Moorabool River FLOWS Study Update

Corangamite Catchment Management Authority

Final Report

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Contents

Executive Summary

Moorabool FLOWS update

The primary purpose of this project is to undertake a review of the environmental flows assessment for the Moorabool River system, based on current science and Victorian policy, using the revised FLOWS method for determining environmental water requirements in Victoria (DEPI 2013a). Specific outputs from this review will also inform the development of the Moorabool Environmental Water Management Plan (EWMP).

FLOWS reaches and assessment sites

Table E.1 outlines the breakdown of FLOWS reaches and FLOWS assessment sites for the Moorabool FLOWS update. A map showing the breakdown of the Moorabool Catchment into FLOWS Reaches is shown in Figure E.1.

No assessment site was surveyed in FLOWS Reach 2 in the previous study and there was not a sufficient justification to spend additional funds in completing a survey as part of the Moorabool FLOWS update. The reach is in poor condition and lacks habitat features suitable for setting ecological objectives and flow recommendations. Biological health in this reach would benefit from improved land management rather than environmental flows.

Table E.1: Moorabool River FLOWS Reaches and FLOWS Assessment Sites.

FLOWS Reach		FLOWS Assessment Site
1	Moorabool River East Branch: Bostock Reservoir to West Moorabool River	Egerton Bungeeltap Road
2	Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir	No site surveyed in this reach
3a	Moorabool River: Lal Lal Reservoir to confluence with East Branch	Elaine-Egerton Road
3b	Moorabool River: Confluence with East Branch to Sharps Road	Sharps Road
4	Moorabool River: Sharps Road to Barwon River	Bakers Bridge Road

Revised ecological objectives

Ecological objectives for the Moorabool River FLOWS Reaches have been updated following a review of additional information made available since the previous FLOWS study and a field assessment of the FLOWS assessment sites. Revised ecological objectives have been developed for fish, macroinvertebrates, vegetation, Platypus, geomorphology and water quality values. A summary of objectives is as follows:

- Rehabilitate migratory fish populations and maintain and expand non-migratory fish populations.
- Maintain the diversity and abundance of macroinvertebrates.
- Maintain the diversity and zonation of instream, riparian and floodplain vegetation communities.
- Restore a self-sustaining breeding population of Platypus that can disperse to the Barwon River contributing to a larger regional metapopulation.
- Maintain channel and floodplain form and processes.
- Minimise likelihood of low dissolved oxygen conditions and elevated electrical conductivity conditions during low flow periods.

Water management goals

Water management goals for the Moorabool River FLOWS Reaches are outlined in Table E.2.

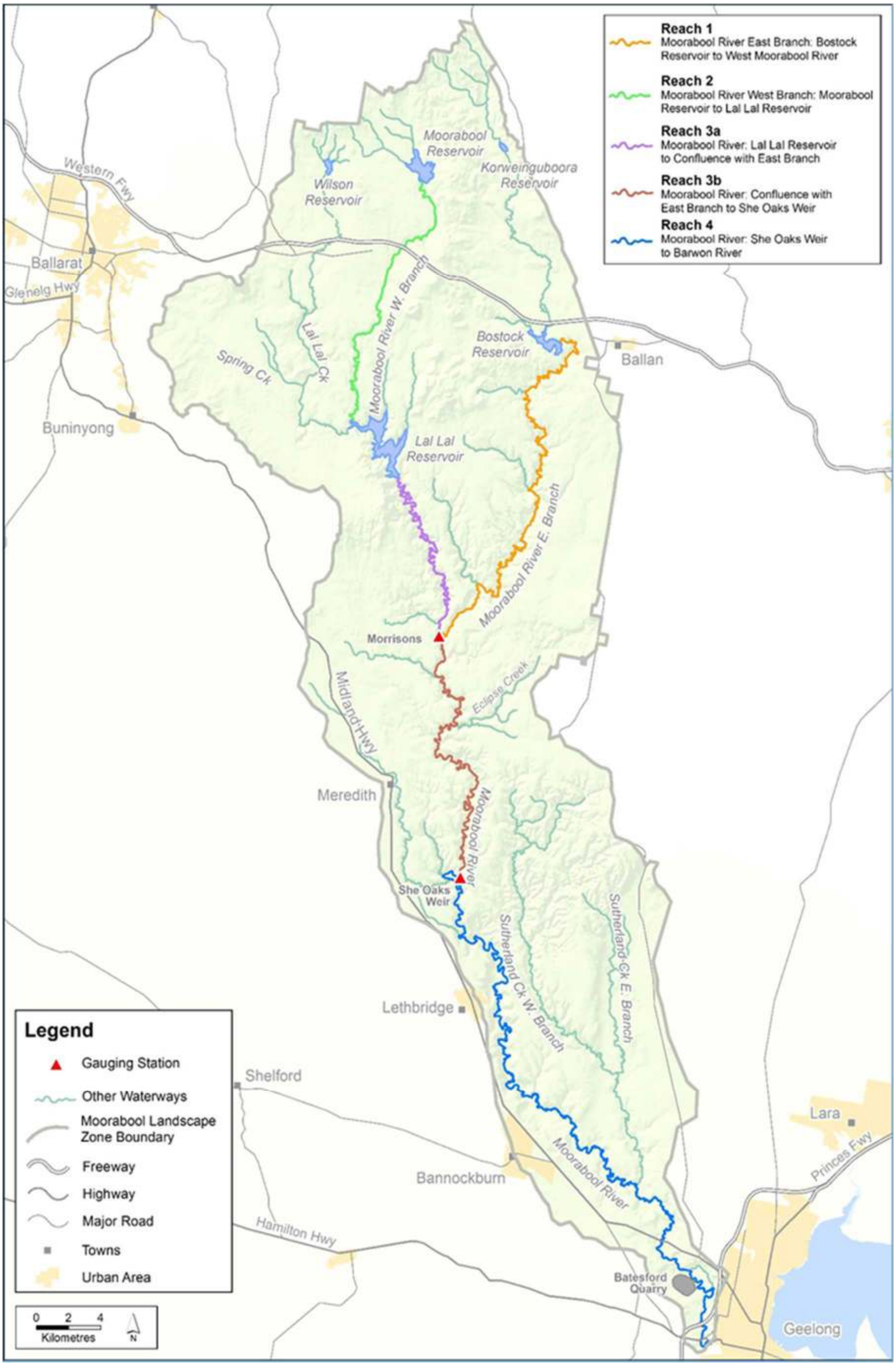

Figure E.1: Moorabool Catchment FLOWS Reaches.

Table E.2: Water management goals for the Moorabool River FLOWS Reaches.

Reach	Water Management Goal
1	To maintain the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing protection to identified habitat refuges through land use management and securing water to maintain pools through dry periods.
2	To maintain the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing protection to identified habitat refuges through land use management and securing water to maintain pools through dry periods.
3a, 3b, 4	To improve the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing high quality breeding and feeding habitat; facilitate their movement through the provision of passage at artificial barriers; and restoration of native vegetation along the river.

Revised environmental flow recommendations

Separate flow recommendations have been developed for wet/average and dry years (Table E.3-E.7). The purpose of these separate recommendations is to provide conditions that will enable native fish and Platypus populations to thrive in wet years, in order to increase their resilience to lower flows in dry years.

For the Moorabool River FLOWS Reaches we have set minimum and aspirational flow recommendations. A minimum flow recommendation refers to the minimum amount of water that is required to meet the ecological objectives. Aspirational flow recommendations are those of a higher magnitude which are recognised as providing a greater benefit to the system and a higher likelihood of achieving river health outcomes.

For FLOWS Reaches 1 and 2 all of the flow recommendations are set as minimum flow recommendations. Aspirational flow recommendations have not been set for these FLOWS reaches as there is not considered sufficient justification to set higher aspirational flow recommendations. For Reaches 3a, 3b and 4, a further distinction has also been made between what is considered ‘Minimum’ as opposed to an ‘Aspirational’ flow recommendation. The updated environmental flow recommendations for FLOWS Reaches 1, 2, 3a, 3b and 4 and the specific objectives they are intended to meet are summarised in the following tables.

The current volume of water allocated in the Moorabool River Environmental Entitlement does not provide sufficient water to meet the environmental needs of FLOWS Reaches 3a, 3b and 4. The 7086 ML Environmental Entitlement falls far short of the volume of water required to achieve the aspirational flow recommendations (14,600 to 36,000 ML). Even the minimum flow recommendations, which range from 3,300 to 9,000 ML cannot be realistically achieved with the existing allocation of water provided in the Environmental Entitlement.

It is our recommendation that the volume of the Environmental Entitlement is increased. A volume of 15,000 ML over three years, with an average of 5,000 ML in each year would go a long way towards meeting the minimum flow recommendations documented in this FLOWS update. This roughly equates to the volume of water required to meet the minimum flow recommendations in a dry year. In order to achieve the aspirational flow recommendations, this would require a more significant increase in the volume of the Environmental Entitlement, upwards of 20,000 to 30,000 ML over three years.

Given the limitations with the amount of water presently available in the Moorabool River Environmental Entitlement and delivery constraints at Lal Lal Reservoir, the following recommendations are made for the prioritisation of flow components for FLOWS Reaches 3a, 3b and 4. The first priority is to provide base flows that are aimed at achieving an average flow rate commensurate with the seasonal minimum low flow recommendation, with trigger based freshes as required to maintain water quality conditions. Second priority is then the Summer/Autumn freshes followed by the Winter/Spring freshes as third priority.

- Primary objective: Delivery of low flows that are aimed at achieving an average flow rate commensurate with the seasonal minimum low flow recommendation, with trigger based freshes as required to maintain water quality conditions.
- Secondary objective: Delivery of freshes to facilitate fish migration/spawning in the Moorabool River, according to the prioritisation of fresh events documented in each season. It is noted that the volume of water needed to deliver multiple freshes may exceed the total amount of water available in the Environmental Entitlement.

For fish migration/spawning freshes to be effective, it is critical that there is connectivity in delivery of flows between FLOWS Reaches 3a, 3b and 4. It is also noted that additional work will be needed to modify existing weir structures to maximise opportunities for movement of fish along the Moorabool River.

Table E.3: Updated environmental flow recommendations for Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River.

Waterway	Moorabool River East Branch: Bostock Reservoir to West Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	All years	Passing flows (1.2 ML/Day) Minimum	December to May		
	Fresh	Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods (W1).	Wet / Average	Not required			
			Dry	2 ML/Day Minimum	Every 8 weeks	2-3 days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	All years	Passing flows (8 ML/Day) Minimum	June to November		
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	37 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	5 Days	2.0/0.7
			Dry	37 ML/Day Minimum	1 event May to August (Tupong) and 1 event September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	5 Days	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day Minimum	1 event every 2 to 3 years, preferably in Winter to avoid risks to Platypus (no control over timing)	2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, a 37 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 8 ML/Day it would take 3 days to ramp up flows to 37 ML/Day and then 4 days to fall down to 8 ML/Day.

Table E.4: Updated environmental flow recommendations for Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir.

Waterway	Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	5 ML/Day Minimum			NA
			Dry	2.5 ML/Day Minimum			NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1).	Wet / Average	30 ML/Day Minimum	3 events	3 Days	2.0/0.7
			Dry	30 ML/Day Minimum	1 event every 2 to 3 years	3 Days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	5 ML/Day Minimum	June to November		
			Dry	2.5 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	40 ML/Day Minimum	3 events	3 Days	2.0/0.7
			Dry	40 ML/Day Minimum	1 event	3 Days	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4).	Wet / Average	250 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus (no control over timing)	1-2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, a 40 ML/Day Winter/Spring Fresh has a recommended duration of 3 days at its peak. If flow started at 5 ML/Day it would take 3 days to ramp up flows to 40 ML/Day and then 6 days to fall down to 5 ML/Day .

Table E.5: Updated environmental flow recommendations for Reach 3a - Moorabool River West Branch: Lal Lal Reservoir to confluence with East Branch.

Waterway	Moorabool River West Branch: Lal Lal Reservoir to East Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	10 ML/Day Minimum	December to May		NA
			Dry	5 ML/Day Minimum	December to May		NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, April/May (Grayling) and January/February (Short-finned Eel)	5 Days	2.0/0.7
				30 ML/Day Minimum	1 event in February/March to water fringing vegetation	3 Days	2.0/0.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet/Average	60 ML/Day Aspirational 10 ML/Day Minimum	June to November		
			Dry	60 ML/Day Aspirational 5 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/0.7

Waterway	Moorabool River West Branch: Lal Lal Reservoir to East Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
		recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 1 event September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day Minimum	1 event every 2-3 years, preferably in Winter to avoid risks to Platypus (no control over timing)	1 to 2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day.

Table E.6: Updated environmental flow recommendations for Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road.

Waterway	Moorabool River: East Moorabool River to Sharps Road		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	20 ML/Day Minimum	December to May		NA
			Dry	10 ML/Day Minimum	December to May		NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, January/February (Short-finned Eel) and April/May (Grayling)	5 Days	2.0/1.7
				30 ML/Day Minimum	1 event in February/March to water fringing vegetation	3 Days	2.0/1.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/1.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	30 ML/Day Minimum	1 event as required	3 Days	2.0/1.7

Waterway	Moorabool River: East Moorabool River to Sharps Road		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	All years	86 ML/Day Aspirational 20 ML/Day Minimum	June to November		
			Dry	86 ML/Day Aspirational 10 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
			Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 1 event September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
	High	Scour pools and maintain channel form and dimensions (G1). Maintain inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	1000 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus	1 to 2 Days	2.0/1.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day.

Table E.7: Updated environmental flow recommendations for Reach 4 - Moorabool River: Sharps Road to Barwon River.

Waterway	Moorabool River: Moorabool River: Sharps Road to Barwon River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	20 ML/Day Minimum	December to May		NA
			Dry	10 ML/Day Minimum	December to May		NA

Waterway	Moorabool River: Moorabool River: Sharps Road to Barwon River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, January/February (Short-finned Eel) and April/May (Grayling)	5 Days	2.0/1.7
				30 ML/Day Minimum	1 event, February/March to water fringing vegetation	3 Days	2.0/1.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/1.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	20 ML/Day Minimum	1 event as required	2 Days	2.0/1.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet/Average	86 ML/Day Aspirational 20 ML/Day Minimum	June to November		
			Dry	86 ML/Day Aspirational 10 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
			Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 1 event in September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
	High	Scour pools and maintain channel form and dimensions (G1). Flushing of sediment to improve spawning sites (F2). Inundate billabongs (G1, G2, V4).	Wet / Average	3000 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus	1 to 2 Days	2.0/1.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day.

Important note about your report

The sole purpose of this report and the associated services performed is to undertake a review of the environmental flows assessment for the Moorabool River system, based on current science and Victorian policy, using the revised FLOWS method for determining environmental water requirements in Victoria (DEPI 2013a). Specific outputs from this review will also inform the development of the Moorabool Environmental Water Management Plan (EWMP). This is in accordance with the scope of services set out in the contract between Jacobs and the Corangamite Catchment Management Authority.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Corangamite Catchment Management Authority and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Corangamite Catchment Management Authority and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context. The scale of this Final Report has been limited by time and budget constraints and with reference to the information that was made available from Corangamite Catchment Management Authority or collated by the author.

This report has been prepared and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Corangamite Catchment Management Authority. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

In 2004, Jacobs (then SKM) determined the flow recommendations for the Moorabool River as part of the Moorabool Water Resources Assessment project. This study was completed over ten years ago, using the State endorsed guidelines: FLOWS – a method for determining environmental water requirements in Victoria (NRE 2002). The major components of the FLOWS method are an assessment of the main flow related issues and the development of environmental flow objectives, which relate the environmental flow requirements of aquatic organisms and processes to critical flow components. Flow recommendations are then developed based on an analysis of the current and natural hydrology of the system and outputs of hydraulic modelling at key sites, to identify flow components that meet the ecological objectives.

1.1 Moorabool River FLOWS study update

In the last decade significant changes have occurred that warrant a review of the 2004 Moorabool River Environmental Flows Assessment. The FLOWS method has been updated, which now requires more explicit distinction between recommendations for dry, average and wet years, including acceptable variation around recommended flows and a risk assessment into the FLOWS process to help manage uncertainties and priorities. There is now a requirement for more justification of the links between flow recommendations and ecological response as supported by relevant science, monitoring and conceptual models.

In addition to changes to the FLOWS method, the period since 2004 has been one of prolonged drought and low flows, punctuated by a number of high magnitude floods. This review provides an opportunity to consider how the system and its values have changed since 2004. The Moorabool River Environmental Entitlement was implemented in 2010. The Moorabool River Environmental Entitlement is held In Lal Lal Reservoir and up to 7086 ML can be stored as a bulk entitlement. This entitlement is subject to delivery rules (a maximum of 7500 ML over three years) which provides the environment with an average of 2500 ML per year. The entitlement can be used to deliver environmental flows to Reaches 3 and 4.

Recent surveys by Arthur Rylah Institute for Environmental Research (ARI) in 2015 have shown that there is a diverse community of small-bodied migratory fish, including threatened Yarra Pygmy Perch, the number and diversity of fish is greater now than previous surveys conducted in the middle of the drought. The previous FLOWS study also did not explicitly consider the flow requirements of Platypus. This project provides the opportunity to update the flow objectives and recommendations to ensure that high value fish and Platypus populations are explicitly considered in the Moorabool system.

Groundwater surface water interaction is identified as an important aspect of stream flows in the Moorabool River system. An investigation of groundwater surface water interactions was undertaken as part of the earlier 2004 water resources assessment (SKM 2004b). Baseflow contributions from groundwater were estimated to be in the order of 50% to 60% in the upper catchment (upstream of Moorabool Reservoir) and 30% to 40% in the middle catchment (upstream of Lal Lal Reservoir). Insufficient information was available to assess the contribution of groundwater to streamflow in the lower catchment (SKM 2004b). The current study reviews the impact that groundwater has on surface water, in particular our understanding of low flows throughout the catchment.

The major components of the FLOWS method that are applied to this review are shown in Figure 1.1. The project builds extensively on the existing FLOWS study and therefore many of the tasks involve reviewing and updating existing information rather than starting from scratch.

