). These criteria have been used in many environmental flow studies in Victoria.

Table 5 Recommended maximum rates of rise and fall for freshwater reaches of the Yea River catchment (expressed as a proportion of unimpacted flow on the previous day)

REACH		RISE	FALL
1	Lower Yea	1.8	0.8
2	Middle Yea	1.9	0.8
3	Upper Yea	1.8	0.8
4	Lower Murrindindi	1.6	0.8

For example, if the flow rate in Reach 1 was 100ML/d, then the maximum rate of permissible fall would be 0.8 x 100ML/d or 80ML/d.

Note: The Yea River is an unregulated system. The rates of rise and fall included in Table 5 reflect the naturally observed patterns in the historic flow regime and play an important role in the maintenance of ecological health. In an unregulated system, these rates are less likely to be affected compared with a system such as the Goulburn River with a large impoundment (Lake Eildon). The rates are provided as a management tool to ensure that large scale pumping does not adversely impact the system. Similarly if an impoundment were to be mooted for an unregulated system in the future, the rates of rise and fall would need to be known and considered.

3 Recommendations: Reach 1 Lower Yea

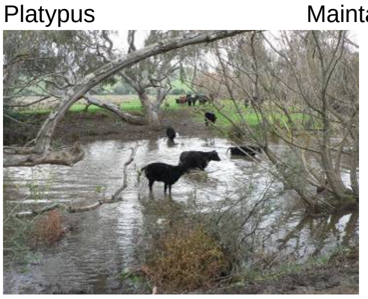
REACH CHARACTERISTICS

- Anabranching, meandering lowland channel;
- Highly sinuous, meandering across a wide floodplain;
- Main habitats consist of deep pools separated by shallow riffle sections;
- Geomorphically active, with the avulsion from the eastern anabranch to the contemporary main channel occurring during the last century;
- Aquatic vegetation such as Water Ribbons (*Triglochin procerum*) were occasionally present as instream vegetation, but in general there were few submerged angiosperms in the reach;
- Indications of some small and degraded floodplain wetlands are present near the main stem of the river;
- Deep pools form the major habitats for Macquarie Perch and Blackfish, while the edges of the pools form one of the main habitats for aquatic macroinvertebrates;
- Immediate catchment is extensively cleared and comprises agricultural land

More background information on the reach can be found in the Issues Paper (Wealands et al, 2007). This background provides the basis for the environmental objectives for the reach.

ENVIRONMENTAL OBJECTIVES

ASSET	REACH 1 OBJECTIVES
Vegetation	Maintain and enhance healthy and diverse vegetation communities in the riparian, fringing and instream zones of the stream including, where possible, control of introduced and weed species and the establishment of native riparian and aquatic species.
Floodplain wetlands and riparian eucalyptus woodlands	Maintain and enhance floodplain wetlands and riparian eucalyptus woodland through periodic inundation and establishment of natural wetting and drying cycles.
Physical form	Maintain and protect the existing values of the lower Yea River while recognising the ongoing channel evolutionary processes.
Macquarie Perch	Rehabilitate a self sustaining population of Macquarie Perch
Blackfish	Maintain a self-sustaining population of River Blackfish and Two-spined Blackfish
Southern Pygmy Perch	Maintain a self-sustaining population of Southern Pygmy Perch in Yea River wetlands and the Yea River anabranch
Invertebrates	Restore community to comply with SEPP objectives for SIGNAL scores. Maintain community to comply with SEPP objectives for AusRivAS and minimum number of macroinvertebrate families.
Hemiphlebia	Maintain a self-sustaining population of the threatened dragonfly (*Hemiphlebia mirabilis*) in Yea River Wetlands.
Platypus	Maintain flow conditions suitable for platypus



Parameters and criteria

Parameters and criteria to meet environmental and flow objectives in Reach 1 are shown in Table 6.

Table 6 Flow criteria for Reach 1 environmental objectives

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Vegetation					
Maintain and enhance native riparian, fringing and instream vegetation	1-V1	Maintain stream depth for instream vegetation	Low flow	Summer-autumn	Stream depth > 0.3 m
	1-V2	Facilitate growth of fringing emergent and amphibious vegetation and entrain terrestrial litter	Low flow fresh	Summer-autumn	Wet fringing benches
	1-V3	Maintain stream depth for instream vegetation	High flow	Winter-spring	Wet fringing benches
	1-V4	Facilitate growth of fringing emergent and amphibious vegetation and entrain terrestrial litter	High flow fresh	Winter-spring	Wet fringing benches
Maintain and enhance floodplain wetlands and riparian woodlands	1-V5	Inundate floodplain wetlands and floodplain eucalypt woodlands	Bankfull Overbank	Winter-spring	Sufficient to provide water to commence flows in small flood runners and inundate floodplain.
Physical Form					
Maintain and protect the existing values of the lower Yea River while recognising the ongoing channel evolutionary processes.	1-G1	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	Low flow fresh	Anytime	Shear stress >8 N/m^2 in pool
	1-G2	Maintain channel form and key habitats, including in-channel bars.	Low flow fresh	Anytime	Inundate in-channel bars
	1-G3	Scour surficial fine sediment from riffles (remove silt from gravels)	Low flow fresh	Anytime	Shear stress >15 N/m^2 on riffle
	1-G4	Scour sediments from base of pools to maintain quantity and quality of habitat.	High flow fresh	Anytime	Shear stress >8 N/m^2 in pool
	1-G5	Movement of bed material to maintain bed diversity for water depth variation.	High flow fresh	Anytime	