The data collation and review tasks specifically focuses on the new information that has become available since the 2004 assessment. This is expanded on through input from all members of the Environmental Flows Technical Panel (EFTP), the Project Control Group (PCG) and the Moorabool Stakeholder Advisory Committee (MSAC). The existing breakdown of reaches and selection of flow assessment sites have been reviewed to determine their suitability. EFTP field assessments were carried out at those sites to confirm environmental values, any requirements for additional survey and improvements to hydraulic models, a review of the ecological objectives and goals for each FLOWS Reach and revision of the environmental flow recommendations.

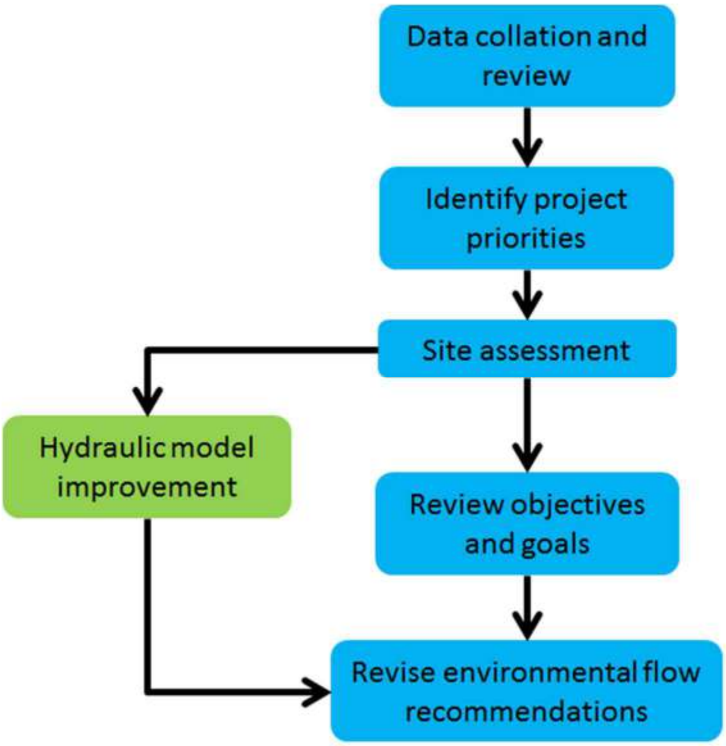

Figure 1.1: Outline of steps involved in the FLOWS method as applied to this project.

This Final Report integrates information presented in earlier revisions to the Site Paper and combined Issues and Flow Recommendations Report. The Final Report provides an updated description of the condition of the Moorabool River system and its trajectory over the next 10 years under different water management scenarios (Section 2, 3 and 4). An updated assessment is provided of water dependant values and an evaluation is provided of the existing ecological objectives, where appropriate these are revised and a long term water management goals have been developed for each FLOWS reach (Section 5). Flow recommendations to support the ecological objectives and additional complementary management actions are documented in this report (Section 5.7 and Section 8).

1.2 Moorabool Environmental Water Management Plan

Corangamite Catchment Management Authority (CMA) is also developing the Moorabool Environmental Water Management Plan (EWMP). An EWMP is a scientifically-based management plan for a wetland or river system that describes the: ecological values present; long-term goal for the site; selected (priority) ecological objectives for the system that environmental watering will support or improve, and; watering requirements of these objectives over the long-term (the regime over an approximately ten year cycle). It provides the 5-10 year management intentions, based on both scientific information and stakeholder consultation that can be used by the Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for both short and longer-term environmental water planning. The EWMP will be informed by an updated understanding of the condition of the Moorabool River and its watering requirements. The activities and outputs outlined in this project will directly contribute to the development of the Moorabool EWMP.

1.3 Environmental flows technical panel

The EFTP for the review of the environmental flow requirement for the Moorabool River consists of the following members:

- Dr Peter Sandercock – fluvial geomorphology
- Dr Simon Treadwell – water quality and ecosystem processes
- Damien Cook – aquatic, riparian and floodplain vegetation ecology

- Wayne Koster – fish ecology
- Dr Melody Serena – Platypus ecology
- Eliza Wiltshire – groundwater surface water interaction
- Amanda Woodman – hydrology and hydraulics
- Kate Austin – hydrology and water resources

1.4 Catchment inspection and site assessments

In preparation for the updated FLOWS assessment, Simon Treadwell and Amanda Woodman undertook an inspection of the Moorabool River Catchment on 19 February 2015. This inspection had the following specific aims:

1) To identify whether there have been significant geomorphological changes since the 2004 assessment and requirements for new feature survey; and
2) To determine what, if any, additional survey would be required at each site to improve the accuracy and reliability of the existing hydraulic models.

Based on this assessment, we do not believe there have been significant geomorphological changes to warrant a new feature survey of the existing FLOWS assessment sites, or the development of new hydraulic models. However, as part of the review of catchment hydrology and hydraulics, we have reviewed the roughness values and downstream boundary conditions for each of the existing hydraulic models.

Peter Sandercock, Simon Treadwell, Damien Cook, Wayne Koster, Melody Serena and Amanda Woodman undertook an inspection of the FLOWS assessment sites on the 6 May 2015 with Saul Vermeeren and Robert Bone from Corangamite CMA. This provided an opportunity for members of the EFTP to meet and discuss changes to the sites since the previous FLOWS assessment with reference to previous ecological objectives, findings from recent monitoring and any other technical information provided by the community.

2. FLOWS reach delineation and site selection

2.1 Moorabool River environmental flow reaches

The Moorabool River flows southward from the Central Highlands between Ballarat and Ballan and joins the Barwon River at Fyansford. The east and west branches of the Moorabool River rise in the southern ranges of the Wombat State Forest. Each branch flows in confined valleys to their confluence near Meredith. Below the confluence of the upper branches, the Moorabool River continues to flow through a tightly confined valley that broadens downstream but occasionally narrows markedly to its confluence with the Barwon River.

For the purpose of providing environmental flow recommendations, the study area is divided into a number of representative FLOWS reaches. FLOWS reaches are selected to be representative of the key features of the waterways within the study area and can be identified by major tributary inflows, changes in landform, geology, channel or floodplain morphology, points of regulation (e.g. major weirs or off-takes), or changes in ecological processes or communities.

The 2004 environmental flow assessment project divided the Moorabool River catchment into four FLOWS reaches:

- FLOWS Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River;
- FLOWS Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir;
- FLOWS Reach 3 - Moorabool River: Lal Lal Reservoir to Sharps Road; and
- FLOWS Reach 4 - Moorabool River: Sharps Road to Barwon River.

These FLOWS reaches broadly align with physical and biological characteristics of each river and with gauge stations for which daily natural and current flows are available. The same reach boundaries have been applied for this review, however we have broken FLOWS Reach 3 into two sections:

- FLOWS Reach 3a - Moorabool River: Lal Lal Reservoir to confluence with East Branch
- FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road

Breaking FLOWS Reach 3 into two sections is considered appropriate given that the upper section is a tributary of the Moorabool River. A significant change in flow contribution is expected downstream of the confluence of the East and West Moorabool River, providing further justification to treat the Moorabool River below the confluence as a separate FLOWS reach component to the West Moorabool River. A map showing the breakdown of the Moorabool Catchment into FLOWS Reaches is shown in Figure 2.1.

The EFTP for the 2004 flow assessment identified FLOWS assessment sites where detailed field assessments and channel survey were undertaken (Table 2.1). A FLOWS site refers to a section of river that contains examples of major geomorphic and ecological features typical of that FLOWS reach. As per the FLOWS method (NRE 2002), FLOWS sites were selected for their:

- representativeness to wider features of the FLOWS reach;
- proximity to stream gauges;
- availability of information to assess the impacts of current water use on stream flow within the system;
- accessibility to the site; and
- availability of biological data.

For the current project, we have reviewed the suitability of the existing FLOWS assessment sites, particularly in the context of known ecological objectives and recent advances in our understanding of the flow requirements of high priority environmental values in each FLOWS reach. The following sections briefly describe the major features associated with each FLOWS reach and discuss why existing FLOWS assessment sites have been retained, supplemented or substituted to improve environmental flow recommendations for each FLOWS reach.

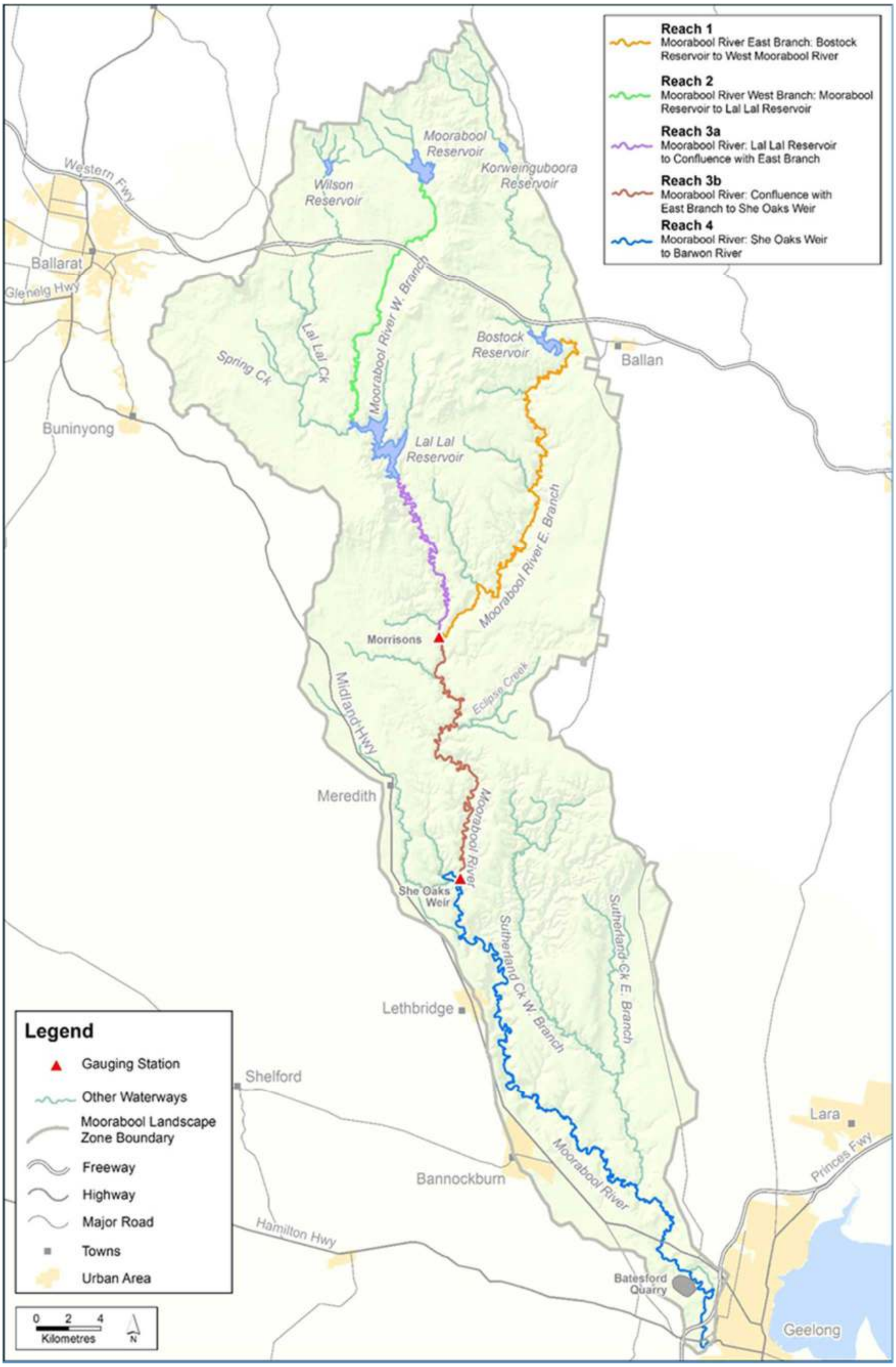

Figure 2.1: Moorabool Catchment FLOWS Reaches.

Table 2.1: Moorabool River reaches and assessment sites used in the 2004 FLOWS Study.

FLOWS Reach	FLOWS Reach Location	FLOWS Site	FLOWS Assessment Site Location	Flow Compliance Point
1	East Moorabool River, Bostock Reservoir to the confluence with west Moorabool River	1	Egerton Bungeeltap Road	East Moorabool River at Egerton-Bungeeltap Road
2	West Moorabool River between Moorabool and Lal Lal Reservoirs	2	No site surveyed in this reach.	West Moorabool River at Hunts Bridge (Elaine-Egerton Road)
3	West Moorabool and Moorabool River, Lal Lal Reservoir to Sharps Road, She Oaks	3	Immediately downstream of She Oaks Weir at Sharps Road	Moorabool River at Sharps Crossing, Sharps Road She Oaks
4	Moorabool River, Sharp Roads, She Oaks downstream to the confluence with the Barwon River	4	Downstream of Bakers Bridge Road	Moorabool River at Bakers Bridge Rd

2.2 FLOWS Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River

The East Moorabool River downstream of Bostock Reservoir flows through the East Moorabool gorge before reaching a narrow floodplain downstream of Egerton Bungeeltap Road. The valley form alternates from narrow gorges to sections where there are broad floodplains (Craigie et al. 2002). Channel contraction is likely to have been a response to flow regulation in this reach, with this leading to encroachment of woody vegetation into the channel and colonisation by emergent macrophytes such as Cambungi (Craigie et al. 2002).

At the time of the 2004 flow assessment, it was noted that there were significant knowledge gaps in relation to the biological condition of the East Moorabool River. Results from one fish survey, undertaken by Tunbridge (1988) indicated that Short-finned Eel was the only native species present. Exotic species included Brown Trout and Redfin. Conditions were assessed as poor for native fish, as there were few pools and those that did exist would have low dissolved oxygen conditions and high temperatures (SKM 2004b). McGuckin and Ryan (2009) completed fish surveys of the East Moorabool River in December 2008 and recorded River Blackfish in addition to Short Finned Eel.

The FLOWS assessment site is located approximately 12 km downstream from Bostock Reservoir. Channel conditions along the East Moorabool River vary markedly, oscillating between confined gorges sections to less confined sections with broader alluvial plains. The assessment site selected is representative of a confined gorge section, the configuration of the channel is strongly influenced by bedrock controls (Figure 2.2). Deeper pools are controlled by bedrock, separated by shallower areas with emergent macrophytes. The flow regime has been significantly altered due to the impoundment of Bostock Reservoir. Compared to natural, there has been a decrease in cease to flow events (from 35% to 15%), a decrease in median flows (3.6 to 2.1 ML/Day) and an increase in the duration of the low flow period (SKM 2004b). No environmental entitlement exists for Bostock Reservoir, though passing flow rules are in place, capped at 1.2 ML/day from December to July and 0.8 ML/day August to November (Corangamite CMA 2015).

The FLOWS assessment site is still considered to be representative of the broader reach and it has been retained for the current project. The EFTP inspection of this site considered how the conditions of the channel have changed since the previous FLOWS study. Platypus objectives were not previously developed for this reach. The potential for Platypus to exist in this reach were assessed in the field by Melody Serena. The recent finding of River Blackfish in this reach is also significant. One of the ecological objectives for FLOWS Reach 1 was to restore a self-sustaining population of River Blackfish. A restore objective was also set for Mountain Galaxias, Australia Smelt, Southern Pygmy Perch and Short-finned Eel (SKM 2004b).

Figure 2.2: Photographs taken in March 2003 showing the condition of the channel at Egerton Bungeeltap FLOWS Assessment Site in FLOWS Reach 1. Left photo at Cross Section 1, looking downstream. Right photo at Cross Section 2, looking downstream.

2.3 FLOWS Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir

The upper section of the West Moorabool River between Moorabool and Lal Lal Reservoirs is characterised by a contracted channel that meanders through pastureland (SKM 2004b). The 2004 flow assessment describes the riparian vegetation as being dominated by willows and pasture grasses. Instream vegetation was assessed as being in poor condition, due in part to grazing, stock access and altered flow conditions resulting from the impoundment of Moorabool Reservoir and large number of farm dams located in the upper catchment. Figure 2.3 shows repeat photographs of the West Moorabool River at Yendon Egerton Road, the first photo taken in March 2003 and the second in February 2015. The morphology of the channel has not changed. However, there is a notable increase in the extent of grassy and woody vegetation across the channel.

Figure 2.3: Repeat photographs of West Moorabool River taken at Yendon Egerton Road looking upstream in March 2003 (left) and February 2015 (right).

Fish species in this FLOWS reach are isolated due to the presence of barriers upstream (Moorabool Reservoir) and downstream (Lal Lal Reservoir). Limited fish survey data was available for this reach at the time of the 2004 flow assessment. Only one native fish species was recorded, Mountain Galaxias. Exotic species such as Redfin, Brown Trout and Tench dominate the fish population (SKM 2004b). More recent fish surveys did not include sites in this reach (Environous 2008; McGuckin and Ryan 2009; Ryan and McGuckin 2007). Water quality parameters were noted as often exceeding State Environment Protection Policy (SEPP) objectives.

Williams and Serena (2004) undertook Platypus surveys at four sites along an 8 km section of the west branch upstream of Lal Lal Reservoir as part of their surveys of the Moorabool in 2003/2004. No Platypus were recorded at these locations.

No channel surveys were completed in this FLOWS reach during the 2004 FLOWS assessment due to narrow and contracted condition of the channel and absence of habitat features (SKM 2004b). The limited channel features makes it difficult to set flow objectives as there is a lack of channel features to set these against. The flow regime has been significantly altered. Compared to natural, there has been an increase in cease to flow events and decrease in median flows (18 to 2 ML/Day). The altered flow regime has created conditions more favourable for exotic fish species, which compete with and prey on small-bodied native fish species (SKM 2004b). No environmental entitlement exists for Moorabool Reservoir, though passing flow rules are in place, the lesser of 3 ML/Day or gauged inflows into the reservoir (Corangamite CMA 2015).