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
	1-G6	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	High flow fresh	Anytime	
	1-G7	Maintain channel form and key habitats, including in-channel benches.	High flow fresh	Anytime	Inundate in-channel bench.
	1-G8	Scour interstitial fine sediment from riffles and overturn of bed substrate (overturn gravels)	High flow fresh	Anytime	Shear stress >10 N/m^2 - assuming 10 mm gravel and no armouring.
	1-G9	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	Bankfull	Anytime	
	1-G10	Maintain channels and inlets for connectivity of main channel with important floodplain and wetland zones.	Overbank	Anytime	Note anecdotal evidence suggests 22 ML/day is required to provide flow to anabranch
Macroinvertebrates					
Maintain adequate habitat	1-M1	Maintain habitat in pools	Low flow High flow	All year	Lower parts of edge vegetation permanently inundated Median depth of 10 cm over shallow areas
	1-M2	Maintain habitat in runs and riffles	Low flow High flow	All year	
	1-M3	Prevent sedimentation of fast flowing habitats	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove deposited sediment
	1-M4	Prevent dominance of filamentous algae	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove attached algae
Maintain wetted habitat in wetlands for *Hemiphlebia*	1-M5	Maintain water regime in wetlands and anabranches	Bankfull	High flow season	Commence-to-flows for wetlands and anabranches
Fish					
Maintain adequate habitat availability for Macquarie Perch	1-F1	Maintain habitat in pools	Low flow High flow	All year	Median pool depth > 1 m
Maintain adequate habitat availability for Blackfish species	1-F2	Maintain habitat in pools for both species	Low flow High flow	All year	Median pool depth > 0.4 m.
Maintain wetted habitat in wetlands for Southern Pygmy	1-F3	Maintain water regime in wetlands and anabranches	Bankfull	High flow season	Commence-to-flows for wetlands and anabranches

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Perch					
Maintain adequate habitat and water quality	1-F4	Prevent water quality decline	Low flow Low flow fresh	Low flow season	Velocity and pool turnover adequate to prevent water quality decline
Enhance Macquarie Perch spawning	1-F5	Stimulate spawning	High flow fresh	October and November	Unknown – use other criteria
Allow pre spawning Macquarie Perch migration	1-F6	Allow reach scale movement between pool habitats	High flow	September to October	Median depth of runs > 0.5 m
Allow movement between pools for Blackfish	1-F7	Provide occasional adequate depth in runs between pools for all species	Low flow fresh High flow fresh	All year	Median depth of runs > 0.2 m
Provide clean spawning sites	1-F8	Flush sediments during spawning season	High flow fresh	September to October	Average run velocity suitable to scour sediments (>0.4 m/s)
Maintain adequate habitat availability for Macquarie Perch	1-F9	Maintain habitat in pools	Low flow, High flow	All year	Median pool depth > 1 m
Platypus					
Maintain flow conditions suitable for Platypus	1-P1	Habitat availability	Low flow, High flow	All year	Flow to maintain depth profiles suitable for resident fish and macroinvertebrate food source
	1-P2	Habitat maintenance	Low flow fresh, High flow fresh	All year	Shear stress at edge or shallow riffles sufficient to remove silt to promote macroinvertebrate populations
	1-P3	Water quality maintenance	Low flow, Low flow fresh	Low Flow Season	Velocity and pool turnover adequate to prevent water quality decline

3.1 Reach 1 recommendations

The environmental flows recommended to meet environmental objectives are described in Table 7.

Anabranching form of the lower Yea River

The anabranching geomorphic form of the lower Yea River (known in this report as Reach 1) has been described in detail in Appendix B of the Issues Paper (Stacey & Wealands, 2007). The detailed geomorphic assessment of the anabranches did not form part of the FLOWS assessment.

It should be noted that the hydrologic modelling, only developed flow series for one flow pathway in Reach 1. Given this constraint, it was not possible within the scope of the FLOWS assessment to develop specific recommendations for western (main) and eastern (anabranch) flow paths.

It was noted during the course of the FLOWS study that the anabranch observed on the Beer property is shutting down with sediment deposition occurring at the upstream extent of the anabranch. It is understood that landholders actively manage the anabranch channel to maintain flow for environmental and consumptive purposes.

Given the complexity of geomorphic change and flow splitting, it is recommended that the Goulburn Broken CMA complete a more detailed analysis of this issue. This may occur as part of the development of the SFMP.

The flow recommendations made in Table 7 are a single recommendation. There are three sections of anabranches downstream of the Murrindindi River confluence. Some of these anabranch sections are likely to be engaged at the levels of flow recommended in Table 7.

More detailed assessment of this issue would be required as part of the management of compliance in this part of the system and should form part of the development of the SFMP.

A note about environmental objectives and controlling criteria

The environmental flow recommendations tables for each of the four reaches contain two columns that list the environmental objectives and the controlling criteria. As can be seen in Table 7 the recommendation for low flow lists 9 objectives that are met by the recommended low flow of 50ML/d. The objective in bold, in this example, **1-F9**, relates to maintaining adequate habitat for Macquarie Perch. Other objectives for vegetation, macroinvertebrates, fish and physical form are also met by the low flow recommendation. In other words, 1-F9 requires the highest flow for all objectives dependent upon low flows. The other 8 objectives that require a low flow were tested in the Technical Panel workshop and found to require less flow. For this reason, the objective that requires the greatest flow volume is termed the 'controlling criteria'.

Table 7 Environmental flow recommendations – Reach 1 Lower Yea

RIVER	Yea River	**REACH**	1
COMPLIANCE POINT	To be determined	**GAUGE NUMBER**	Not applicable

FLOW					**RATIONALE**	
PERIOD	**FLOW COMPONENT**	**MAGNITUDE**	**FREQUENCY**	**DURATION**	**OBJECTIVES**	**CONTROLLING CRITERIA AND DISCUSSION**
Dec-May	Low flow	50 ML/d or natural	Continuous	Continuous	1-V1, 1-M1, 1-M2, 1-F1, 1-F2, 1-F4, **1-F9**, 1-P1, 1-P3	Average depth in pools 1.0m for Macquarie Perch habitat.