Given the lack of an existing FLOWS assessment site and the generally stated poor condition of the river in this section, it was recommended that an assessment site not be surveyed in the current project. We note, that the 2004 flow assessment did set ecological objectives and recommendations for this reach, using a site surveyed downstream of Lal Lal Reservoir (i.e. in Reach 3). This is not ideal, as the hydraulic model that has been constructed represents the conditions of the river downstream of Lal Lal Reservoir. In the absence of a FLOWS assessment site within this reach, we have adopted a similar approach.

2.4 FLOWS Reach 3 - Moorabool River: Lal Lal Reservoir to Sharps Road

This FLOWS reach is located in the middle of the Moorabool River catchment and includes the west branch of the Moorabool River downstream of Lal Lal Reservoir to Sharps Road downstream of She Oaks Weir (SKM 2004b). This section of river is significantly impacted by flow regulation, with some reversal of flow seasonality and greatly reduced variability as the river is used as a conduit for delivering water to She Oak’s Weir, which serves as an offtake point for Barwon Water (Corangamite CMA 2015; SKM 2004b). The river flows through extensive tracts of endangered remnant vegetation that include Stream Bank Shrubland, Riparian Woodland and Grassy Woodland Ecological Vegetation Communities (Corangamite CMA 2015).

As stated in Section 2.1, we have broken FLOWS Reach 3 into two sections:

- FLOWS Reach 3a - Moorabool River West Branch: Lal Lal Reservoir to confluence with East Branch; and
- FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road

2.4.1 FLOWS Reach 3a - Moorabool River West Branch: Lal Lal Reservoir to confluence with East Branch

The West Moorabool River downstream of Lal Lal Reservoir flows through relatively confined gorge sections until it reaches the confluence with East Moorabool River. Less information on the biological condition of the West Moorabool River exists than for section of Moorabool River downstream. Long term water quality monitoring is undertaken further downstream at Morrisons gauging station on the Moorabool River. Environous (2008) surveyed the Moorabool River West Branch at Elaine-Egerton Road in July 2007 and captured 15 River Blackfish. McGuckin and Ryan (2009) recorded Short-finned Eel, River Blackfish and Flat Headed Gudgeon in their 2008 survey of the West Branch. Williams and Serena (2004) trapped one female Platypus 4 km downstream of Lal Lal Reservoir in 2003/2004. No further Platypus surveys of the West Branch have been completed.

SKM (2004b) included a FLOWS assessment site in this section of the river at Elaine-Egerton Road, with this used to inform the flow recommendations for FLOWS Reach 2. This site is located approximately 4 km downstream from Lal Lal Reservoir. Figure 2.4 shows repeat photographs of the river from the Elaine-Egerton Road Bridge, taken in March 2003 and February 2015. Notable is the increased cover of vegetation at the channel margins and presence of water ribbons in the channel in 2015, compared to 2003. A variety of hydraulic habitats are present at this site, including large and small pools, separated by riffles. For the current project, this FLOWS assessment site is used to inform an updated set of objectives and flow recommendations for FLOWS Reach 3a.

Figure 2.4: Repeat photographs of West Moorabool River taken at Elaine-Egerton Road Bridge looking downstream in March 2003 (left) and February 2015 (right).

2.4.2 FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road

Downstream from the confluence of the East and West Branches, the valley form varies from sections where there are broad floodplains to sections with more confined narrow gorges.

Native fish species documented in this FLOWS reach at the time of the 2004 flow assessment include River Blackfish, Short-finned Eel, Australian Smelt and Southern Pygmy Perch (SKM 2004b). Environous (2008) captured River Blackfish in their 2007 surveys. McGuckin and Ryan (2009) captured Short-finned Eel, River Blackfish, Southern Pygmy Perch, Flat Headed Gudgeon and Australian Smelt in their December 2008 surveys. She Oaks Weir forms a major barrier preventing fish movement further upstream into this reach. A number of smaller weirs are also present further downstream between She Oaks and Batesford that are likely to limit migration of native fish species such as Australian Grayling and Tupong to She Oaks Weir (SKM 2004a; 2004b).

Live-trapping surveys indicate that Platypus were widely distributed along the Moorabool River downstream of Lal Lal Reservoir in the mid-2000s, with up to four individuals captured overnight at a single site (Williams 2005; Williams and Serena 2004; 2006). Population size undoubtedly shrunk when flow ceased along much of the Moorabool in the final years of the Millennium Drought, with the species still likely to be in a post-drought recovery phase.

The FLOWS assessment site for this reach is located immediately downstream of She Oaks Weir at Sharps Road. This site was selected as the preferred site, to two other sites (Morrisons and Stieglitz Road). The channel immediately below She Oaks Weir includes multiple channels, associated with the bifurcation of the river downstream of the road bridge, a long pool, vegetated bar, riffles and woody debris accumulations. Substrates at the site consist of bedrock in the pools, and cobbles and pebbles in the riffles.

The site provides a range of habitats and flow levels that are useful for setting objectives and flow recommendations for the reach. The FLOWS assessment site is considered to be representative of the reach and we have retained this for the current project. Little change in channel form is evident when comparing repeat photographs of the river channel from 2003 and 2015 (Figure 2.5). There appears to have been a slight increase in the amount of reeds at the edges of the channel. The hydraulic model for this site has been reviewed and where appropriate changes made to roughness values to reflect changes in vegetation.

Figure 2.5: Repeat photographs taken of Moorabool River at Sharps Road FLOWS Assessment Site, looking upstream in March 2003 (left) and February 2015 (right).

2.5 FLOWS Reach 4: Moorabool River: Sharps Road to Barwon River

This FLOWS reach commences downstream of Sharps Road, She Oaks Weir and extends to the confluence with the Barwon River. The in-stream and riparian vegetation communities through this reach range from excellent condition at the top end to poor to fair condition at the lower end (SKM 2004b).

There are several small irrigation weirs along this reach. The weirs create pools upstream, where silt and organic matter accumulate smothering aquatic vegetation and reducing habitat availability. The channel downstream of these weirs appears to have contracted (SKM 2004a). Further channel adjustments upstream and downstream of the weirs is likely due the presence of these structures and the highly regulated flows in this reach (SKM 2004a). Downstream of Batesford, the river has been extensively modified through realignment and concrete lining to allow the development of a large limestone quarry (Craigie et al. 2002; SKM 2004a).

The large number of weirs acts as barriers to fish movement through this reach. Eight species of native fish were previously noted in the 2004 flow assessment as recorded from the Moorabool River downstream of She Oaks Weir, and that their distribution is generally limited to the lower parts of this reach downstream of Batesford. This list included River Blackfish, Common Galaxias, Spotted Galaxias, Short-finned Eel, Short-headed Lamprey, Australian Grayling, Southern Pygmy Perch and Tupong. Flat headed Gudgeon were also recorded in surveys by McGuckin and Ryan (2009) in December 2008.

Recent fish surveys by ARI (2015) indicate that high river flows in 2010-11 may have facilitated the recolonisation of migratory and estuarine fish species in this reach, highlighting the importance of high flows in providing opportunities for movement of fish upstream of weirs (Corangamite CMA 2015). Live-trapping surveys in the mid-2000s showed that Platypus were widely distributed in this reach (Williams 2005; Williams and Serena 2004; 2006). The population size is expected to have lowered during the Millennium Drought, with the species still likely to be in a post-drought recovery phase.

The FLOWS assessment site is located immediately downstream of Bakers Bridge Road. This site was selected as the preferred site, to three other sites (Midland Hwy, Parker Road, Perdrisat Road). The river at this site is characterised by a u-shaped channel, with a series of alternating deep pools and shallow glides. Deeper pools are controlled by bedrock, separated by shallower glides with cobbles. Riparian vegetation consists of sparse mature River Red Gum and occasional Blackwood. A range of instream vegetation types were noted as present (SKM 2004b). Little change in channel form is evident when comparing photographs of the river channel from 2013 and 2015 (Figure 2.6).

Figure 2.6: Repeat photographs taken of Moorabool River at Bakers Bridge Road, looking upstream in March 2003 (left) and February 2015 (right).

For the current project, this FLOWS assessment site is used to inform an updated set of objectives and flow recommendations for the section of Moorabool River downstream of Sharps Road to the confluence of the Barwon River. In the time since the 2004 flow assessment, our understanding of the flow requirements for fish has increased dramatically, particularly the timing and incremental increase in flow needed to facilitate fish movement and spawning. This updated understanding has been taken into account when setting revised ecological objectives and flow recommendations. Furthermore, the influence of groundwater / surface water interactions on stream flows was not assessed in the previous 2004 flows assessment. Losses of streamflow due to seepage from the river into Batesford Quarry have since been identified as a significant issue, particularly during low flow periods. Revised flow recommendations need to take into account potential losses to the quarry during low flows.

3. Water Resource Management

3.1 Hydrology

The Moorabool River rises as the east and west branches to the North East of Ballarat. Both the east and west branches are heavily regulated, including the Korweinguboora and Bostock Reservoirs on the east branch and the Moorabool and Lal Lal reservoirs on the west branch. The hydrology is summarised in detail in the 2004 Environmental Flows study (SKM 2004b).

High flows are July through to November with the peak flows observed in the months from August to October. The flow regime is significantly impacted by harvesting of water in urban storages and farm dams, private farm dams, private diverter usage and groundwater usage. The impact of water harvesting is apparent when comparing historic and natural flows that have been derived for FLOWS assessment sites in the Moorabool Catchment (Figure 3.1).

Farm dams, which capture water before it reaches the river, are having a significant impact on river inflows. The catchment contains more than 4000 dams, with an estimated total storage capacity of 14,401 ML. Modelling of farm dams indicates that the collection of water in farm dams results in a reduction in stream flow of 12,300 ML (Corangamite CMA 2005).

Since the 2004 study, the Moorabool River Environmental Entitlement has been established. The Moorabool River Environmental Entitlement is held In Lal Lal Reservoir and up to 7086 ML can be stored as a bulk entitlement. This entitlement is subject to delivery rules (a maximum of 7500 ML over three years) which provides the environment with an average of 2500 ML per year. The volume is not sufficient to supply all environmental recommendations, and is constrained by the reservoir outlet capacity of approximately 140 ML/Day.

3.2 Groundwater and Surface Water Interactions

This section on groundwater and surface water interactions has been written with reference to a review of the previous FLOWS assessment (SKM 2004b) and information obtained from more recent investigations.

Harbour (2012) conceptualised baseflow to the East Moorabool River to come from the Newer Volcanic basalt and the upper and lower Tertiary aquifers. During dryer periods the baseflow from the basement aquifer may also contribute to streamflow. Baseflow could potentially sustain flow in the river all year around in this part of the catchment. Harbour (2012) supported SKM (2004b) estimates baseflow contribution of between 30% and 50%, although notes that there is not enough gauge information at the weir to actually quantify the estimates. Nevertheless, this more recent work provides further supporting evidence that groundwater discharge is an important component of baseflow in FLOWS Reach 1 of the Moorabool River catchment.

Evans (2006) undertook a study of the geology and groundwater flow systems in the West Moorabool River Catchment and their relation to river salinity. Evans (2006) noted that compared to the level of knowledge available for surface water flow components of the West Moorabool River catchment, the groundwater contribution to river flow is poorly understood. The highly regulated nature of the surface water flows makes it difficult to quantify groundwater contribution. Evans (2006) did note that watertable elevation contours and electrical conductivity patterns suggest that groundwater does flow to and discharge into parts of the West Moorabool River. SKM (2004b) quantified baseflow contribution to surface water. In the upper catchment (upstream of Moorabool Reservoir), baseflow contribution estimates range from 50% to 60%. In the middle catchment (upstream of Lal Lal Reservoir, FLOWS Reach 2), baseflow contribution estimates range from 30% to 40%. No additional or more recent information regarding baseflow contributions in the West Moorabool River is available to update these estimates.

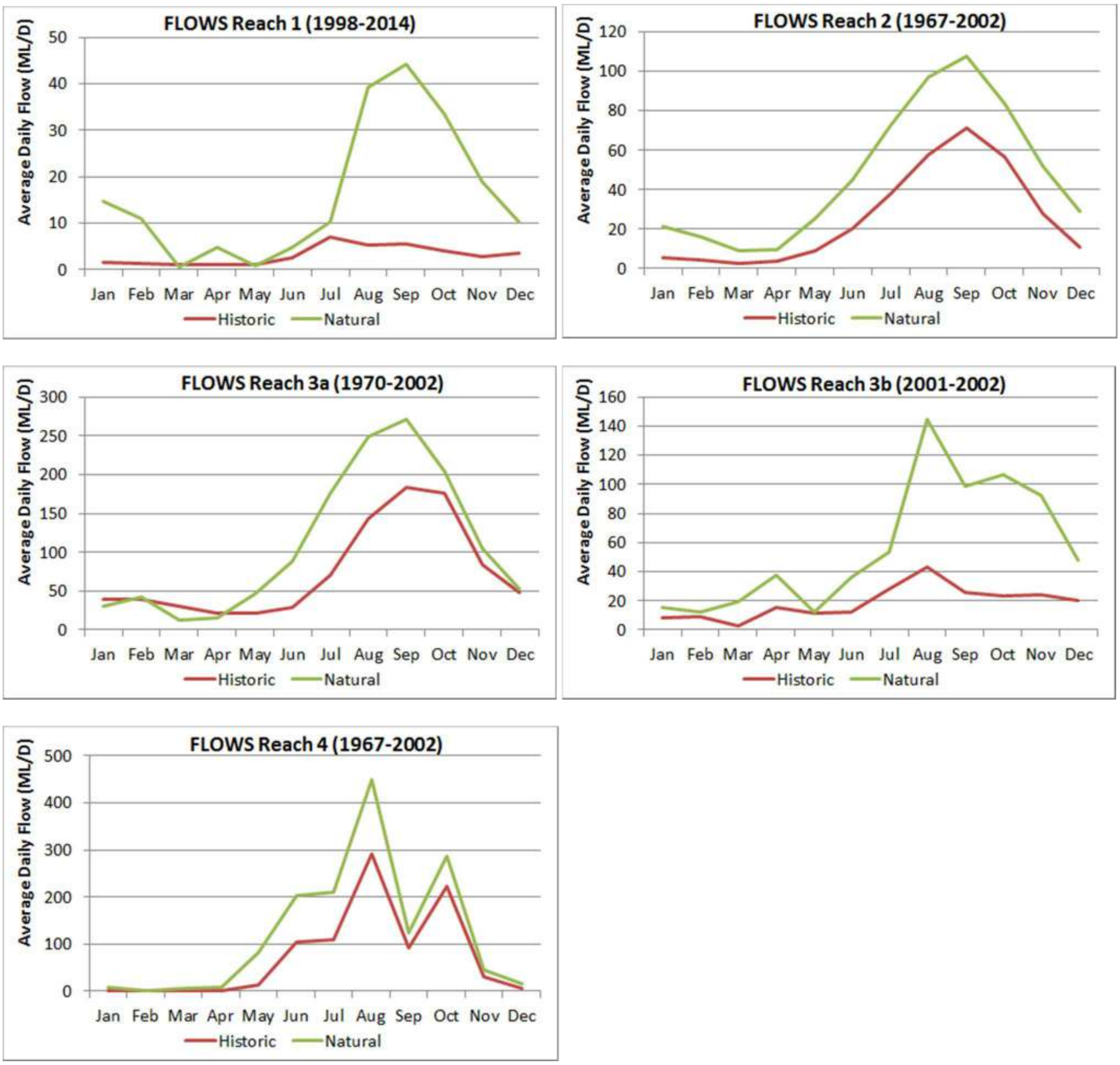

Figure 3.1: Average historic and natural flow volumes for FLOWS Assessment sites in the Moorabool Catchment. Historic flow is the infilled gauge record. This represents the flow in the river at any given time based on climate conditions, storage management and extraction rates. This record therefore includes changes in the system over time. Natural flows are the flows in the river that result from the climate conditions with no storages or extractions (including farm dams and private diverters).

Horgan (2006) completed an honours thesis on the hydrogeology of the Morrisons-She Oaks Area, which corresponds with sections of the Moorabool River downstream of Lal Lal Reservoir (FLOWS Reaches 3a, 3b and 4). Stream flow data and groundwater level monitoring in this area are largely non-existent or of insufficient quality to produce a meaningful interpretations of the groundwater – surface water interactions (Horgan 2006). Table 3.1 summarises current understanding of groundwater surface water interactions along the Moorabool River downstream of Lal Lal Reservoir as it relates to the different hydrogeological units. In contrast to the upper catchment, the general indications are that the baseflow contribution to the streamflow from the Newer Volcanics, Quaternary Deposits and Highland Gravel Caps are lower and groundwater discharge from the Palaeozoic Basement Rocks is greater than previously thought. The reduction in average stream flows at Morrisons and Batesford and respective corresponding increases in electrical conductivity has been attributed to an increasing portion of streamflow being derived from baseflow contributions, throughout a period of below average rainfall.

Table 3.1: Summary of findings on groundwater surface water interactions for the Moorabool River downstream of Lal Lal Reservoir (after Horgan 2006).

Hydrogeological unit	Summary of findings on groundwater surface water interactions
Newer Volcanics	Not considered to contribute significant base flow to the Moorabool River. Thought to be little connectivity between newer volcanics in the northern upper catchment with those in the southern catchment.
Quaternary Deposits	Shallow alluvial aquifers are not likely to provide significant baseflow to streams, based on the observation that discharge sites that were observed after above average rainfall, ceased discharge after a period of below average rainfall. It is more likely that the alluvial aquifers allow excess water to move through them as throughflow after high rainfall periods
Highland Gravel Caps	The initial groundwater conceptual model created for this area involved saline discharge from the Tertiary highland gravel caps to the Moorabool River. This hypothesis was deemed largely incorrect (or not a significant process in the catchment) given the caps are locally thin and do not contain a permanent watertable.
Palaeozoic Basement Rocks	Major drainage lines incise the Palaeozoic basement rocks and form discharge zones for groundwater flow to the Moorabool River. Greater hydraulic conductivities have been measured than those previously estimated, meaning there is a potential that baseflow and salt wash off from discharge areas may be significant and therefore potentially provides more salt to the Moorabool River and its tributaries than expected.