Dec-May	Low flow fresh	180 ML/d	2 / season or natural	3 days or natural	**1-V2**, 1-G1, 1-G2, 1-G3, 1-M3, 1-M4, 1-F4, 1-F7, 1-P2, 1-P3	Inundation of sandy benches facilitate growth of fringing emergent and amphibious vegetation and entrain terrestrial litter
Jun-Nov	High flow	180 ML/d or natural	Continuous	Continuous	**1-V3**, 1-M1, 1-M2, 1-F1, 1-F2, 1-F6, 1-F9, 1-P1	Inundation of sandy benches to maintain instream vegetation.
Jun-Nov	High flow fresh	780 ML/d	2 / season* or natural	14 days or natural	1-V4, 1-G4, 1-G5, 1-G6, **1-G7, 1-G8**, 1-M3, 1-M4, 1-F5, 1-F7, 1-F8, 1-P2	Inundation of in-channel benches and shear stress exceeding 10 N/m^2 to scour interstitial fine sediment from riffles and overturn of bed substrate
Any	Bankfull	3460 ML/d#	1 / year or natural	1 day or natural	**1-V5, 1-G9, 1-M5, 1-F3**	Top of bank flow to maintain channel form.
Any	Overbank	4060 ML/d#	1 / year or natural	1 day or natural	**1-V5, 1-G10**	Out of channel flow sufficient to provide water to small flood runners to floodplain depressions and inundate floodplains.

***** one high flow fresh to occur in September once every four years

flow volumes recommended are converted from cumecs. They should be interpreted as achieving the controlling around this flow level. It is acknowledged that there will be errors associated with the hydrology, survey and interpretation of hydraulic models.

Notes:

- Controlling criteria for each flow component is highlighted in **bold**.
- 10 day independence is recommended between events.
- Rates of rise and fall to be adopted as defined in Table 5.
- Flow recommendations for this reach refer to the flow passing through the main channel of the Yea River, not the cumulative flow through the main channel and anabranch.

3.2 Comparison of recommendations to unimpacted and current flow regime

Compliance of recommended flows to the current and unimpacted daily flow regime cannot be determined in this reach as the daily flows modelled in REALM relate to the total flow in the reach (main channel and anabranch flow). The environmental flows recommended in this report refer to the discharge in the main channel of the river and substantial volumes of water could flow down the anabranch sections at these flows.

4 Recommendations: Reach 2 Middle Yea River

REACH CHARACTERISTICS

- Largely comprised of a partially confined waterway with a discontinuous floodplain;
- Sinuosity is substantially lower than Reach 1 and channel slope is considerably higher;
- Dominated by deep pools separated by exposed bedrock bars, and alternating runs and riffles;
- Some sections confined by bedrock and others showing limited floodplain development;
- Much of the riparian zone had either been converted to pasture (the right hand bank especially) or degraded by access for camping and angling.
- Riparian vegetation at the sites examined during the field inspection included dense thickets of Tea-tree and Tree Violet amongst a canopy of She Oaks (*Allocasuarina* spp) and various eucalypts.
- Catchment is extensively cleared with agricultural use dominating the surrounding area.

More background information on the reach can be found in the Issues Paper (Wealands et al, 2007). This background provides the basis for the environmental objectives for the reach.

ENVIRONMENTAL OBJECTIVES

ASSET	ENVIRONMENTAL OBJECTIVES
Vegetation	Maintain and enhance healthy and diverse vegetation communities in the riparian, fringing and instream zones of the stream including, where possible, control of introduced and weed species and the establishment of native riparian and aquatic species.
	Prevent permanent colonisation of instream habitats by terrestrial plant species.
Floodplain wetlands and riparian eucalyptus woodlands	Maintain and enhance floodplain wetlands and riparian eucalyptus woodland through periodic inundation and establishment of natural wetting and drying cycles.
Water quality	Provide a flow regime that prevents the occurrence of anoxic conditions in deep pools over summer.
Physical form	Maintain and protect the current largely intact physical form.
Macquarie Perch	Rehabilitate a self sustaining population of Macquarie Perch
Blackfish	Maintain a self-sustaining population of River Blackfish and Two-spined Blackfish
Invertebrates	Maintain current macroinvertebrate community to comply with SEPP objectives for AusRivAS, SIGNAL and minimum number of macroinvertebrate families.
Platypus	Maintain flow conditions suitable for platypus

Parameters and criteria

Parameters and criteria to meet environmental and flow objectives in Reach 2 are found Table 8.

Table 8 Hydraulic criteria for Reach 2 environmental objectives

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Vegetation					
Maintain and enhance native riparian, fringing and instream vegetation	2-V1	Maintain stream depth for instream vegetation	Low flow	Summer-autumn	Run depth > 0.3 m; pool depth > 1 m
	2-V2	Facilitate growth of fringing emergent and amphibious vegetation and entrain terrestrial litter	Low flow fresh	Summer-autumn	Wet fringing benches
	2-V3	Maintain stream depth for instream vegetation	High flow	Winter-spring	Stream depth > 0.3 m; pool depth > 1 m
	2-V4	Facilitate growth of fringing emergent and amphibious vegetation and entrain terrestrial litter	High flow fresh	Winter-spring	Wet fringing benches
Prevent permanent colonisation of instream habitats by terrestrial taxa	2-V5	Inundate instream islands	Bankfull	Winter-spring	Bankfull with sufficient velocity to scour instream sediment accumulations
Maintain and enhance floodplain wetlands and riparian woodlands	2-V6	Inundate floodplain wetlands and floodplain eucalypt woodlands	Bankfull Overbank	Winter-spring	Sufficient to provide water to small flood runners to floodplain depressions and inundate floodplains
Physical form					
Maintain instream habitat diversity	2-G1	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	Low flow fresh	Any	Shear stress >8 N/m^2 in pool
	2-G2	Maintain channel form and key habitats, including in-channel bars.	Low flow fresh	Any	Inundate in-channel bars
	2-G3	Scour surficial fine sediment from riffles (remove	Low flow fresh	Any	Shear stress >8 N/m^2 on riffle

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
		silt from rock bars)			
	2-G4	Scour silt sediments from base of pools to maintain quantity and quality of habitat.	High flow fresh	Any	Shear stress >8 N/m^2 in pool
	2-G5	Maintain channel form and key habitats, including in-channel benches.	High flow fresh	Any	Inundate in-channel benches
	2-G6	Prevent channel encroachments	Bankfull	Any	Provision of bankfull events
Macroinvertebrates					
Maintain adequate habitat	2-M1	Maintain habitat in pools	Low flow, High flow	All year	Lower parts of edge vegetation permanently inundated
	2-M2	Maintain habitat in runs and riffles	Low flow, High flow	All year	Median depth of 10 cm over shallow areas
	2-M3	Prevent sedimentation of fast flowing habitats	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove deposited sediment
	2-M4	Prevent dominance of filamentous algae	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove attached algae
Fish					
Maintain adequate habitat availability for Macquarie perch[3]	2-F1	Maintain habitat in pools	Low flow High flow	All year	Median pool depth > 1 m
Maintain adequate habitat availability for blackfish species[4]	2-F2	Maintain habitat in pools for both species	Low flow High flow	All year	Median pool depth > 0.4 m.
Maintain adequate habitat and water quality	2-F3	Prevent water quality decline	Low flow Low flow fresh	Low flow season	Velocity and pool turnover adequate to prevent water quality decline
Enhance Macquarie perch spawning	2-F4	Stimulate spawning	High flow fresh	October and November	Unknown – use other criteria
Allow pre spawning Macquarie Perch migration	2-F5	Allow reach scale movement between pool habitats	Low flow fresh High flow	September to October	Median depth of runs > 0.5 m
Allow movement between pools for blackfish	2-F6	Provide occasional adequate depth in runs between pools for all species	Low flow fresh, High flow fresh	All year	Median depth of runs > 0.2 m

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Provide clean spawning sites	2-F7	Flush sediments during spawning season	High flow fresh	September to October	Average run velocity suitable to scour sediments (>0.4 m/s)
Platypus					
Maintain flow conditions suitable for Platypus	2-P1	Habitat availability	Low flow, High flow	All year	Flow to maintain depth profiles suitable for resident fish and macroinvertebrate food source
	2-P2	Habitat maintenance	Low flow fresh, High flow fresh	All year	Shear stress at edge or shallow riffles sufficient to remove silt to promote macroinvertebrate populations
	2-P3	Water quality maintenance	Low flow, Low flow fresh	Low Flow Season	Velocity and pool turnover adequate to prevent water quality decline

4.1 Reach 2 recommendations

The environmental flows recommended to meet environmental objectives are described in Table 9.

Table 9 Environmental flow recommendations – Reach 2 Middle Yea

RIVER	Yea River	**REACH**	2
COMPLIANCE POINT	Yea River @ Devlins Bridge	**GAUGE NUMBER**	405 217

FLOW					**RATIONALE**	
PERIOD	**FLOW COMPONENT**	**MAGNITUDE**	**FREQUENCY**	**DURATION**	**OBJECTIVES**	**CONTROLLING CRITERIA AND DISCUSSION**
Dec-May	Low flow	20 ML/d or natural	Continuous	Continuous	**2-V1**, 2-M1, 2-M2, 2-F1, 2-F2, 2-F3, 2-P1, 2-P3	Median depth of 0.3m over runs, providing for inundation of instream vegetation.
Dec-May	Low flow fresh	90 ML/d	2 / season or natural	3 days or natural	2-V2, 2-G1, 2-G2, 2-G3, 2-M3, 2-M4, 2-F3, **2-F5**, 2-F6, 2-P2, 2-P3	Minimum depth 0.5m to provide reach scale movement between pool habitats for Macquarie Perch.
Jun-Nov	High flow	90 ML/d or natural	Continuous	Continuous	2-V3, 2-M1, 1-M2, 2-F1, 2-F2, **2-F5**, 2-P1	Minimum depth 0.5m to provide reach scale movement between pool habitats for Macquarie Perch.
Jun-Nov	High flow fresh	430 ML/d	2 / season or natural	14 days or natural	2-V4, 2-G4, **2-G5**, 2-M3, 2-M4, 2-F4, 2-F6, 2-F7, 2-P2	Inundation of in-channel benches to maintain channel form and key habitats.
Any	Bankfull	1500 ML/d#	2 / season* or natural	1 day or natural	**2-V5, 2-V6, 2-G6**	Bankfull flow to prevent channel encroachment and maintain channel form.
Any	Overbank	2500 ML/d#	1 / year or natural	1 day or natural	**2-V6**	Overbank flow sufficient to provide water to small flood runners to floodplain depressions and inundate floodplain.

* one bankfull to occur in September/October once every four years

flow volumes recommended are converted from cumecs. They should be interpreted as achieving the controlling around this flow level. It is acknowledged that there will be errors associated with the hydrology, survey and interpretation of hydraulic models.

Notes:

- 10 day independence is recommended between events.
- Rates of rise and fall to be adopted as defined in Table 5.
- Controlling criteria for each flow component is highlighted in **bold**.

4.2 Comparison of recommendations to unimpacted and current flow regime

A comparison of current, unimpacted and recommended flows is shown in Table 10.

Table 10 Compliance with unimpacted current flow regime in Reach 2 Middle Yea

PERIOD	FLOW COMPONENT	MAGNITUDE	FREQUENCY	DURATION	UNIMPACTED FLOW REGIME	CURRENT FLOW REGIME
Dec-May	Low flow	20 ML/d	Continuous	Continuous	Occurs 99 % of days	Occurs 94% of days
Dec-May	Low flow fresh	90 ML/d	2 / period	3 days	3 / period, 39 day mean duration	3 / period, 31 day mean duration
Jun-Nov	High flow	90 ML/d	Continuous	Continuous	Occurs 88% of days	Occurs 86% of days
Jun-Nov	High flow fresh	430 ML/d	2 / period	14 days	2 / period, 38 day mean duration	2 / period, 37 day mean duration
Any	Bankfull	1500 ML/d	2 / period	1 day	117 events in 50 year period, mean duration 3 days	115 events in 50 year period, mean duration 3 days
Any	Overbank	2500 ML/d	1 / year	1 day	30 events in 50 year period, mean duration 2 days	30 events in 50 year period, mean duration 2 days

Note: this comparison does not take into consideration the 'or natural' qualifier on the flow recommendations. Therefore, in many instances, the current flow regime may be complying with recommendations despite being of smaller magnitude. Further detailed hydrologic modelling is required to determine the exact compliance of current flows.