4. Ecological condition and trajectory

4.1 Current condition

The Moorabool River is considered one of the most heavily committed and flow stressed rivers in Victoria. The catchment is heavily farmed with about 75 per cent of its 1,150 km^2 area used for agriculture. The amount of water that enters the river is substantially reduced by the number of farm dams in the catchment. There are more than 4000 farm dams in the catchment with an estimated volume of 14,400 ML (SKM 2004b).

The Moorabool River is a highly regulated waterway with several large water storages in the upper reaches (Figure 4.1). There are three major water storages at the headwaters of the Moorabool River. These are the Moorabool, Bostock, and Lal Lal Reservoirs. The catchment is an important source of water for a range of users, including the major urban centres of Geelong and Ballarat, the smaller urban centres of Ballan, Meredith and Bannockburn, stock and domestic water users and irrigators. Water is sourced from both surface and groundwater (SKM 2004b).

The Moorabool River Environmental Entitlement is held In Lal Lal Reservoir and up to 7086 ML can be stored as a bulk entitlement. This entitlement is subject to delivery rules (a maximum of 7500 ML over three years) which provides the environment with an average of 2500 ML per year. No environmental entitlement exists for Bostock or Moorabool reservoirs, however passing flow rules are in place. For the Moorabool Reservoir the passing flow requirements downstream of the reservoir are the lesser of 3 ML/Day or gauged inflows into the reservoir. For Bostock Reservoir it is the lesser of flow into the reservoir and 1.2 ML/Day from December to July and 0.8 ML/day August to November (Corangamite CMA 2015). The minimum passing flow requirements are less than the existing recommended minimum environmental flows (SKM 2004b).

Passing flows from Lal Lal Reservoir are also a significant component of annual stream flow below this structure and are important in maintaining base flows through winter. Holders of bulk entitlements must allow a portion of inflow into Lal Lal Reservoir to continue into the river below the dam. Passing flow rules stipulate release of 5 ML/Day (or calculated inflows into the reservoir) when inflow has been less than 43 GL over 2 years, or 20 ML/Day (or calculated inflows into the reservoir) when inflow has been over 43 GL for 2 years. Passing flows from Lal Lal Reservoir are currently at 5 ML/day or calculated inflows into the reservoir (whichever is lesser). Passing flows do not impact the volume of water allocated to the environmental entitlement, nor do they restrict the ability to use the Moorabool River Environmental Entitlement. Passing flows are an important source of water for the Moorabool River and where opportunity exists, the environmental entitlement will be used to enhance these flows (Corangamite CMA 2015).

Downstream from Lal Lal Reservoir, are a series of weirs, the largest of which is She Oaks weir with a height of 9 m. In the lower reach between She Oaks and Batesford there are nine private diversion weirs that are a significant barrier to fish. The potential for upstream movement of migratory fish species is limited by the sequence of barriers. These barriers have increased the extent of slow flowing habitat and reduced habitat diversity in the lower reach of the Moorabool (SKM 2004b).

The Third Index of Stream Condition (ISC) Report for the period 2004 to 2010 describes the East Moorabool River (FLOWS Reach 1) as having poor to moderate condition and the West Moorabool River (FLOWS Reach 2 and 3a) as having moderate condition (Table 4.1). The section of river from the confluence of the East and West Branch of the Moorabool River to She Oaks Weir (FLOWS Reach 3b) is assessed as having a moderate condition and the section of river downstream from Sharps Road (FLOWS Reach 4) as having very poor condition (Table 4.1).

The condition of riparian vegetation catchment ranges from extensively cleared in the upper reaches to dense, but fragmented areas of native remnants in the mid and lower reaches. Lack of streamside vegetation and invasion by exotic species such as willows and gorse have been identified as significant issues in the catchment. Water quality monitoring shows high nutrient concentrations throughout the catchment, and high electrical conductivity occurs in the lower reaches, likely due to saline groundwater inputs. Macroinvertebrate communities appear to be indicative of moderate environmental condition.

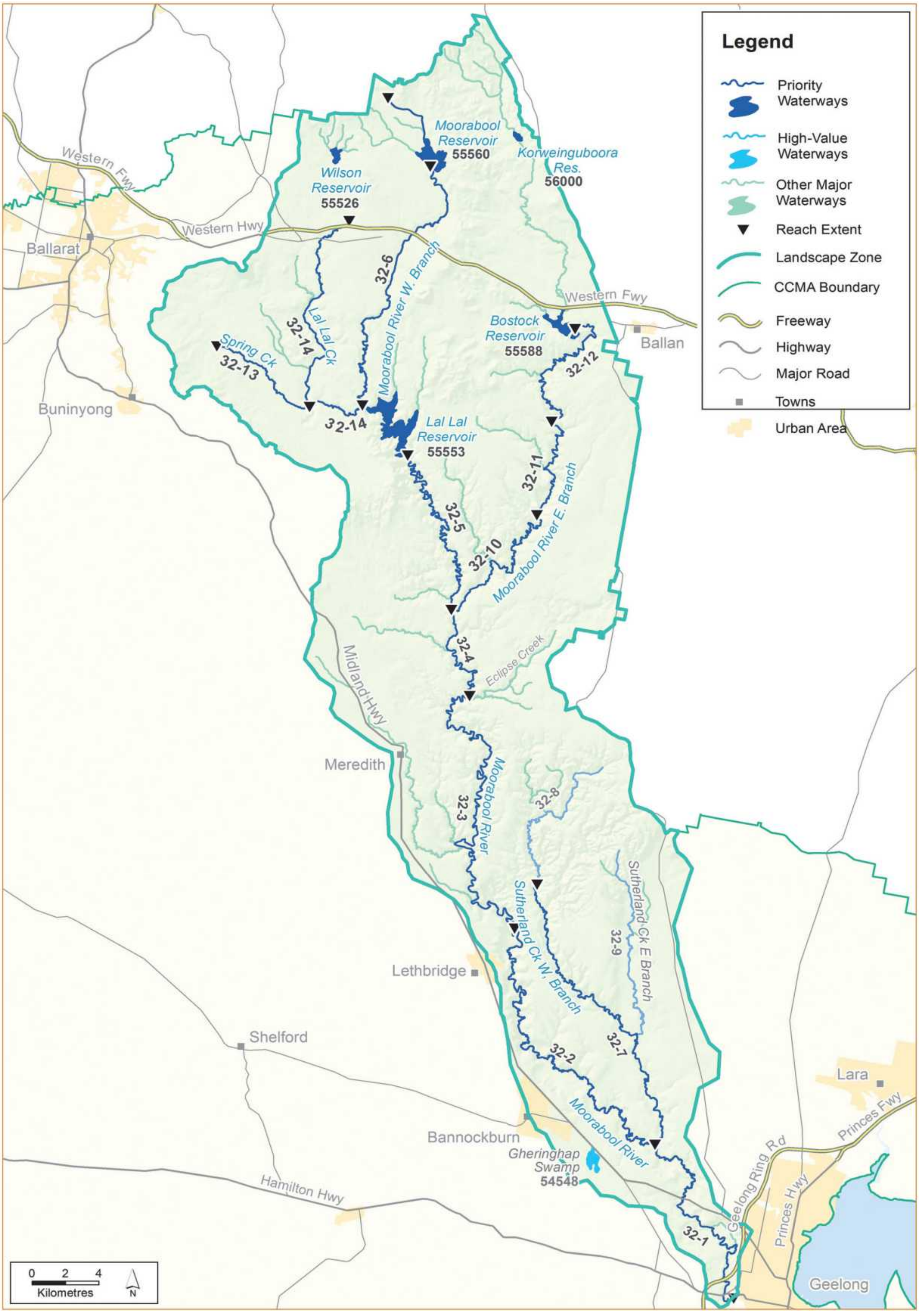

Figure 4.1: Moorabool River catchment highlighting priority and high-value waterways (Corangamite CMA 2014).

The Moorabool River is listed as a priority waterway in the Corangamite Waterway Strategy for 2014-22 as it is a water supply catchment and has significant environmental values (Corangamite CMA 2014). Environmental values in the Moorabool River catchment include a number of native freshwater fish species, including Short-finned Eel, River Blackfish, Common Galaxias, Mountain Galaxias, Spotted Galaxias, Southern Pygmy Perch, Yarra Pygmy Perch, Short Headed Lamprey, Flat-headed Gudgeon, Australian Grayling, Australian Smelt and Tupong (ARI 2015; Environous 2008; McGuckin and Ryan 2009; Ryan and McGuckin 2007; Tunbridge 1988). Platypus have also been recorded in the Moorabool River catchment (McGuckin and Ryan 2009; Williams 2005; Williams and Serena 2004; 2006).

Table 4.1: 2013 ISC Assessment for the Moorabool River FLOWS Reaches (DEPI 2013b). Each of the Sub-Indicesscores are rated out of 10, which combine to produce a combined ISC score rated out of 50.

FLOWS Reach		ISC Reach	Sub-Indices					ISC Score	Condition
			Hydrology	Physical Form	Streamside Zone	Water quality	Aquatic Life		
1	Moorabool River East Branch: Bostock Reservoir to West Moorabool River	10[1,2]	4	6	7	4	4	22	Poor
		11[1]	4	6	5		6	24	Moderate
		12[1,2]	4	8	8	5	8	29	Moderate
2	Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir	6[1]	8	7	5	4	4	24	Moderate
3a	Moorabool River: Lal Lal Reservoir to confluence with East Branch	5[1,2]	8	7	8	6	6	33	Moderate
3b	Moorabool River: Confluence with East Branch to Sharps Road	3[1,2]	8	6	8	5	8	32	Moderate
		4[1]	8	7	6	6	8	33	Moderate
4	Moorabool River: Sharps Road to Barwon River	1[1]		7	6	5	6	19	Very Poor
		2[1]		5	6		7	18	Very Poor

[1] Hydrology score based on 2011 environmental watering objectives

[2] Only 1 year of water quality available

Members of the Moorabool Advisory Stakeholder Committee (MSAC) who attended the project meeting on the 21 April 2015 in Geelong was asked to describe the environmental values associated with the Moorabool River, how the river has changed over time, environmental threats and what improvements they would like to see made to the river. Response by MSAC members indicate the following:

- Moorabool River is valued for its function in supporting significant flora and fauna, recreation activities such as fishing and bushwalking and as a water supply;
- Other than the altered flow regime and extractions, the main threats are sedimentation and barriers impacting on flow connectivity and fish passage and uncontrolled stock access to waterways;
- Suggested improvement actions include flow management to increase flow to the meet the water requirements of the environment, increased collaboration between authorities to manage the entitlement and onground works, removal of barriers and works to improve flow connectivity and fish passage.

More detail of the information provided by members of the MSAC is presented in Table 4.2. This information has been used to help develop water management goals and ecological objectives for the Moorabool FLOWS Reaches.

Table 4.2: Moorabool values, observed changes, key threats and improvement actions. This information was collated through discussions with the Moorabool Stakeholder Advisory Committee (MSAC).

Environmental and social values	• Functioning river that supports biodiversity. Fish populations (Blackfish, Grayling). Other significant fauna include Platypus, Turtles, Water Rats, Waterbirds, Bats and Frogs • Recreation (fishing, picnics, bush walking, camping) • Remnant native vegetation (Stream Bank Shrubland, Riparian Woodland and Grassy Woodland EVCs) • Landscapes and bioregions, volcanic uplands and plains • Water supply and use of water in dams to assist the environment
How has the river changed over time	• Dramatic decreases in flows due to dams • Drought led to deterioration in water quality and availability of water along the river • Encroachment of vegetation and increase in weedy vegetation • Some areas that have been fenced off are experiencing good revegetation • Noted improvements to river health with recent flow management
Key threats	• Development in the catchment and impacts on water quality (Plantations, Vineyards) • Dams, diversions/pumping and groundwater extractions • Drought, limited ability to deliver water • Sedimentation and barriers impacting on flow connectivity and fish passage • Stock access to waterways • Introduced species, willows and exotic fish • Changes in land management and fire regime. Climate change. • Rubbish (tyres)
Improvement actions	• Increase the amount of water available for the environment and to support social amenities • Increased collaboration between authorities to manage entitlement and onground works • Barrier removal and future works to improve flow connectivity and fish passage • Rehabilitate degraded sections of waterway through partnerships arrangements (i.e, Landcare) • Better management of domestic water/recycling • Water resource modelling to improve allocation of environmental water/prioritisation • Removal of exotic vegetation (Willows, Blackberries, Gorse) • Increase community awareness and appreciation of the river

4.2 Condition trajectory

If the current volume of the environmental water entitlement is not increased and no additional waterway management works are conducted, then over the next 10 years we can expect the overall condition of the Moorabool River to deteriorate.

Passing flows from the larger storages do not meet minimum environmental water requirements required to maintain existing environmental values. Opportunities for downstream and upstream movement of migratory fish species are limited as a resulted of the regulated flow regime and the presence of a number of artificial and natural barriers. The majority of migratory fish species are restricted to the lower parts of the Moorabool River, downstream of Batesford Weir. The condition of instream habitat in some sections is also threatened by stock access to and degradation of riparian zone, the downstream movement of sediment slugs, seepage losses to Batesford Quarry and failure of concrete channel lining works.

The ecological values will benefit from long term environmental watering, however the volume of water stored in the Moorabool River Environmental Entitlement is not sufficient to meet all of the environmental flow recommendations. Figure 4.2 presents average daily flows for Morrisons Gauging Station for the period 2002 to 2015 against existing recommended flows for FLOWS Reach 3. Table 4.3 provides an assessment of the compliance of flows delivered over this period with the environmental flow recommendations.

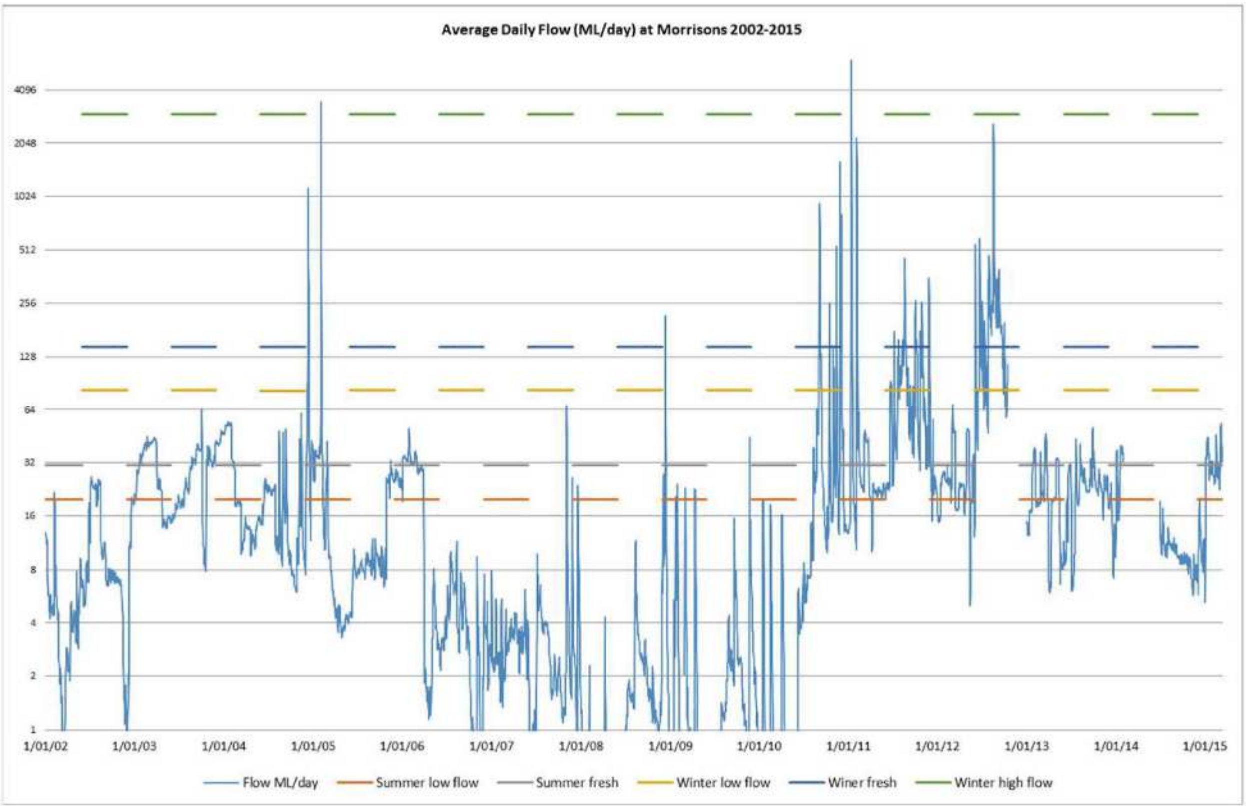

Figure 4.2: Average daily flow (ML/Day) at Morrisons Stream Gauge for the period 2002-2015 showing recommended flows (from Corangamite CMA 2015).

Table 4.3: Compliance assessment of flow recommendation for FLOWS Reach 3 as measured at Morrisons Gauging Station 2001-2015 (after Corangamite CMA 2015).

Flow component		2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	Observations
Summer	Cease to flow															
	Low flow															E,O
	Freshes															E
Winter	Low flow															
	Freshes															E
	High flow															

E = Managed environmental water release

O = Consumptive water en route/other managed flow

Key

(red)	No significant part of the flow component achieved
(amber)	Flow component partially achieved
(green)	Flow component has been completely achieved, i.e. complete magnitude, duration and frequency

To date, environmental flows from Lal Lal Reservoir have predominantly been released during the summer period. This is primarily due to the differences in magnitude between summer and winter flow recommendations, delivery constraints at Lal Lal Reservoir (approximately 140 ML/Day) and limits to the total volume of water available within the Moorabool River Environmental Entitlement. Existing summer flow recommendations for FLOWS Reach 3 and 4 are to maintain base flows of 20/21 ML/Day between December and May and provide three Summer Freshes of greater than 31/32 ML/Day for 10 days. The volume of water required to deliver the Summer flow recommendations (>4000 ML) exceeds the average yearly volume of water available for the environmental entitlement (2500 ML/Day). Summer releases by Barwon Water between Lal Lal Reservoir and She Oaks contribute to the achievement of summer flow flows.

Achieving all of the existing flow recommendations for the Moorabool River within the delivery constraints and environmental water availability is not possible. The recommended base flow for FLOWS Reach 3/4 is 83/86 ML/Day between June and November. Two to three Winter Freshes greater than 146/162 ML/Day for 5/10 days and a Winter High of greater than 3000 ML/Day are also recommended. There is insufficient volume of water available in the environmental entitlement to meet the Winter low flow recommendation, however in wet years this can be met by high flows associated with high rainfalls and reservoir spills. The winter freshes are achievable in wet or average rainfall years, when these flows can be built on top of smaller event generated by rainfall over the catchment (Corangamite CMA 2015).

The ecological objectives and flow recommendations for the Moorabool FLOWS Reaches have been updated in this report following a review of additional information made available since the previous FLOWS study and a field assessment of FLOWS assessment sites. Delivery of the updated FLOWS Recommendations as presented in this report will provide greater benefits to the ecological values, in particular fish. The timing of freshes have been revised based on improvements in our understanding of the seasonality of flows required to trigger upstream and downstream movement and spawning of migratory fish species. However, questions do still remain about the influence of natural and artificial barriers have on fish movement along the Moorabool. Further monitoring of flows and fish movement and investigation into the influence of barriers is required and where required, further increases in flow, barrier modification or removal may be needed to provide for fish passage.

5. Review of water dependant values and ecological objectives

5.1 Fish

5.1.1 Values

Since the previous Moorabool River environmental flows assessment (SKM 2004b), there has been a number of additional fish surveys conducted in the River, which has improved our understanding of the fish assemblages present (Environous 2008; McGuckin and Ryan 2009; Raymond unpublished data; Ryan and McGuckin 2007). A summary of the current condition of fish assemblages in the Moorabool River based on this new information is provided below.

Twelve native freshwater fish species have been recorded in Moorabool River system. Records of one of the species, Yarra Pygmy Perch, appear restricted to Sutherland Creek. Blue-Spot Goby, which predominantly inhabit estuarine waters, have also occasionally been recorded in the lower reaches of the River.

Six of the native freshwater fish species exhibit obligatory diadromous life histories i.e. move between freshwater and marine habitats at some stage during their life cycle (Harris 1984). Of the diadromous species in the Moorabool River, most are catadromous i.e. enter rivers from the sea as juveniles, and adults return to the sea or estuary to spawn (e.g. Tupong, Short-finned Eel, Common Galaxias). A small number of the species are amphidromous (i.e. mature and spawn in fresh water and the larvae drift downstream to the sea, with juveniles migrating back into fresh water) (e.g. Australian Grayling, Spotted Galaxias) or anadromous (i.e. enter rivers from the sea as mature adults and migrate to upstream spawning grounds, with juveniles later migrating downstream to the sea) (e.g. Short-headed Lamprey). Australian Grayling has declined dramatically since European settlement and is currently listed as threatened under State[1] and Federal legislation[2] (Backhouse et al. 2008b). Altered flow regimes, barriers to movement, habitat degradation and alien species are considered likely contributors to the decline (Backhouse et al. 2008a).

Most diadromous fish species in the Moorabool River are more prevalent in the lower reaches below Batesford Weir, an exception is Short-finned Eel, which are capable of climbing over barriers. One of the most significant findings of recent surveys was collections of low numbers of Spotted Galaxias, Common Galaxias and Tupong upstream of Batesford Weir, which indicates that some fish have been able to take advantage of occasional migration opportunities, possibly when the weir is 'drowned' out during elevated flows.

Five of the native freshwater species in the Moorabool River system are 'non-migratory', although one species, Australian Smelt, may have both diadromous and non-diadromous components (Crook et al. 2008). Mountain Galaxias reportedly had a previously limited distribution restricted to the upper reaches, but was not recorded in recent surveys. Little detailed information is provided on Flat-headed Gudgeon in the previous flows assessment, but the results of recent surveys indicate that this species is widely distributed. This species generally tolerates a wide range of environmental conditions and flow regulation is unlikely to have a major adverse effect on them (Balcombe et al. 2011; Humphries et al. 2012).

River Blackfish and Southern Pygmy Perch reportedly previously had a wide distribution that extends from the junction with the Barwon River to the junction with Coolebarghurk Creek near Meredith, although recent surveys indicate that the former species is also found further upstream including in the East and West Branches. It has been suggested that River Blackfish are not particularly flow sensitive (Davies 1989) and that impacts such as removal of woody debris, sedimentation and cold-water pollution may have a greater impact on this species than flow regulation (Doeg and Koehn 1994; Gippel and Stewardson 1995). Southern Pygmy Perch have a strong preference for abundant aquatic vegetation in slow flowing water (Humphries 1995).

Six introduced fish species have been recorded in the Moorabool River system. Three species, Eastern Gambusia, Carp and Goldfish, were not previously listed as recorded in the River. Recent surveys indicate that

[1] Flora and Fauna Guarantee Act 1988
[2] Environment Protection and Biodiversity Conservation Act 1999

Eastern Gambusia are widespread. This introduced species is a highly successful invader of aquatic environments, thought to detrimentally impact native fishes directly (Macdonald et al. 2012).

5.1.2 Evaluation of existing objectives

Since the original flows assessment (SKM 2004b), significant new information has been obtained to improve our understanding of the flow-ecology relationships for several species, in particular Australian Grayling. A summary of this increased understanding is provided below.

The most comprehensive previous study of the life history of Australian Grayling, in the Tambo River, suggested that spawning most likely occurs in upriver freshwater reaches (Berra 1982). In contrast, recent research demonstrates the existence of a long-distance downstream spawning migration to lower river reaches immediately upstream of the estuary, associated with increased river discharge in Autumn (Figure 5.1) (Koster et al. 2013). The large distances (e.g. ~ 30 km) often travelled, and a tendency of Australian Grayling to cease downstream migration when discharge declines, highlights a need to provide flow events of sufficient magnitude and duration to allow adults to reach spawning areas (e.g. lower freshwater reaches of the Barwon River). In the previous flows assessment, flow recommendations focused on flow events in spring-summer to trigger spawning. However, downstream migration and peak egg abundance occur predominantly in April-May (Koster et al. 2013).

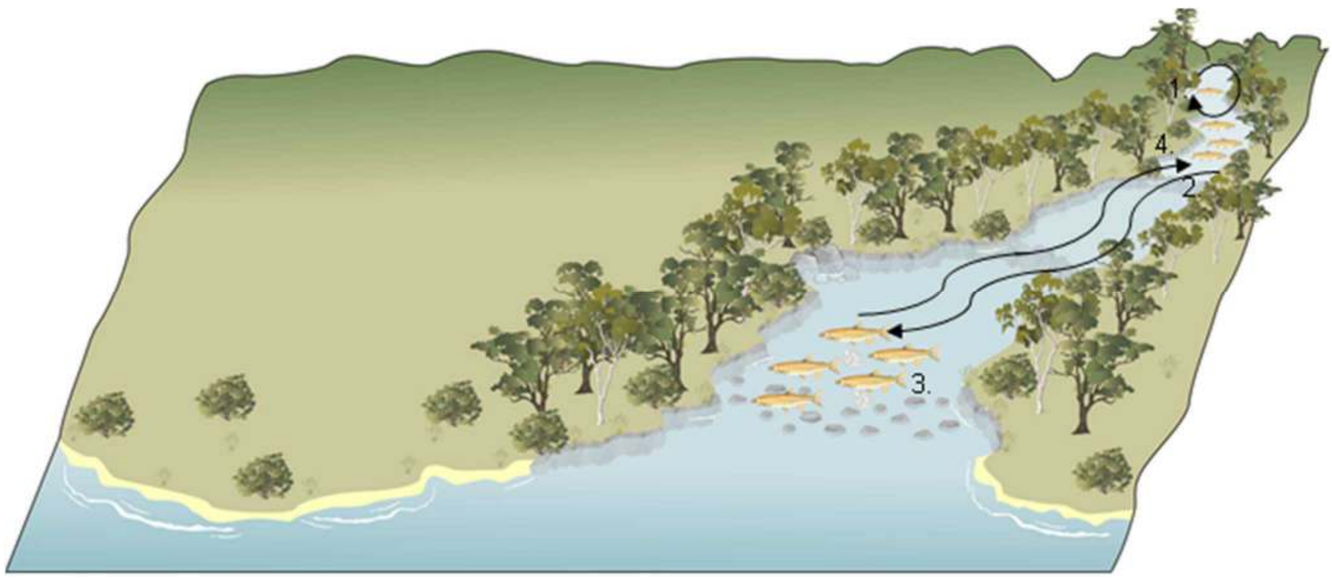

Figure 5.1: Summary of movement behaviours of adult Australian Grayling and links to flow. 1. Fish display only small-scale movement prior to migrating downstream. 2. Fish undertake rapid long-distance downstream migrations to the lower reaches of rivers in April–May, coinciding with increased flows. Fish that have not arrived at the lower reaches during the high flows cease their migrations temporarily, and then recommence migration on the next flow event. 3. Spawning activity is concentrated in the lower freshwater reaches. 4. Following downstream migration, most individuals return upstream to the area they previously occupied.

Our understanding of the flow-ecology relationships for Tupong and Short-finned Eel has also improved (Crook 2004; Crook et al. 2010). Recent research shows downstream migration of Tupong to the sea occurs predominantly in May-August and is associated with high river discharges (Crook et al. 2010), while Short-finned Eel migrate from fresh water into the estuary primarily over Summer and following high river flows, before entering the sea (Crook et al. 2014). In the previous flows assessment, flows were recommended in Autumn-Winter to trigger migration of adult Tupong, whilst there was no recommendation to promote downstream migration of adult Eels.

Recent research has also improved our understanding of the flow-ecology relationships for River Blackfish. Previous studies suggest that the River Blackfish is a sedentary species that occupies a highly restricted range (<30 m) (Khan et al. 2004; Koehn 1986). However, at times they also undertake frequent localised movements among habitats at night, longer-distance upstream movements, and lateral movements onto inundated riparian areas during or following increased discharge (Koster and Crook 2008). Flows to maintain adequate depths through riffles to allow for fish passage may be important for River Blackfish to allow them to move through shallower areas between their usual locations in deeper habitats.

Winter-Spring freshes to trigger upstream movement of Mountain Galaxias to spawn were recommended in the previous flows assessment. There is, however, a lack of empirical evidence for this flow–ecology response relationship for Mountain Galaxias. Recent research shows that spawning of Mountain Galaxias occurs at upland sites in Winter, followed by downstream larval migration and subsequent upstream movement in late Spring (Dexter et al. 2014). While cease-to-flow periods such as during drought years could disrupt such recolonisation, and sufficient flows to allow periodic longitudinal movements may be important (Dexter et al. 2014), evidence of Winter-Spring freshes acting as an upstream spawning movement trigger is lacking.

Similarly, Spring-Summer freshes to trigger a post-spawning return upstream movement of Spotted Galaxias were recommended in the previous flows assessment, but there is a lack of empirical evidence for this flow–ecology response relationship. Research suggests that for stream-dwelling populations of Spotted Galaxias spawning is associated with decreasing temperature and photoperiod and most likely occurs in the freshwater upriver reaches (Crook and White 1995; Humphries 1989).

5.1.3 Revised ecological objectives

Revised ecological objectives for fish are presented in Table 5.1. The revised objectives have been consolidated into two broad objectives for migratory and non-migratory species. These objectives are supported by more specific guidance on the timing of flow components required for specific fish species. The main changes are April-May freshes for Grayling, May-August freshes for Tupong and Summer Freshes for Short-finned Eels, plus removal of freshes for post-spawning of Mountain Galaxias and freshes for return upstream movement of Spotted Galaxias.

Table 5.1: Revised ecological objectives for fish for selected FLOWS Reaches.

Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1 3a 3b 4	F1	Rehabilitate migratory species (Tupong, Short-finned Eel, Common Galaxias, Spotted Galaxias, Short-headed Lamprey, Australian Grayling)				
		- Provide opportunities for upstream migration of adult anadromous and juvenile catadromous and amphidromous fish	Upstream migration	Freshes	Spring/Early Summer	Increased distribution, abundance and diversity of migratory fish species
		- Trigger downstream spawning migration of adult catadromous and amphidromous fish	Downstream spawning migration	Freshes	April-May - Australian Grayling May-Aug – Tupong Summer - Short-finned Eel	
		- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	
				Freshes	All seasons	
1 2 3a 3b 4	F2	Maintain and expand non-migratory fish species (Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				
		- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species

5.2 Macroinvertebrates

5.2.1 Values

Macroinvertebrates are often used as indicators of river health due to their sensitivity to changes in catchment use, pollution and habitat preference. In addition, macroinvertebrates break down organic matter and provide a food source for many animals higher up in the food chain (eg. fish, birds and Platypus).

Based on data collected by the Environmental Protection Authority (EPA) in 1998 and 2000, the 2004 FLOWS study reported the macroinvertebrate community at She Oaks to be in good condition with relevant biological metrics meeting or exceeding State Environment Protection Policy (SEPP) objectives (Table 5.2). This indicates that in general, at this site, the macroinvertebrate community diversity is high and is not limited by habitat availability or water quality.

AUSRIVAS predicts the macroinvertebrates which should be present in specific stream habitats under reference conditions (EPA 2000) whereas SIGNAL scores provide an indication of the level of pollution, based on the types of invertebrate families collected at that site (Chessman 1999).

Table 5.2: Macroinvertebrate ratings for edge and riffle habitats in 1998 and 2000 and their compliance with SEPP objectives (EPA, 2001).

Year	Habitat	AUSRIVAS		SIGNAL		Number of families		Number of key families combined habitat	
		She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective
1998	Edge	1.06	0.85	5.71	5.5	31	26	29	22
1998	Riffle	0.95	0.82	5.63	5.5	29	23		
2000	Edge	0.96	0.85	5.53	5.5	40	26	32	22
2000	Riffle	1.05	0.82	5.71	5.5	27	23		

Macroinvertebrate assessments have also been completed as part of the Index of Stream Condition (ISC) assessments in 1999, 2004 and 2010 (Table 5.3). Aquatic life scores are derived from a combination of SIGNAL and AUSRIVAS indices (in 2010 Number of Families was added to the aquatic life score). It is difficult to directly compare differences in ISC scores across years because of slight changes in the way scores have been calculated, however, in general, the scores indicate macroinvertebrate communities are in moderate to very good condition with the majority of taxa expected to be present recorded in surveys. In particular, sites in FLOWS Reaches 3a and 3b, downstream of Lal Lal Reservoir, are in good to very good condition. Further downstream, sites in Reach 4 are also generally in good condition, although moderate SIGNAL Scores (score of 2 out of 4) do indicate potential for some water quality impacts. Sites in Reach 2 are generally in poor condition with fewer families present than expected, while sites in Reach 1, are in poor to very good condition (depending on site specific locations).

Community based waterwatch surveys in 2007 at 3 sites downstream of Lal Lal Reservoir reported the macroinvertebrate community to be in very good condition (Waterwatch, 2007), with good numbers of sensitive taxa present (e.g. mayfly, dragonfly, stonefly and caddis fly larvae). Waterwatch surveys in 2013 reported similar conditions (Corangamite Waterwatch Program unpublished). The taxa present in FLOWS reaches downstream of Lal Lal Reservoir are those that require permanent, well oxygenated flowing conditions through riffle habitats.

The common decapod species of Yabby, Yarra Spiny Cray, Burrowing Cray and Freshwater Shrimp have also been recorded from the Moorabool River system (NRE 1999). Raadik and Koster (2000) also caught the Southern Victorian Spiny Cray at four sites between Batesford and She Oaks weir in 1998.

Table 5.3: Macroinvertebrate AUSRIVAS, SIGNAL and Number of Families biometric scores and consequent ISC Aquatic life score (http://ics.water.vic.gov.au/ics/). Ausrivas, Signal and Number of Families scores are rated out of 4, ISC aquatic Life scores are rated out of 10.

		1999			2004			2010			
FLOWS Reach	ISC Reach	AUSRIVAS	SIGNAL	ISC Aquatic life score	AUSRIVAS	SIGNAL	ISC Aquatic life score	AUSRIVAS / key families	SIGNAL	No. families	ISC Aquatic life score
1	10	4	0	**5**				2	3	1	**4**
	11	4	3	**9**				3	3	3	**6**
	12				4	3	**9**	3	2	4	**8**
2	6	2	4	**8**				1	3	1	**4**
3a	5	2	4	**8**	4	3	**9**	2	2	3	**6**
3b	3				3	3	**8**	3	2	4	**8**
	4			**8***			**8***	4	3	4	**8**
4	1	2	4	**8**				3	2	3	**7**
	2						**8***	2	2	3	**6**

* Score extrapolated from similar nearby sample reach

5.2.2 Evaluation of existing objectives

Existing macroinvertebrate objectives are to maintain a diverse macroinvertebrate community in all FLOWS reaches comprising a mix of both slow water (i.e. pools) and fast water (i.e. riffles) taxa (SKM 2004b). Given the macroinvertebrate community is in a good to very condition, the objective to maintain diversity is still appropriate. The flow components recommended for each FLOWS reach are generally appropriate. However, given the presence of riffle taxa downstream of Lal Lal Reservoir, which are sensitive to low flows and particularly cease to flows (see Section 5.2.1), the recommendation for a summer cease-to-flow in FLOWS Reach 3 is not supported (see section 5.2.3 for justification).

5.2.3 Revised ecological objectives

It is recommended that revised objectives for macroinvertebrates remain similar to those from the 2005 FLOWS study, namely, objectives for all FLOWS reaches are to "Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats" (Table 5.4). The flow components required to achieve this objective is a combination of low flows to maintain access to suitable habitats (especially inundation riffle habitats in Reaches 3a, 3b and 4, and inundation of large woody habitat in pools in Reach 4) and freshes at various times throughout the year to provide a disturbance regime that flushes fine sediment from riffle habitats and scours accumulated biofilms in order to create a mosaic of benthic habitat types.