5 Recommendations: Reach 3 Upper Yea River

REACH CHARACTERISTICS

- Immediate catchment generally comprised of forested hills with isolated cleared floodplain pockets surrounding the major waterways;
- Consists of a small, sand-cobble bed channel, generally with a good coverage of native riparian vegetation;
- Main habitat types consist of relatively shallow pools separated by shallow riffle sections;
- Pools form the major habitats for Blackfish and Mountain Galaxias, while the edges of the pools form one of the main habitats for aquatic macroinvertebrates;
- Intervening riffles are also important for macroinvertebrates;
- Summer flows in the upper Yea River are the most significantly altered in the catchment;
- Stream channel is mostly a mixture of cobbles and silt, and the riparian zone is often dense and wide;
- Riparian and nearby forest vegetation consisted of a canopy of eucalyptus with a shrub layer as well as a wide range of ferns.

More background information on the reach can be found in the Issues Paper (Wealands et al, 2007). This background provides the basis for the environmental objectives for the reach.

ENVIRONMENTAL OBJECTIVES

ASSET	ENVIRONMENTAL OBJECTIVES
Vegetation	Maintain healthy and diverse riparian, fringing and instream vegetation communities.
	Maintain fringing wet forest vegetation communities.
Physical form	Maintain and protect the current largely intact physical form.
Blackfish	Maintain a self-sustaining population of River Blackfish and Two-spined Blackfish
Mountain Galaxias	Maintain a self-sustaining population of Mountain Galaxias
Invertebrates	Maintain current macroinvertebrate community to comply with SEPP objectives for AusRivAS, SIGNAL and minimum number of macroinvertebrate families.
Platypus	Maintain flow conditions suitable for platypus



Parameters and criteria

Parameters and criteria to meet environmental and flow objectives in Reach 3 are found in Table 11.

Table 11 Preliminary flow criteria for Reach 3 environmental objectives

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Vegetation					
Maintain native riparian, fringing and instream vegetation	3-V1	Maintain stream depth for instream vegetation	Low flow	Summer-autumn	Stream depth > 0.3 m
	3-V2	Inundate moss communities on exposed coarse woody debris	Low flow fresh	Summer-autumn	Inundate woody debris
	3-V3	Maintain stream depth for instream vegetation	High flow	Winter-spring	Inundation of benches and wetting of plant roots.
	3-V4	Entrain and trans-locate downstream terrestrial litter	High flow fresh	Winter-autumn	
	3-V5	Inundate moss communities on exposed coarse woody debris and maintain wet soil conditions for fringing forest communities	Bankfull	Winter-spring	Inundate woody debris
Maintain fringing wet forest vegetation, especially ferns and other understory species	3-V6	Inundate riparian and nearby forest zones	Overbank	Winter-spring	Overbank
Physical Form					
Maintain instream habitat diversity	3-G1	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	Low flow fresh	Any	Shear stress >8 N/m^2 in pool
	3-G2	Maintain channel form and key habitats, including in-channel bars.	Low flow fresh	Any	Inundate in-channel bars
	3-G3	Scour surficial fine sediment from riffles (remove silt from gravel, sand and wood)	Low flow fresh	Any	Shear stress >15 N/m^2 on riffle
	3-G4	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	High flow fresh	Any	Shear stress >8 N/m^2 in pool

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
	3-G5	Movement of bed material to maintain bed diversity for water depth variation.	High flow fresh	Any	
	3-G6	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	High flow fresh	Any	
	3-G7	Maintain channel form and key habitats, including in-channel benches.	High flow fresh	Any	Inundate in-channel bench
	3-G8	Scour interstitial fine sediment from riffles and overturn of bed substrate (overturn gravels and cobbles)	High flow fresh	Any	Shear stress >20-30 N/m^2 Assuming 20-30 mm gravel and no armouring
	3-G9	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	Bankfull	Any	Provide bankfull events
	3-G10	Maintain channels and inlets for connectivity of main channel with important floodplain and wetland zones.	Overbank	Any	Provide overbank events
Macroinvertebrates					
Maintain adequate habitat	3-M1	Maintain habitat in pools	Low flow, High flow	All year	Lower parts of edge vegetation permanently inundated
	3-M2	Maintain habitat in runs and riffles	Low flow, High flow	All year	Median depth of 0.1 m over shallow areas
	3-M3	Prevent sedimentation of fast flowing habitats	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove deposited sediment
	3-M4	Prevent dominance of filamentous algae	Low flow fresh, High flow fresh	All year	Velocity and shear stress adequate to remove attached algae
Fish					
Maintain adequate habitat availability for blackfish species	3-F1	Maintain habitat in pools for both species	Low flow, High flow	All year	Median pool depth > 0.4 m.
Maintain adequate habitat availability for Mountain	3-F2	Maintain habitat in pools	Low flow, High flow	All year	Median pool depth > 0.2 m.