Table 5.4: Revised ecological objectives for macroinvertebrates for selected FLOWS Reaches.

FLOWS Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1 2 3a 3b 4	M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
			Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae

A cease-to-flow is not recommended due to the potential impacts this may have on the availability and quality of riffle habitats, especially in Reaches 3 and 4, and on the quality of water in pools (which may suffer from low dissolved oxygen during extended periods of low and no flow – See Section 5.6).

Boulton (2003) suggested that macroinvertebrate communities respond to stream drying as a combination of gradual changes and step changes (see Figure 5.2). Small or moderate reductions in stream flow have relatively little effect on the abundance or diversity of macroinvertebrates as long as the flow reductions were not associated with the loss of specific habitats. However, there are particular flow thresholds below which certain habitats would become unavailable to macroinvertebrates and that any flow change that crossed these thresholds would result in a significant reduction in the total abundance of macroinvertebrates and a change in community composition. The first step change associated with a drying stream occurs when falling water levels isolate the stream from littoral or overhanging vegetation that provides habitat, food and shelter for many macroinvertebrates. The second step change occurs when flow ceases and riffle habitats dry up. Riffle dwelling macroinvertebrates respond to this stage by moving to remnant pools, burrowing into the substrate and the hyporheic zone, flying to other streams or entering a desiccation resistant dormant phase of their life cycle. Once the stream stops flowing, water quality in the pools deteriorates (i.e. dissolved oxygen levels fall, water temperature and electrical conductivity increase), and some more sensitive taxa in the Ephemeroptera, Plecoptera and Trichoptera (EPT) orders (i.e. mayfly, stonefly and caddisfly respectively) disappear. Furthermore, Rose et al. (2008) reported that during low flows riffle habitats retained the majority of macroinvertebrate taxa types until flows ceased and riffles dried out. The third step change occurs when surface water completely disappears and pools dry up. The only macroinvertebrates that persist at that point are those that are able to persist as active or resting stages under rocks and damp leaf packs in the main stream channel and those species that are able to burrow into and survive in the damp sediments below the stream bed (the hyporheic zone).

Based on the above, a cease-to-flow is not recommended, especially in reaches with good riffle habitat (namely Reaches 3 and 4). However, suitable low flows are required to maintain access to riffle habitat and to maintain inundation of littoral vegetation at pool margins. Freshes are also required to scour biofilms and maintain a mosaic of habitat types.

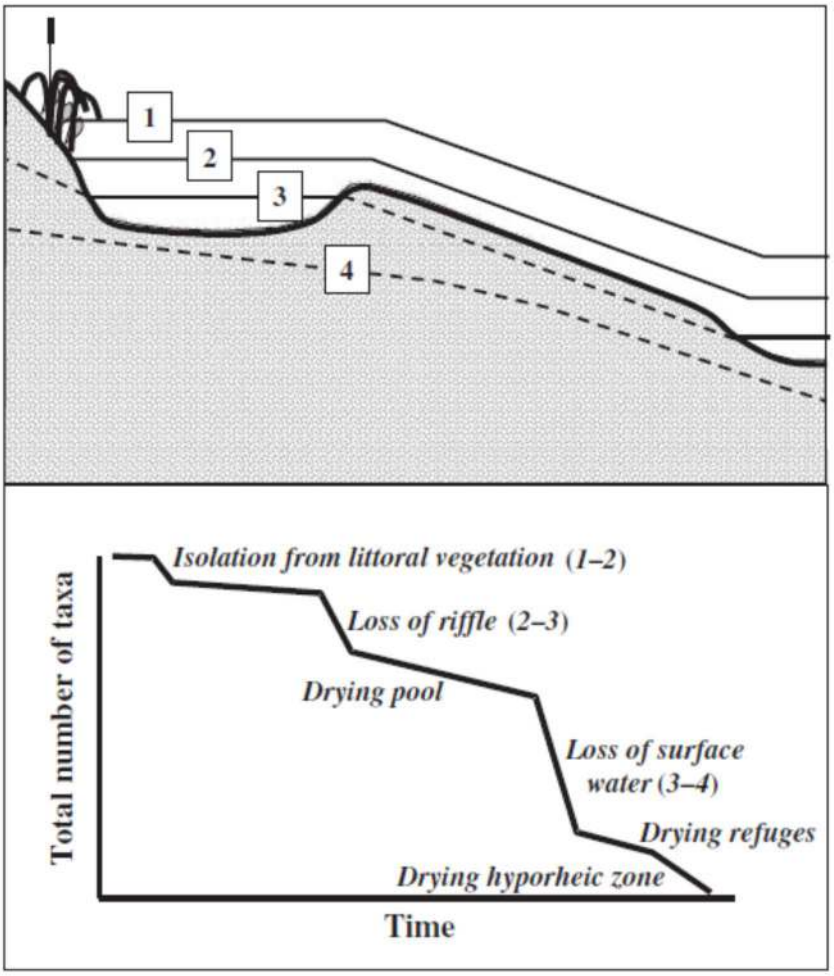

Figure 5.2: Changes in macroinvertebrate assemblage composition in a 'stepped' fashion during transitions across threshold discharges or water levels. During drying, total numbers of taxa are decline sharply when submerged or trailing littoral vegetation is isolated from the free water (1 to 2), then as flow ceases in the riffle (2 to 3), and when surface water disappears (3 to 4). (Figure reproduced from Boulton 2003).

5.3 Vegetation

5.3.1 Values

The FLOWS assessment site for Reach 1 supports no eucalypt canopy. There is a scattered small tree layer of Blackwood, most of which are either dead or in poor health. EVC mapping indicates this FLOWS assessment site supports Stream Bank Shrubland, flanked by Escarpment Shrubland on the steeper eastern side and Valley Grassy Forest on the more gently sloping western side. All of these vegetation types support a high cover and diverse range of indigenous species, however they have been invaded to varying degrees by environmental weeds. This reach supports three riparian plant species which are characteristic of environments with relatively high salinity, indicating out-cropping ground water.

The FLOWS assessment site for Reach 3a supports an open woodland of healthy Manna Gums. There is a scattered small tree and tall shrub layer of Blackwood, Silver Wattle, Hemp Bush, Woolly Tea-tree, Sweet Bursaria, Broad-leaf Tree Violet and Hazel Pomaderris. EVC mapping indicates this FLOWS assessment site supports Stream Bank Shrubland, however a number of the species present are also consistent with Riparian Forest (Hazel Pomaderris, Hemp Bush and Manna Gum). This vegetation type supports a high cover and diverse range of indigenous species. It has been invaded by a range of environmental weeds, none of which are particularly abundant. No species characteristic of environments with relatively high salinity were observed in this reach. This may be due to the flushing effect of consistent fresh water releases from Lal Lal Reservoir. The flow weighted salinity of the Moorabool River West Branch at Lal Lal is 290 EC, with short duration spikes of higher salinity up to 3000 EC (SKM 2005).

The FLOWS assessment site for Reach 3b supports an open woodland of healthy, large old River Red Gums, with a few scattered Manna Gums. The occurrence of River Red Gum and Manna Gum in the same area is indicative that this reach is in the transition zone between the foothills and lowland plains. There is a scattered small tree and tall shrub layer of Blackwood, Silver Wattle, Hemp Bush, Woolly Tea-tree, Sweet Bursaria, Broad-leaf Tree Violet and Prickly Currant-bush. EVC mapping indicates this FLOWS assessment site supports Stream Bank Shrubland. This reach supports five riparian plant species which are characteristic of environments with relatively high salinity, indicating out-cropping ground water.

The FLOWS assessment site for Reach 4 supports an open woodland of healthy River Red Gums, some of which are very old and large. These trees support many hollow branches, which are an important resource for a diversity of birds and mammals. There is a scattered shrub layer of Tree violet and Tangled Lignum, with Blackwood occurring further downstream. EVC mapping indicates this FLOWS assessment site supports Floodplain Riparian Woodland. Stream Bank Shrubland occurs in this reach downstream of Dog Rocks. This reach supports five riparian plant species which are characteristic of environments with relatively high salinity, indicating out-cropping ground water. The flow weighted salinity of the Moorabool River at Batesford Rd is 780 EC, with short duration spikes of higher salinity up to 4000 EC (SKM 2005).

The area of the Reach 4 FLOWS assessment site upstream of Bakers Bridge Rd is protected from grazing and supports a dense growth of instream aquatic and littoral amphibious species. Downstream of the bridge vegetation is unprotected from grazing and stock is causing considerable damage to soils and vegetation, particularly on the banks and in the littoral zone.

Vegetation species identified in the field are categorised with reference to the different zone in which the vegetation is present, using the categories outlined in Figure 5.3. In the bed of the channel are submerged and emergent macrophytes which make up the “aquatic zone” species. On to the edge of the channel emergent amphibious species make up the “marginal zone”. Higher up on the stream banks the plants are accustomed to less and less inundation. Macrophytes give way to the grasses, bushes and trees of the “damp zone”. Plants in the “damp zone” can access water in a number of ways; from capillary action of moisture wicking from the stream channel into the adjacent soil, directly from groundwater discharge, by roots which reach down to the stream channel and/or from brief inundation during freshes and floods.

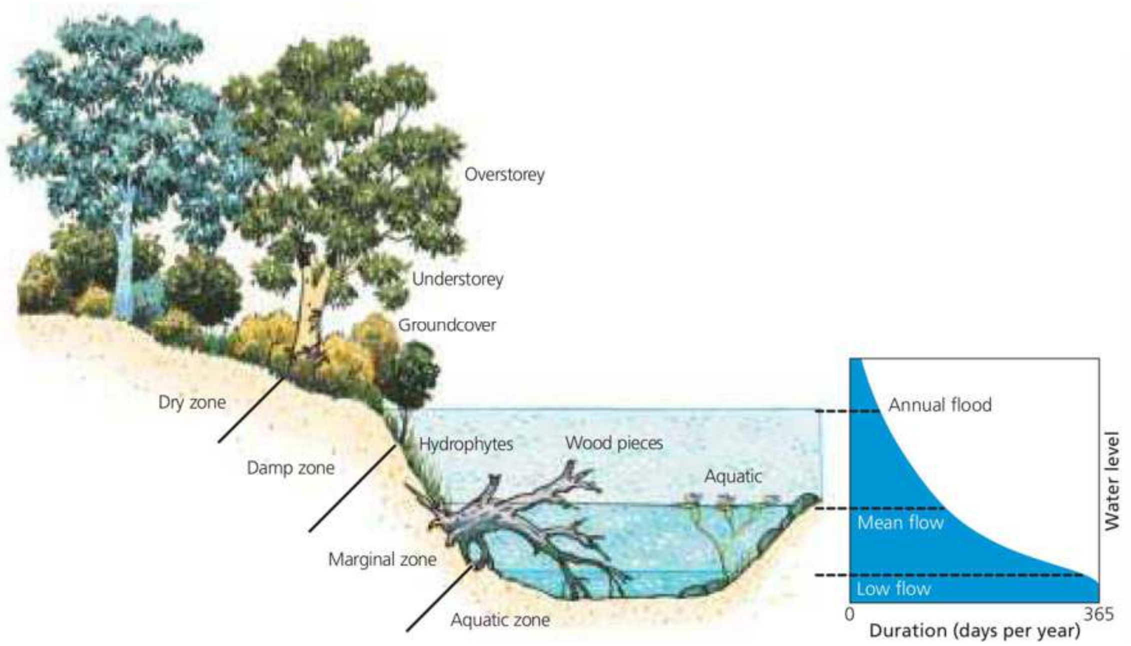

Figure 5.3: Schematic example of riparian vegetation and its interaction with flow (Rutherfurd et al. 2007).

5.3.2 Evaluation of existing objectives

Previous ecological objectives for vegetation as documented in SKM (2004b) were quite generic and lacked detailed information relating to vegetation species and types present in each FLOWS reach.

5.3.3 Revised ecological objectives

Existing objectives have been refined to make them more relevant to the vegetation found within each FLOWS reach. Revised ecological objectives for vegetation are presented in Table 5.5.

For Reach 1 the "cease to flow" flow component to "manage Typha" has been deleted. This is because it is considered likely the duration of a cease to flow period that would limit the growth of Typha would also have adverse effects on desirable riparian vegetation. Roberts and Marston (2011) suggest that a dry period of two years is required to reduce the vigour of Typha species. A spells analysis of the cease to flow revealed that even under natural conditions a cease to flow component of this duration would be unlikely to occur.

Freshes to limit the encroachment of terrestrial vegetation have been added as a flow component and objective to maintain marginal zone species in all reaches. This is because under prolonged dry conditions this zone can be invaded by species such as River Red Gums, which once well-established are difficult to drown out.

A "low flow" component to provide sufficient depth of water to maintain marginal zone vegetation has been added in Reaches 3a, 3b and 4. This is because marginal zone species in these reaches require consistent access to moisture to maintain health and vigour. The objective of scouring Elodea was removed from Reach 4 as this weed was not observed in this reach of the river.

Issues that may prevent ecological objectives from being achieved even if flows are implemented include weed invasion and damage to vegetation and soil caused by unrestricted livestock (particularly in Reach 4).

Table 5.5: Revised ecological objectives for vegetation for selected FLOWS Reaches.

Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1	V1	Maintain aquatic zone species (Varied Water-milfoil, Small River Buttercup and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
			Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
	V2	Maintain marginal zone species (Tall Sedge, Tassel Sedge, River Club-sedge and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
	V3	Maintain damp zone species (Blackwood, River Bottlebrush, Woolly Tea-tree and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
	V4	Maintain inset benches	Maintain diversity of vegetation	High flows	All seasons	
2	V1	Maintain aquatic zone species	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
			Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
	V2	Maintain marginal zone species	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
	V3	Maintain damp zone species	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population
	V4	Maintain inset benches	Maintain diversity of vegetation	High flows	All seasons	
3a	V1	Maintain aquatic zone species (Varied Water-milfoil and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
			Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
	V2	Maintain marginal zone species (Tall Sedge, Tassel Sedge, Fen Sedge, Common Reed and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
	V3	Maintain damp zone species (Manna Gum, Hazel Pomaderris, Blackwood, Hemp Bush, Woolly Tea-tree and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population
	V4	Maintain inset floodplains	Maintain diversity of vegetation	High flows	All seasons	

Reach	Ecological objective		Function	Required flow component	Timing	Expected response
3b	V1	Maintain aquatic zone species (Varied Water-milfoil and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
			Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
	V2	Maintain marginal zone species (Tall Sedge, Fen Sedge, Streaked Arrow-grass, River Club-rush, Common Reed and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
	V3	Maintain damp zone species (River Red Gum, Manna Gum, Blackwood, Hemp Bush, Woolly Tea-tree, Prickly Currant-bush, Knobby Club-sedge and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population
	V4	Maintain inset floodplains	Maintain diversity of vegetation	High flows	All seasons	
4	V1	Maintain aquatic zone species (Stonewort, Ivy-leaf Duckweed and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
			Limit terrestrial encroachment and flush Azolla	Freshes	All seasons	
	V2	Maintain marginal zone species (Creeping Monkey-flower, Sea Club-rush, Streaked Arrow-grass, River Club-rush, Common Reed and Mud Dock)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
	V3	Maintain damp zone species (River Red Gum, Tangled Lignum, Broad-leaf Tree-violet, Jagged Bitter-cress and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population
	V4	Maintain floodplain wetlands	Maintain diversity of vegetation	High flows	All seasons	

5.4 Platypus and water-rats

5.4.1 Values

The Australian Platypus Conservancy (APC) conducted Platypus live-trapping surveys along the Moorabool River from 2003 to 2006 (Williams 2005; Williams and Serena 2004; 2006), with additional Platypus live-trapping records subsequently generated as a by-product of fish surveys (McGuckin and Ryan 2009). In brief, the findings from these studies were as follows:

- Reach 1, Moorabool River East Branch: Bostock Reservoir to West Moorabool River.
  The APC set survey nets at one site (Egerton-Ballan Road) on one occasion in January 2004, resulting in no Platypus captures. Similarly, McGuckin and Ryan (2009) failed to record Platypus in December 2008 in fish survey nets set in pools near the Bostock Reservoir spillway and the Egerton-Bungeeltap Road. However, in both cases the level of live-trapping effort was too low to rule out the possibility that Platypus were present in the vicinity. Three landholders interviewed by APC staff in 2006 reported seeing Platypus on a reasonably regular basis on their respective properties from the 1950s-2005 (near the Egerton-Ballark Road), from 1992-2006 (near the Egerton-Bungeeltap Road), and from the 1970s-2006 (near the Egerton-Ballan Road). All sightings were said to be associated with reliably perennial aquatic habitats associated with deep pools and/or maintained by springs that continued to flow in dry periods.
- Reach 2, Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir
  The APC set survey nets at four sites located above Lal Lal Reservoir (to as far upstream as Clohesy's Road) in January 2004, resulting in no Platypus captures. Platypus habitat quality at all sites was deemed to be poor, with little surface water available at the time of the survey. Farther upstream, a landholder interviewed in 2005 reported that he saw Platypus at a few sites between Moorabool Reservoir and Springbank Road from the late 1960s until c. 1997, when summer flow ceased after a bulk water entitlement was mandated. He also said that Platypus sightings resumed in about 2002 or 2003 after farmers agreed to abide by a stream flow management plan to maintain some environmental flow along the river in summer. In addition, a landholder interviewed in 2006 reported seeing Platypus regularly just upstream of the Western Highway from the 1960s until the mid-1990s, when sightings ceased. More recently, a Platypus was observed in a weir pool associated with Thiess gauging station 232210A on a number of occasions from about 2004 to 2009, and again on one occasion about 12 months ago (Hamish Burrows, Central Highlands Water, pers. comm.). It is possible that the ongoing presence of a Platypus at this gauging weir in the final years of the Millennium Drought is related to the fact that Lal Lal Reservoir (which is located approximately 0.5 kilometres downstream) may potentially serve as a refuge for the species during severe drought.
- Reach 3a, Moorabool River: Lal Lal Reservoir to confluence with East Branch
  The APC set Platypus survey nets at Hunts Bridge (Elaine-Egerton Road) in January 2004, resulting in the capture of one adult or subadult female. No Platypus were captured when fish survey nets were set (again, on a single occasion) by McGuckin and Ryan at Hunts Bridge in December 2008. However, this result may well have been influenced by the fact that Platypus are generally much less likely to be captured in nets targeting fish than those targeting Platypus.
- Reach 3b, Moorabool River: Confluence with East Branch to Sharps Road
  The APC set survey nets at seven sites (from the Dollys Creek confluence to Sharps Road) on 2-3 occasions each in the period from January 2004 to January 2006. Up to four animals were captured overnight at a given site (i.e. Morrisons Bridge), with Platypus recorded in one or more years at all sites apart from the Dollys Creek confluence. Importantly, a very high proportion of adults or subadults captured in this reach were females (79%), indicating that this reach had (and presumably still has) outstanding value as a Platypus breeding area. McGuckin and Ryan (2009) captured a Platypus (sex not specified) at Marchments Road near Meredith pumping station in December 2008, one of six sites in this reach where fish survey nets were set.
- Reach 4, Moorabool River: Sharps Road to Barwon River.
  The APC set survey nets at nine sites (from Spillers Bridge to the Midland Highway Bridge) on three occasions each in the period from October 2003 to January 2006. Up to four animals were captured overnight at a given site (i.e. end of Buchter Road), with Platypus recorded in one or more years at all sites. However, only 28% of captured adults and subadults were females, implying that Platypus habitat quality

was (and presumably still is) substantially lower on average in Reach 4 than in Reach 3b. McGuckin and Ryan captured a Platypus (sex not specified) at Parkers Road in December 2008, one of three sites in this reach where fish survey nets were set. A Platypus was seen downstream of Batesford Weir by two reliable observers on one occasion within the last 18 months (Saul Vermeeren, Corangamite CMA, pers. comm.), and also by a reliable observer in December 2014 at a site located about midway between Sharps Bridge and the Perdrisat Bridge (APC, unpub. data).