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
galaxias					
Maintain adequate habitat and water quality	3-F3	Prevent water quality decline	Low flow Low flow fresh	Low flow season	Velocity and pool turnover adequate to prevent water quality decline
Allow pre-spawning movement of Mountain galaxias	3-F4	Provide adequate depth in runs between pools	High flow	September and October	Median depth of runs > 0.15 m
Allow movement between pools for blackfish	3-F5	Provide occasional adequate depth in runs between pools for all species	Low flow fresh, High flow fresh	All year	Median depth of runs > 0.2 m
Provide clean spawning sites for all fish species	3-F6	Flush sediments during spawning season	High flow fresh	September to October	Average run velocity suitable to scour sediments (>0.4 m/s)
Platypus					
Maintain flow conditions suitable for Platypus	3-P1	Habitat availability	Low flow, High flow	All year	Flow to maintain depth profiles suitable for resident fish and macroinvertebrate food source
	3-P2	Habitat maintenance	Low flow fresh, High flow fresh	All year	Shear stress at edge or shallow riffles sufficient to remove silt to promote macroinvertebrate populations
	3-P3	Water quality maintenance	Low flow, Low flow fresh	Low Flow Season	Velocity and pool turnover adequate to prevent water quality decline

5.1 Reach 3 recommendations

The environmental flows recommended to meet environmental objectives are described in Table 12.

Table 12 Environmental flow recommendations – Reach 3 Upper Yea

RIVER	Yea River	**REACH**	3
COMPLIANCE POINT	To be determined	**GAUGE NUMBER**	Not applicable

FLOW					**RATIONALE**	
PERIOD	**FLOW COMPONENT**	**MAGNITUDE**	**FREQUENCY**	**DURATION**	**OBJECTIVES**	**CONTROLLING CRITERIA AND DISCUSSION**
Dec-May	Low flow	7 ML/d or natural	Continuous	Continuous	3-V1, 3-M1, **3-M2**, 3-F1, 3-F2, 3-F3, 3-P1, 3-P3	Depth of 0.1m in shallow areas to maintain habitat for macroinvertebrates in runs and riffles.
Dec-May	Low flow fresh	20 ML/d	4 / season or natural	4 days or natural	3-V2, **3-G1**, 3-G2, 3-M3, 3-M4, 3-F3, 3-P2, 3-P3	Shear stress > 8 N/m^2 to scour silt and sand from base of pools to maintain quantity and quality of habitat.
Dec-May	Low flow fresh	50 ML/d	1 / season or natural	4 days or natural	3-V2, 3-G1, 3-G2, 3-G3, 3-M3, 3-M4, 3-F3, **3-F5**, 3-P2, 3-P3	Median depth of runs > 0.2 m to provide movement for fish.
Jun-Nov	High flow	20 ML/d or natural	Continuous	Continuous	**3-V3**, 3-M1, 3-M2, 3-F1, 3-F2, 3-F4, 3-P1	Inundation of benches to wet plan roots over winter period.
Jun-Nov	High flow fresh	100 ML/d	2 / season or natural	14 days or natural	3-V4, 3-G4, 3-G5, 3-G6, 3-G7, **3-G8**, 3-M3, 3-M4, 3-F5, 3-F6, 3-P2	Shear stress >20 N/m^2 to scour interstitial fine sediment from riffles and overturn of bed substrate (overturn gravels and cobbles).
Any	Bankfull	800 ML/d#	1 / year or natural	2 days or natural	**3-V5, 3-G9**	Bankfull flow to prevent channel encroachment and maintain channel form.
Any	Overbank	2000 ML/d#	1 / 10 years or natural	1 day or natural	**3-V6, 3-G10**	Overbank flow sufficient to provide water to floodplain and maintain floodplain vegetation community.

flow volumes recommended are converted from cumecs. They should be interpreted as achieving the controlling around this flow level. It is acknowledged that there will be errors associated with the hydrology, survey and interpretation of hydraulic models.

Notes:

- 10 day independence is recommended between events.
- Rates of rise and fall to be adopted as defined in Table 5.
- Controlling criteria for each flow component is highlighted in **bold**.

5.2 Comparison of recommendations to unimpacted and current flow regime

A comparison of current, unimpacted and recommended flows is shown in Table 13.

Table 13 Compliance with unimpacted and current flow regime in Reach 3 Upper Yea River

PERIOD	FLOW COMPONENT	MAGNITUDE	FREQUENCY	DURATION	UNIMPACTED FLOW REGIME	CURRENT FLOW REGIME
Dec-May	Low flow	7 ML/d	Continuous	Continuous	Occurs 96% of days	Occurs 85% of days
Dec-May	Low flow fresh	20 ML/d	4 / period	3 days	3 / period, 47 day mean duration	3 / period, 33 day mean duration
Apr-May	Low flow fresh	50 ML/d	1 / period	3 days	1 / period, 16 day mean duration	1 / period, 13 day mean duration
Jun-Nov	High flow	20 ML/d	Continuous	Continuous	Occurs 91% of days	Occurs 89% of days
Jun-Oct	High flow fresh	100 ML/d	2 / period	14 days	2 / period, 41 day mean duration	2 / period, 40 day mean duration
Any	Bankfull	800 ML/d	1 / 2 years	1 day	46 events in 50 year period, 1 day mean duration	44 events in 50 year period, 1 day mean duration
Any	Overbank	2000 ML/d	1 / 10 years	1 day	5 events in 50 year period, 1 day mean duration	5 events in 50 year period, 1 day mean duration

Note: this comparison does not take into consideration the 'or natural' qualifier on the flow recommendations. Therefore, in many instances, the current flow regime may be complying with recommendations despite being of smaller magnitude. Further detailed hydrologic modelling is required to determine the exact compliance of current flows.

6 Recommendations: Reach 4 Lower Murrindindi River

REACH CHARACTERISTICS

- Largely unconfined meandering alluvial stream system within a wide floodplain;
- Streamside zone showed some small banks and ledges, which were occasionally colonised by *Juncus* spp.;
- Main habitat types consist of relatively shallow pools separated by shallow riffle sections;
- Stream banks and floodplain comprise fine grained material;
- Pools form the major habitats for Blackfish, while the edges of the pools form one of the main habitats for aquatic macroinvertebrates;
- Representative site has no bedrock controls and has been largely cleared of vegetation;
- Catchment is extensively cleared for grazing and only narrow riparian fringes remain, at least in the sites visited during the field examination.