Based on the information presented above, the Moorabool River supported a widespread and substantial Platypus population in the mid-2000s. Reach 3b apparently providing the most favourable habitat for breeding, with adult or subadult females also confirmed to occur in Reaches 3a and 4. Although Platypus continued to be found in Reaches 1 and 2 in the mid-2000s, their status appears to have been relatively sparse and fragmented, ultimately limited by patchy availability of reliable surface water in summer as well as badly degraded habitat in some areas (notably Reach 2). Local landholders broadly agree that the frequency of Platypus sightings downstream of Lal Lal Reservoir dropped sharply in the late 2000s (i.e. in the final years of the Millennium Drought) though sightings have again been noted within the past 12 months at least at one locality (Rob Bone, Corangamite CMA, pers. comm.). It is reasonable to infer that the Moorabool Platypus population is still in a post-drought recovery phase, given that Platypus litter size is normally just 1-2 juveniles, females take at least two (though sometimes up to four and possibly more) years to reproduce for the first time, and less than half of mature females reproduce successfully on average in any given year (Burrell 1974; Grant 2004).

The Moorabool Platypus population is also appropriately viewed as contributing to the genetic integrity and demographic sustainability of a larger Platypus metapopulation encompassing the Moorabool, Barwon and Leigh River catchments. To maintain metapopulation viability, it is imperative that movement by dispersing juveniles and breeding age males is successfully maintained among these three river systems.

Water-rats (*Hydromys chrysogaster*) often enter nets set for Platypus, but characteristically escape shortly thereafter by chewing Rakali-sized holes in the netting. The location of Platypus survey sites where such holes appeared (or Water-rats or their tracks were observed) was recorded in the course of Platypus fieldwork carried out along the Moorabool River from 2003 to 2006 (Williams 2005; Williams and Serena 2004; 2006). In brief, Water-rat population density generally appeared to be greatest at the downstream end of the river. In Reaches 3b and 4 (where each site was surveyed on 2-3 occasions), Water-rats entered nets at all of the nine survey sites contained in Reach 4 (100%) as compared to four of seven sites contained in Reach 3b (57%). In Reaches 1, 2 and 3a (where six sites were collectively surveyed on one occasion each), Water-rat activity was recorded at 1 of 4 survey sites in Reach 2 as paw prints in mud (25%), but no actual captures in nets occurred.

Based on the above, the Moorabool River appears to have supported a widespread and at least reasonably sizable Rakali population in the mid-2000s, especially in Reach 4. Although no data are available regarding the impact of reduced environmental flows in the final years of the Millennium Drought on Rakali numbers in the Moorabool catchment, population density is predicted to have declined, perhaps dramatically. Although Water-rats are opportunistic predators and scavengers, their diet is typically dominated by fish and large aquatic macro-invertebrates (Watts and Aslin 1981). Water-rats also become reproductively senescent by the age of 3-4 years (Olsen 1982), so local populations may virtually disappear if reproduction fails for three or more consecutive years in response to drought. Although no studies have been conducted to quantify Water-rat population recovery following drought, vacant habitats may potentially be recolonised quite rapidly by these animals when conditions improve. This reflects their relatively high reproductive rate in favourable environments along with high mobility: Rakali have been known to move 3.1 km in less than 6 hours (Gardner and Serena 1995) and at least 3 and probably 4.5 km overnight (Vernes 1998).

5.4.2 Background to objectives

Flow-related objectives for Platypus were not included in SKM (2004b). The current overarching management objective for this species along the Moorabool River is to support post-drought population recovery to ensure that the population is reliably self-sustaining. Safe migration of animals from the Moorabool River to the Barwon River and vice-versa should also be facilitated to promote development of a larger (and hence inherently more resilient) Platypus metapopulation across the Barwon basin as a whole. To achieve these objectives, flow-related requirements for three key aspects of the species' biology need to be considered:

- Foraging requirements
  The Platypus consumes a broad range of benthic macro-invertebrates, though caddis-fly larvae typically comprise a large part of its diet (Faragher et al. 1979; McLachlan-Troup et al. 2010). The animals travel sizable distances while feeding, with adult female and male home ranges respectively encompassing up to 4.5 and 15.1 km of channel (Gardner and Serena 1995; Serena et al. 1998). In-stream habitat features that are preferentially associated with foraging include slow-flowing pools and backwaters, suitably undercut (or notched) banks, relatively coarse inorganic substrates and submerged woody debris and leaf packs (Grant 2004; McLachlan-Troup et al. 2010; Serena et al. 2001). Foraging mostly occurs at a depth of 1-3 metres, though occasionally down to nearly 9 metres (Bethge et al. 2003; Grant 2004). The animals are believed to limit their use of very shallow water to reduce the risk of being attacked by predators such as foxes (Serena and Williams 2010).
- Reproduction
  The Platypus mating season in Victoria extends from August to October (De-La-Warr and Serena 1999; Easton et al. 2008). Eggs are laid in burrows excavated in the banks, so a substantial rise in water level can severely reduce Platypus reproductive success if burrows are inundated, particularly around the time that juveniles first start to emerge from burrows in Summer. Conversely, lactating females and their offspring can become vulnerable to predators if a substantial gap develops between the water’s edge and the entrance to nesting burrows due to receding water levels in Spring or Summer. Lactating females need to consume the equivalent of up to 80% of their body mass each day (Holland and Jackson 2002), so successful breeding is limited to habitats supporting reliably productive macro-invertebrate populations.
- Juvenile dispersal
  Juvenile Platypus most typically start to disperse from their natal range in late Autumn (Serena and Williams 2012a), when many juveniles are in relatively poor physical condition. Young Platypus are also highly vulnerable to predators as a presumed outcome of their small body size and general lack of experience (Serena and Williams 2010). The likelihood that they disperse successfully is therefore predicted to depend strongly on their ability to locate adequate macro-invertebrate food resources and to avoid predators en route. Predation risk in relation to dispersing juveniles can best be managed by (1) maintaining reasonable flow in river and stream channels from approximately late April through June and (2) promoting the establishment of fringing emergent plants and/or overhanging bank vegetation to provide protective cover. Dispersing juvenile Platypus have been documented to move >40 kilometres (Serena and Williams 2012) and undoubtedly will travel much farther in search of a suitable new home range.

Platypus flow requirements will generally align closely with those for benthic macro-invertebrates (given that this species requires access to an ample food supply through the year), geomorphological processes that help to create and maintain diverse channel habitat features (particularly pools and backwaters) and healthy and abundant vegetation growing on the banks (to provide protective cover from predators and act as a source of in-stream woody habitat and other organic matter). In addition, to avoid potentially compromising Platypus breeding success, it is worth noting that substantial (more than roughly 1 metre) rises in river height may inundate nesting burrows and thereby cause juveniles to drown in the period from about September through February. A lactating female blocks the tunnel leading to her nursery burrow with a series of consolidated soil ‘pugs’ when it houses young juveniles, presumably to help protect them from drowning if water levels rise for a relatively short period, i.e. in the order of a day or less (Burrell 1974). However, this practice stops as juveniles reach the age where they are old enough to leave the burrow (from approximately late December to February), exacerbating the risk that they may drown if flow increases substantially in this period, i.e. before they are proficient swimmers. A series of schematic diagrams showing how the size and timing of high flow events may threaten Platypus are presented in Figure 5.4, Figure 5.5 and Figure 5.6.

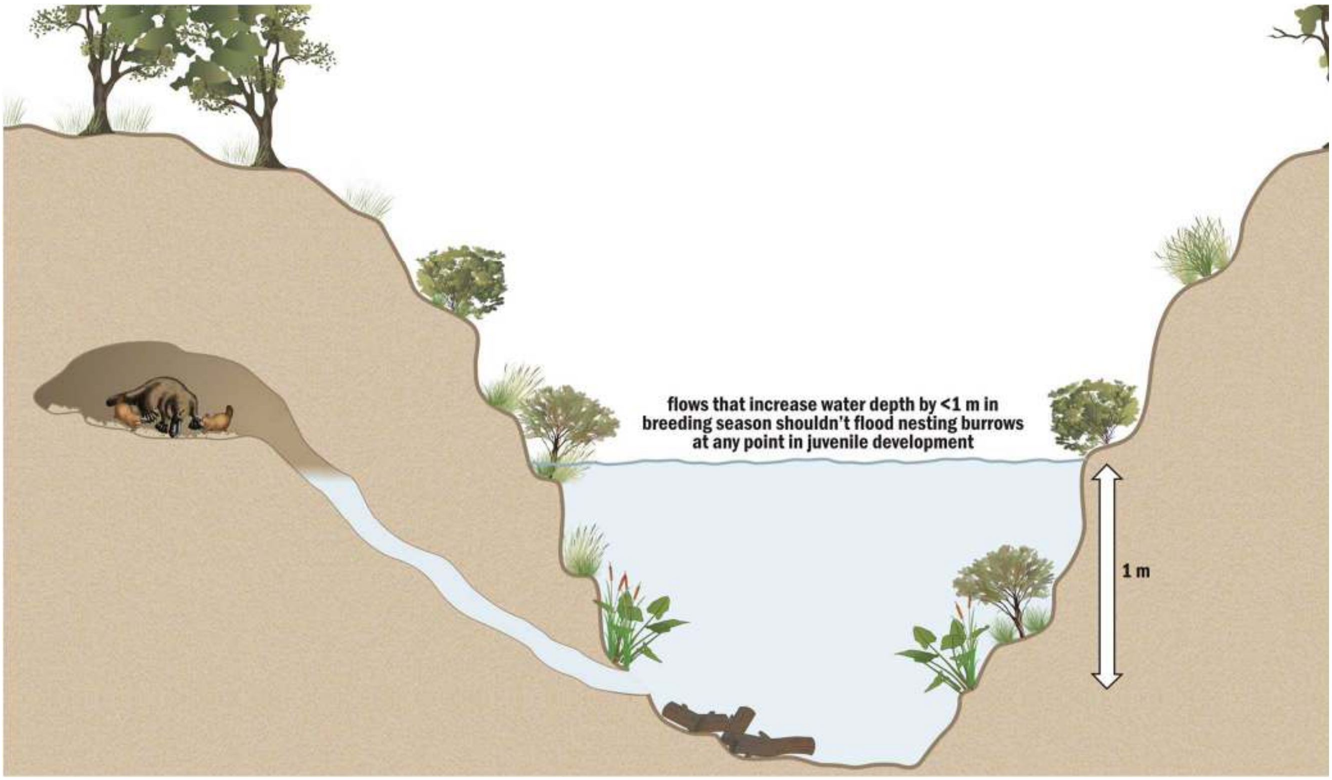

Figure 5.4: Schematic showing Platypus nesting burrows are unlikely to be inundated by rises in river height < 1 m.

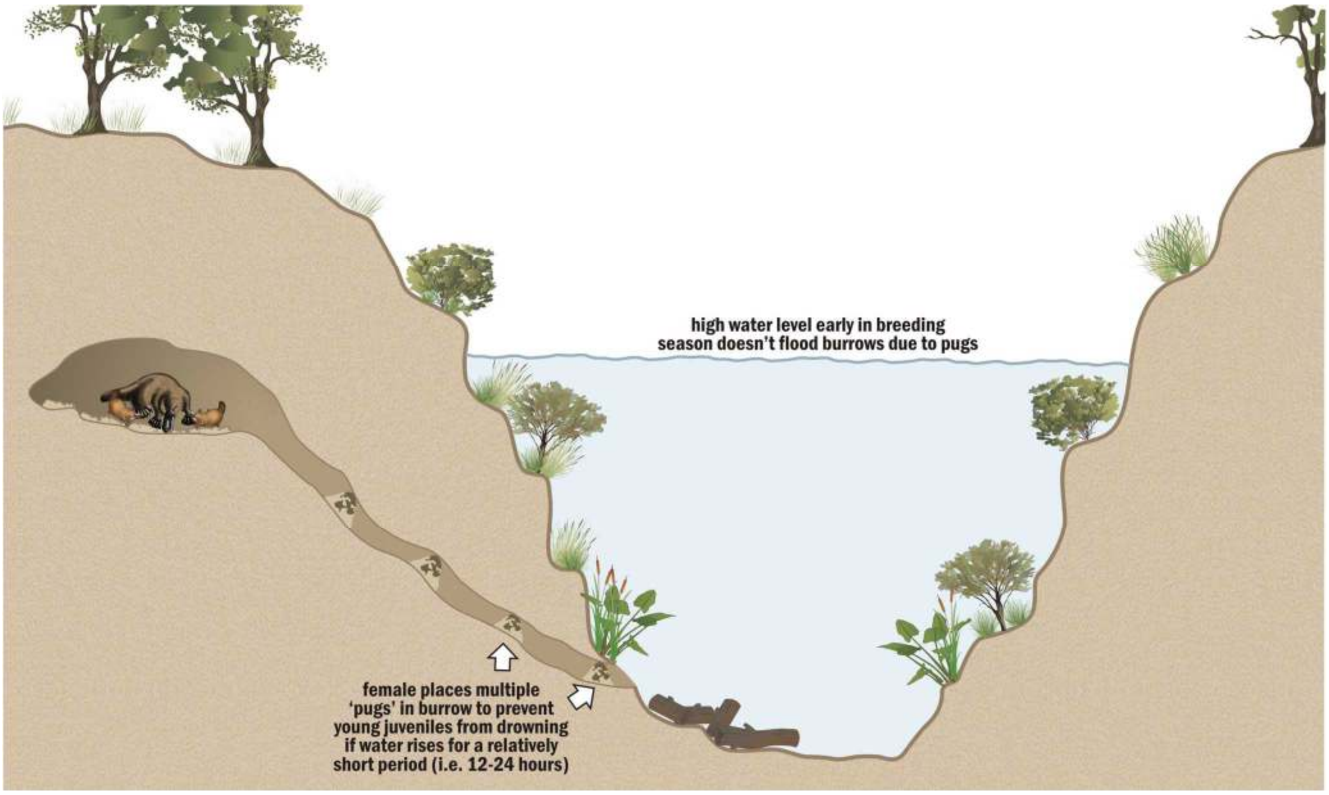

Figure 5.5: Schematic showing high water level early in breeding season doesn't flood burrows due to pugs.

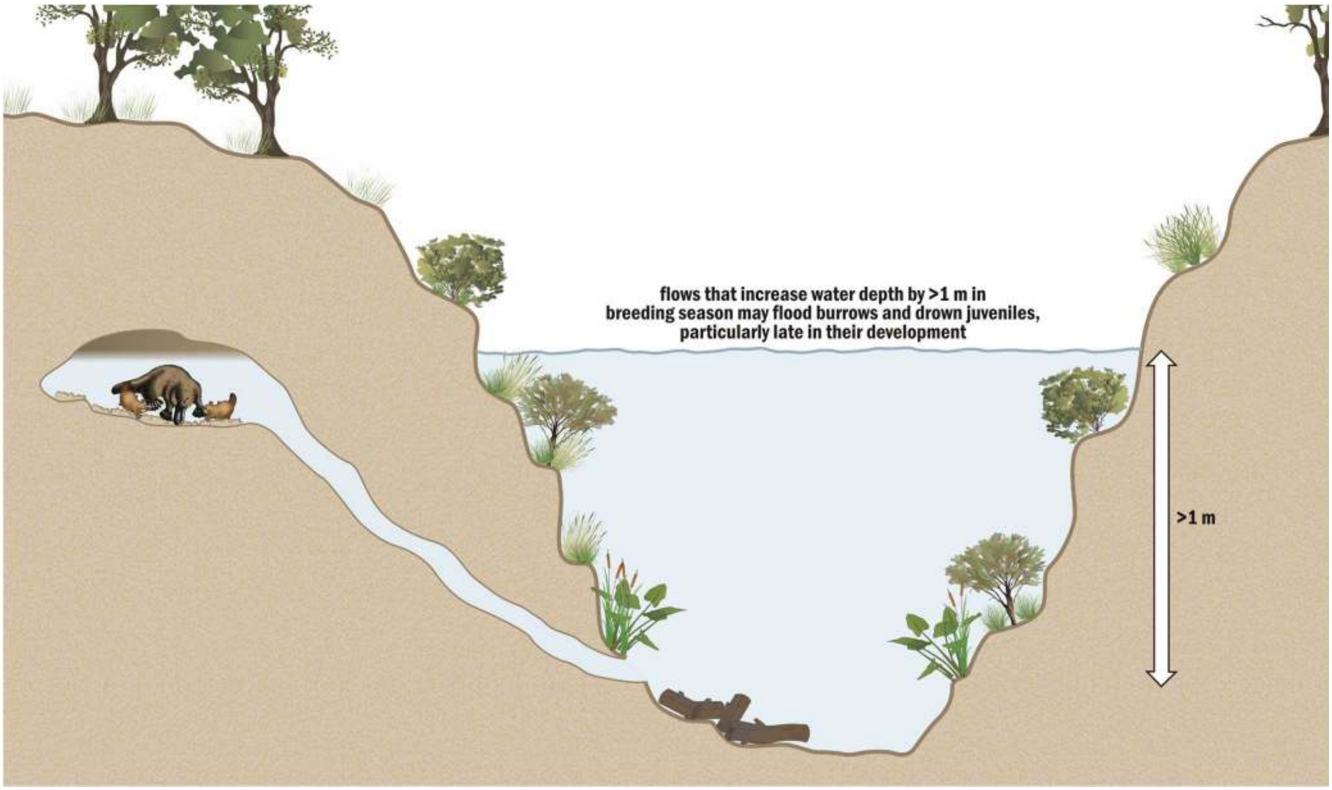

Figure 5.6: Schematic showing that flows that increase water depth by > 1 m in breeding season may flood burrows and drown juveniles, particularly late in their development.