More background information on the reach can be found in the Issues Paper (Wealands et al, 2007). This background provides the basis for the environmental objectives for the reach.

ENVIRONMENTAL OBJECTIVES

ASSET	ENVIRONMENTAL OBJECTIVES
Vegetation	Maintain and enhance healthy and diverse vegetation communities in the riparian, fringing and instream zones of the stream including, where possible, control of introduced and weed species and the establishment of native riparian and aquatic species.
Floodplain wetlands	Maintain and enhance floodplain wetlands through periodic inundation and establishment of natural wetting and drying cycles.
Physical form	Maintain and protect the current intact physical form.
Blackfish	Maintain a self-sustaining population of Two-spined Blackfish.
Invertebrates	Maintain current macroinvertebrate community to comply with SEPP objectives for AusRivAS, SIGNAL and minimum number of macroinvertebrate families.
Platypus	Maintain flow conditions suitable for platypus.

Parameters and criteria

Parameters and criteria to meet environmental and flow objectives in Reach 4 are found in Table 14.

Table 14 Preliminary flow criteria for Reach 4 environmental objectives

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
Vegetation					
Maintain adequate habitat	4-V1	Maintain habitat in pools	Low flow High flow	All year	Lower parts of edge vegetation permanently inundated
	4-V2	Maintain habitat in runs and riffles	Low flow High flow	All year	Median depth of 20 cm over shallow areas
	4-V3	Prevent sedimentation of fast flowing habitats	Low flow fresh High flow fresh	All year	Velocity and shear stress adequate to remove deposited sediment
	4-V4	Prevent dominance of filamentous algae	Low flow fresh High flow fresh	All year	Velocity and shear stress adequate to remove attached algae
Maintain and enhance floodplain wetlands and riparian woodlands	4-V5	Inundate floodplain wetlands	Bankfull Overbank	Winter-spring	Sufficient to provide water to small flood runners to floodplain depressions and inundate floodplain
Physical form					
Maintain instream habitat diversity	4-G1	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	Low flow fresh	Any	Shear stress >8 N/m^2 in pool
	4-G2	Maintain channel form and key habitats, including in-channel bars.	Low flow fresh	Any	Inundate in-channel bars
	4-G3	Scour surficial fine sediment from riffles (remove silt from sand and wood)	Low flow fresh	Any	Shear stress >8 N/m^2 on riffle
	4-G4	Scour silt and sand from base of pools to maintain quantity and quality of habitat.	High flow fresh	Any	Shear stress >8 N/m^2 in pool
	4-G5	Movement of bed material to maintain bed diversity for water depth variation.	High flow fresh	Any	

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
	4-G6	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	High flow fresh	Any	
	4-G7	Maintain channel form and key habitats, including in-channel benches.	High flow fresh	Any	Inundate in-channel bench
	4-G8	Scour surficial fine sediment from riffles (remove silt from sand and wood)	High flow fresh	Any	Shear stress >8 N/m^2
	4-G9	Control riparian vegetation encroachment to prevent catastrophic erosion processes.	Bankfull	Any	Provide bankfull events
	4-G10	Maintain channels and inlets for connectivity of main channel with important floodplain and wetland zones.	Overbank	Any	Provide overbank events
Macroinvertebrates					
Maintain adequate habitat and water quality	4-M1	Prevent water quality decline	Low flow fresh	Low Flow Season	Velocity and pool residence time adequate to prevent water quality decline
Fish					
Maintain adequate habitat availability for blackfish [3]	4-F1	Maintain habitat in pools for Two-spined blackfish	Low flow, High flow	All year	Median pool depth > 0.3 m.
Maintain adequate habitat and water quality	4-F2	Prevent water quality decline	Low flow Low flow fresh	Low flow season	Velocity and pool turnover adequate to prevent water quality decline
Allow movement between pools for blackfish	4-F3	Provide occasional adequate depth in runs between pools for all species	Low flow fresh, High flow fresh	All year	Median depth of runs > 0.2 m
Provide clean spawning sites	4-F4	Flush sediments during spawning season	High flow fresh	September and October	Average run velocity suitable to scour sediments (>0.4 m/s)
Platypus					
Maintain flow conditions suitable for Platypus	4-P1	Habitat availability	Low flow, High flow	All year	Flow to maintain depth profiles suitable for resident fish and macroinvertebrate food source
	4-P2	Habitat maintenance	Low flow fresh,	All year	Shear stress at edge or shallow riffles sufficient to

OBJECTIVE	NO.	FLOW PROCESS/FUNCTION	FLOW COMPONENT	TIMING	CRITERIA
			High flow fresh		remove silt to promote macroinvertebrate populations
	4-P3	Water quality maintenance	Low flow, Low flow fresh	Low Flow Season	Velocity and pool turnover adequate to prevent water quality decline

6.1 Reach 4 recommendations

The environmental flows recommended to meet environmental objectives are described in Table 15.

Table 15 Environmental flow recommendations – Reach 4 Murrindindi River

RIVER	Murrindindi River	**REACH**	4
COMPLIANCE POINT	Murrindindi River @ Colwells Bridge	**GAUGE NUMBER**	405 205

FLOW					**RATIONALE**	
PERIOD	**FLOW COMPONENT**	**MAGNITUDE**	**FREQUENCY**	**DURATION**	**OBJECTIVES**	**CONTROLLING CRITERIA AND DISCUSSION**
Dec-May	Low flow	20 ML/d or natural	Continuous	Continuous	4-V1, **4-V2**, 4-F1, 4-F2, 4-P1, 4-P3	Depth >0.2m over shallow areas to maintain instream vegetation.
Dec-May	Low flow fresh	90 ML/d	2 / season or natural	3 days or natural	4-V3, 4-V4, **4-G1**, 4-G2, **4-G3**, 4-M1, 4-F2, 4-F3, 4-P2, 4-P3	Shear stress greater than 8 N/m^2 to scour silt and sand from base of pools and riffles, maintaining quantity and quality of habitat
Jun-Nov	High flow	60 ML/d or natural	Continuous	Continuous	4-V1, 4-V2, 4-F1, 4-P1	Inundation of in-channel benches.
Jun-Nov	High flow fresh	350 ML/d	2 / season or natural	4 days or natural	4-V3, 4-V4, 4-G4, 4-G5, 4-G6, **4-G7**, 4-G8, 4-F3, 4-F4, 4-P2	Inundation of high in-channel benches.
Any	Bankfull#	500 ML/d	1 / year or natural	1 day or natural	**4-V5, 4-G9**	Bankfull flow to maintain channel form.
Any	Overbank#	700 ML/d	1 / 4 years or natural	1 day or natural	**4-V5, 4-G10**	Significant inundation of floodplain wetlands for Canopy tree recruitment

flow volumes recommended are converted from cumecs. They should be interpreted as achieving the controlling around this flow level. It is acknowledged that there will be errors associated with the hydrology, survey and interpretation of hydraulic models.

Notes:

- Controlling criteria for each flow component is highlighted in **bold**.
- 10 day independence is recommended between events.
- Rates of rise and fall to be adopted as defined in Table 5.

6.2 Comparison of recommendations to unimpacted and current flow regime

A comparison of current, unimpacted and recommended flows is shown in Table 16.

Table 16 Compliance with unimpacted and current flow regime in Reach 4 Murrindindi River

PERIOD	FLOW COMPONENT	MAGNITUDE	FREQUENCY	DURATION	UNIMPACTED FLOW REGIME	CURRENT FLOW REGIME
Dec-May	Low flow	20 ML/d	Continuous	Continuous	Occurs 100% of days	Occurs 100% of days
Dec-May	Low flow fresh	90 ML/d	2 / period	3 days	4 / period, 42 day mean duration	4 / period, 39 day mean duration
Jun-Nov	High flow	60 ML/d	Continuous	Continuous	Occurs 100% of days	Occurs 99% of days
Jun-Nov	High flow fresh	350 ML/d	2 / period	4 days	2 / period, 7 day mean duration	2 / period, 7 day mean duration
Any	Bankfull	500 ML/d	1 / period	1 day	53 events in 50 year period, 3 day duration	53 events in 50 year period, 3 day duration
Any	Overbank	700 ML/d	1 / 4 years	1 day	14 events in 50 year period, 3 day duration	14 events in 50 year period, 3 day duration

Note: this comparison does not take into consideration the 'or natural' qualifier on the flow recommendations. Therefore, in many instances, the current flow regime may be complying with recommendations despite being of smaller magnitude. Further detailed hydrologic modelling is required to determine the exact compliance of current flows.

7 Supporting recommendations

To achieve the environmental objectives for each reach, it is recognised that, in addition to providing environmental flows, a complementary suite of actions may be required.

Supporting recommendations are listed below:

- **Install streamflow gauges**
  To ensure compliance with environmental flow recommendations in Reach 1 and 3, it is recommended that streamflow gauges be installed. As described in the Issues Paper, the flows in Reach 3 are significantly altered during summer months due to extractions associated with the cultivation of strawberry runners. Currently, the closest stream gauge is well downstream at Devlins Bridge (Gauge # 405217) in the middle of Reach 2. Reach 1 does not contain a gauge. As has been discussed in Section 3, the presence of complex flow paths due to anabranch and uncertainty around the hydrology in Reach 1 create management challenges that cannot be solved by this FLOWS study alone. The absence of gauges causes two main problems:
    - Where environmental flows are put in place via the SFMP, compliance will need to be linked back to a gauge. If flows at the gauge used for compliance bare little or no resemblance to environmental flows in the target reach, then consumptive users may be subject to bans sooner than necessary. Conversely, extractions may be occurring over and above those that are required to sustain an ecologically healthy river.
    - The ability to accurately model the hydrology in a catchment the scale of the Yea River is heavily compromised due to the paucity of streamflow gauges. The installation of gauges will increase the understanding of gains and losses throughout the system and in particular the flow behaviour in the multiple channel environment of the lower Yea River.
- **Develop and implement a monitoring and evaluation program**
  Monitoring the effect of environmental flow delivery in the catchment is essential to improving and adapting the management of the environmental water reserve. This monitoring and evaluation program may consist of methods such as repeat fish surveys, water quality monitoring, repeat cross section surveys and macroinvertebrate sampling. As part of the development of the SFMP and the finalisation of environmental flows for the Yea River an environmental monitoring program should be developed. There is considerable work that is happening currently through the Victorian Government's *Victorian Environmental Flow Monitoring Assessment Program (VEFMAP)* and Melbourne Water's *SFMP Monitoring Program* that could provide excellent guidance for a monitoring program on the Yea River. The monitoring program will need to linked to the environmental objectives being targeted with the individual flow components. Elements that should be considered (but not necessarily limited to):
    - Rehabilitation of native vegetation in the riparian zone, and the control of exotic vegetation.
    - Limiting livestock access to waterways.
    - Encourage responsible recreational fishing for native species.
    - Management of water quality with consideration of nutrient inputs from agricultural runoff.

Once the SFMP is signed off a monitoring program will then be developed that links flows to environmental objectives to monitoring. For example, if the low flow recommendation for Reach 1 is implemented as part of the SFMP, then a monitoring program needs to include assessment of Macquarie Perch populations given that the local flow is based upon providing sufficient habitat for this species.

- **Continue to implement complimentary works outlined in the *Local Waterway Health Strategy for the Yea and Murrindindi Rivers* (Ecos and Fluvial Systems, 2002)**
This complementary strategy for the Yea River catchment provides a framework for implementation of activities that address non-flow related threats (eg. stock access, degraded riparian vegetation, water quality). These works are essential for achieving long term river health targets for the catchment and will ensure environmental objectives outlined in this FLOWS report are achieved and the environmental flows are delivered for the greatest environmental benefit. For more detail of the specific management actions, refer to the strategy (Ecos and Fluvial Systems, 2002).

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