Accordingly, it is recommended that:

- Flows should be high enough throughout the year to minimise the likelihood that resident Platypus are killed by predators (particularly foxes), and to provide a corridor for safe passage by dispersing juveniles in late Autumn-early Winter and breeding males in late Winter-Spring.
- The duration of substantial freshes scheduled in Spring or Summer (i.e. when juveniles are restricted to burrows or are just learning to swim) should be limited to the minimum length of time needed to carry out their designated environmental function (and ideally peak for <24 hours).
- Freshes scheduled in Spring or Summer that are likely to cause water depth to increase by >1 metre above baseflow should be coupled to a preceding event of similar or greater magnitude in early August (i.e. around the time that breeding females select nursery burrow sites), to encourage females to locate nesting chambers above the point where they are likely to flood.

Flow-related objectives for *Hydromys* were not included in SKM (2004b). The current overarching management objective for this species along the Moorabool River is to maintain a self-sustaining population that can persist through long-term droughts. Successful migration of Water-rats from the Moorabool River to the Barwon River and vice-versa should also be facilitated to help maintain a larger (and hence more resilient) Water-rat metapopulation across the Barwon basin as a whole.

Although Water-rats are associated with diverse aquatic environments, their ideal habitat appears to consist of slow-flowing water in creeks, irrigation channels and wetlands, or pools and backwaters in larger rivers (Smart et al. 2011; Speldewinde et al. 2013; Watts and Aslin 1981). Water-rat activity has also been found to be positively associated with bank stability and the prevalence of emergent in-stream vegetation and low-growing plants on the banks (Smart et al. 2011; Speldewinde et al. 2013). The Water-rat reproductive calendar is fairly similar though not identical to that of the Platypus: although Water-rat pregnancies were recorded from early September to January in northern Victoria, most females (92%) were either pregnant or had already given birth by the end of October (McNally 1960). Given that gestation and lactation collectively require around 9 weeks to complete (Olsen 1982), most juvenile Rakali should be weaned by early January. Juveniles continue to grow through Summer and mainly disperse in Autumn (McNally 1960). Structural parameters of burrows used by Rakali and Platypus are also likely to be much the same, given that the two species are roughly the same size and shape. A lactating Water-rat and adult female Platypus have been documented to occupy the same burrow within a few weeks of each other (Serena 1994).

Based on the above, Water-rat flow requirements are generally expected to align quite closely with those for Platypus. The only obvious strong point of difference between the two species is that a large proportion of the Water-rat diet commonly consists of small and medium-bodied fish, which are not consumed by Platypus. Flow management components that aim to maintain productive and diverse fish communities should therefore be directly advantageous to Rakali.

5.4.3 Ecological objectives for Platypus

Components of the Moorabool River's flow regime needed to achieve important Platypus ecological objectives are identified by reach in Table 5.6. The rationale for these objectives and flow components and the need for complementary actions to strengthen the effectiveness of flow-related management are outlined below. As mentioned previously, Platypus and Water-rat flow requirements are similar (though arguably somewhat less critical for Water-rats due to the fact that this species can find a proportion of its food and travel quite effectively on land). For the sake of simplicity, the text below will focus on Platypus requirements; the discussion starts with Reach 4 (i.e. the reach located at the downstream end of the Moorabool), as this is characterised by the widest array of management objectives for Platypus.

5.4.3.1 FLOWS Reach 4, Moorabool River: Sharps Road to Barwon River

Reach 4 supported a substantial Platypus population (including breeding age females) until at least the mid-2000s, with recent sightings confirming that Platypus currently continue to inhabit the reach. It provides a corridor for Platypus movement through which all dispersing juveniles must necessarily pass when travelling to or from the Barwon River. In addition, adult males inhabiting the lowest 10-15 kilometres of channel (i.e. downstream of approximately Bakers Bridge, within one night's journey by a Platypus to the Barwon confluence) are highly likely to travel back and forth to the Barwon on a reasonably frequent basis during the breeding season in search of mates. Reach 4 also supported the highest known density of Water-rats found along the Moorabool in the mid-2000s.

The three main objectives for Platypus management in Reach 4 are:

1) To support restoration of a self-sustaining breeding population,
2) To promote safe passage by juveniles dispersing to and from the Barwon River, and
3) To promote safe passage by adult males travelling back and forth from the Barwon River during the breeding season.

The first objective will best be achieved by maintaining adequate flow throughout the year (to support a reliably productive and diverse macro-invertebrate community), and periodically scheduling freshes in dry periods (to scour biofilms on submerged substrates and maintain enough dissolved oxygen to enable gilled insect larvae to survive in pools). Enough water is also needed in the channel to maintain a depth of (ideally) $\geq$1 metre in pools (to provide preferred Platypus foraging habitat) and $\geq$0.1 metre over runs/riffles (to reduce the risk of predation by foxes, feral cats and birds of prey). These actions will also serve to maintain favourable conditions for juvenile dispersal (particularly in the period from late April through June) and breeding-related travel by adult males (particularly in the period from July through October). Maintaining a flow regime conducive to juvenile dispersal is particularly critical in average-to-wet years, as the number of surplus juveniles is likely to be higher in average-to-wet than dry years.

As discussed in more detail in Section 5.4.2, to reduce the risk that juveniles drown or are prematurely displaced from burrows, water releases leading to substantial increases in river height (exceeding baseflow by $\geq$1 metre) should be avoided from approximately September through February, especially in the latter half of the period. If a higher flow is required for some reason when young are likely to be present in burrows, its duration should be kept as short as possible (peaking for <24 hours if possible) and a preceding flow event of similar or greater magnitude should ideally be scheduled in early August (i.e. around the time that breeding females select nursery burrow sites), to encourage females to locate nesting chambers above the peak flow level.

5.4.3.2 FLOWS Reach 3b, Moorabool River: Confluence with East Branch to Sharps Road

Reach 3b comprises the most important known Platypus breeding area in the Moorabool system: four-fifths of adult or subadult animals captured in the mid-2000s were females. This reach also supported substantial numbers of Water-rats until at least the mid-2000s.

The main objectives for Platypus management in Reach 3b are:

1) To support restoration of a self-sustaining breeding population, and
2) To promote safe passage by surplus juveniles dispersing to and from the Barwon River.

Some long-distance movements by adult males travelling to or from the Barwon River may occur, especially during the breeding season, but presumably less often than in the case of Reach 4.

The flow recommendations and complementary actions outlined for Reach 4 apply with equal validity to Reach 3b.

5.4.3.3 Reach 3a, Moorabool River: Lal Lal Reservoir to confluence with East Branch

Very little live-trapping survey work for Platypus or Water-rats has been carried out in this reach. However, an adult or subadult female Platypus was recorded at Hunts Bridge in 2004, implying that a breeding population was present. Given that Reach 3a is located between Lal Lal Reservoir and Reach 3b and contains some apparently high quality Platypus habitat (e.g. at Hunts Bridge), the sensible precautionary approach will be to adopt the same management objectives, flow recommendations and complementary actions for Reaches 3a as for Reach 3Bb. In addition, it is recommended that a database should be established to consistently record Platypus and Rakali sightings made in Reach 3A by landholders or management agency staff, as the most cost-effective method to map the current local distribution of these species.

5.4.3.4 Reach 2, Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir

The occurrence of both Platypus and Water-rats in Reach 2 is likely to be patchy, limited by poor habitat quality and/or inadequate flow in dry seasons. Population size and extent are also likely to fluctuate considerably through time for both species, increasing in reasonably wet years and possibly contracting during severe drought to a few animals surviving in refuge habitats in Moorabool and/or Lal Lal Reservoirs.

The main objective for Platypus management in Reach 2 is to maintain some animals in this part of the Moorabool, including through drought periods. Strategically delivering flows with a view to maintaining pool size and dissolved oxygen levels for as long as possible during dry periods will assist in addressing this objective.

5.4.3.5 Reach 1, Moorabool River East Branch: Bostock Reservoir to West Moorabool River

Platypus habitat quality is generally higher in Reach 1 than Reach 2, implying that this reach has greater potential to support the species and maintain a self-sustaining population in its own right as long as adequate surface water is reliably available. The main objective for Platypus management in Reach 1 is to maintain some animals in this part of the Moorabool, including during drought periods.

Table 5.6: Ecological objectives for Platypus for selected FLOWS Reaches.

FLOWS Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1	P1	Maintain Platypus population, particularly in refuge pools during dry years	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (Summer critical)	Should be capable of supporting populations of Platypus in refuge pools
				Freshes	All seasons	
2	P1	Maintain Platypus population, particularly in refuge pools during dry years	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (Summer critical)	Should be capable of supporting populations of Platypus in refuge pools
				Freshes	All seasons	
3a	P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus.
				Freshes	All seasons	
	P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (April-June critical)	Avoid flows higher than Winter flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
3b	P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus.
				Freshes	All seasons	
	P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (April-June critical)	Avoid flows higher than Winter flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
4	P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus.
				Freshes	All seasons	
	P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (April-June critical)	Avoid flows higher than Winter flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
	P3	Support movement of adult males to/from the Barwon River	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Low flows	All seasons (July-October critical)	

5.5 Habitat/Processes and Floodplains

5.5.1 Values

The Moorabool River and its tributaries provide important habitat values to a range of aquatic and terrestrial organisms. The diversity and complexity of habitat areas present (pools, riffles, benches, billabongs) is maintained by physical processes that shape the channel and floodplain environment. The different habitat areas represent different geomorphological features and the processes that form and shape these features can be broadly described as geomorphological processes, the nature of these processes being influenced by environmental variables such as geology, climate, vegetation and human influences.

The Moorabool Catchment drains a landscape comprised of undulating hills and ridgelines formed by outcrops of Newer Volcanics basalt and underlying Tertiary sediments or Ordovician bedrock. In the upper parts, the west and east branch are variable in alternating between sections that are narrow gorges and more open with broader floodplains. Downstream of the confluence of the west and east branch, the river valley opens more and there is greater development of alluvial benches and floodplain (Figure 5.7).

Figure 5.7: East Branch, section of channel in confined gorge with localised pools (left photo). Moorabool River downstream of Bakers Bridge, alluvial channel with benches and broader floodplain.

Historical land use changes, clearing of vegetation, willow establishment and flow regulation have impacted on the physical form of the waterways. The removal of native vegetation and alluvial mining practices in the upper catchments of the Moorabool River from the 1850s to 1900s caused extreme erosion (Cecil et al. 1988; Dahlhaus 2003). Fabris et al. (2006) completed a study of sediment sources to Lake Connewarre on the Lower Barwon River. The Moorabool River catchment was identified as being the source of the majority of sediments in Lake Connewarre.

Craigie et al. (2002) previously highlighted a number of areas where the river, and its tributaries are actively adjusting through bed and bank erosion. The upper reaches of the West Moorabool River have been identified as an area that is prone to bed and bank erosion. The channel also appears to have contracted below reservoirs and there is potential for ongoing adjustments due to the highly regulated nature of flows. Sediment slugs have been reported as an issue along Dollys Creek and extending downstream of the confluence of the creek with the Moorabool River. These sediment slugs are believed to be a legacy of historical mining.

There are a large number of weirs along the Moorabool River which impact on the flow regime and sediment transport processes. Typically, it would be expected that the channel upstream of these barriers is shallower and wider (due to upstream deposition) and narrower downstream (localised erosion). The Moorabool River downstream of Batesford has been extensively modified through realignment and concrete lining during the 1930s and the 1980s to allow the development of a large limestone quarry (Craigie et al. 2002; SKM 2004b). Sections of the concrete lining are cracked, leading to increased seepage and erosion of the bed. The river along this section has also experienced significant landslips that have led to aggradation of sediments and formation of a large sediment slug and creation of shallow area of shallow flow conditions (Figure 5.8).

Figure 5.8: Photographs of Moorabool River diversion downstream of Batesford adjacent to limestone quarry. Cracking and erosion of concrete channel lining works (left photo). Large sediment slug filling valley and creation of shallow flow conditions (right).

5.5.2 Evaluation of existing objectives

The previous flows assessment set three habitat/process objectives for the four FLOWS reaches:

- Re-shape in-channel forms to maintain physical habitat diversity and complexity.
  - The specific process associated with this objective was the transport of sediment. The rationale for the objective was to flush sediment and maintain pool habitat (also flush from weir pools), with freshes/high flows selected as the relevant flow components.
- Maintain physical processes.
  - The specific process associated with this objective was organic matter transport. The rationale for the objective was to flush organic matter through the system that has accumulated in the pools (also flush from weir pools) and transfer carbon energy downstream, with Winter/Spring High flows selected as the relevant flow component.
- Maintain woody debris/snag habitat.
  - The specific process associated with this objective was submergence. The rationale for the objective was to maintain habitat for fish and macroinvertebrates, with low flows selected as the relevant flow component.

Two additional objectives were also set for floodplains for Reach 4:

- Restore floodplain communities
  - The specific process and rationale associated with this objective was wetting and the regeneration of River Red Gums, with Spring high flows selected as the relevant flow component.
- Restore floodplain processes (connectivity)
  - The specific process and rationale associated with this objective was inundation with floodplain areas identified in the lower reaches in the vicinity of Lethbridge, with Spring high flows selected as the relevant flow component.

The objectives themselves are sound, but in this review it was identified that a number of these objectives are specific to particular environmental values. The objective to “maintain physical processes” relates to transport of organic material which is relevant to water quality and macroinvertebrates and the objective to "maintain woody debris/snag habitat" is important for fish and macroinvertebrates. The "restore floodplain communities" is specific to the regeneration of red gums and therefore is relevant to vegetation values. In revising these habitat/process objectives it was decided that where there was overlap with the objective with specific environmental values, the objective would be better captured under the relevant environmental value.

5.5.3 Revised ecological objectives

Revised ecological objectives to maintain the physical form of the channel and floodplain are presented in Table 5.7. The flow components required to support these objectives are freshes and high flows. The timing of these flow components is not critical to achieving the geomorphological objectives.

We have chosen not to add a specific requirement for a bankfull or overbank flow to the revised objectives for any the FLOWS reaches, but instead use the term high flows to refer to larger events capable of filling the channel and inundating floodplain environments.

There are a number of geomorphological issues that cannot be addressed through the management of flow. Specific issues include the management of sand slugs, bank erosion resulting from stock access, impact of weirs and erosion issues associated with river diversion and concrete channel lining works.

Table 5.7: Revised ecological objectives for geomorphology for selected FLOWS Reaches.

FLOWS Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1	G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
			Maintain channel and scour pools	High flows	Anytime	
	G2	Maintain inset floodplains	Engage and maintain floodplain processes	High flows	Anytime	Maintain floodplain features
2	G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
			Maintain channel and scour pools	High flows	Anytime	
	G2	Maintain inset floodplains	Engage and maintain floodplain processes	High flows	Anytime	Maintain floodplain features
3a	G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
			Maintain channel and scour pools	High flows	Anytime	
	G2	Maintain inset floodplains	Engage and maintain floodplain processes	High flows	Anytime	Maintain floodplain features
3b	G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
			Maintain channel and scour pools	High flows	Anytime	
	G2	Maintain inset floodplains	Engage and maintain floodplain processes	High flows	Anytime	Maintain floodplain features
4	G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
			Maintain channel and scour pools	High flows	Anytime	
	G2	Maintain floodplain	Engage billabongs and maintain floodplain processes	High flows	Anytime	Maintain floodplain features

5.6 Water Quality

5.6.1 Values

Routine water quality data is available for several sites along the Moorabool River from the Victorian Water Quality Data Warehouse (http://data.water.vic.gov.au/monitoring.htm). Of sites relevant to the current study, monthly data is available for the Moorabool River at Morrison's (relevant to Reaches 3a and 3b) and at Batesford (relevant to Reach 4) – both sites are downstream of Lal Lal Reservoir. Similar historic data was not available for this review for sites in Reaches 1 or 2 (Moorabool River East Branch and Moorabool River West Branch upstream of Lal Lal Reservoir). Continuous water quality (dissolved oxygen, electrical conductivity and flow) is available for a site at Croppers Bridge. Additional data is also available from several waterwatch sites (CCMA unpublished).

Summary water quality in the Moorabool River downstream of Lal Lal Reservoir over the last 14 years is shown in Table 5.8 (Morrison's – Reach 3a/3b) and Table 5.9 (Batesford – Reach 4).

There is high compliance with State Environment Protection Policy (SEPP) water quality objectives for pH and turbidity, however, dissolved oxygen is generally low and fails to meet the 25^{th}%ile criteria of 85% saturation at both Morrison's and Batesford. Dissolved oxygen concentrations correlate with low flows at both sites (Figure 5.9). At Morrison's, a flow of at least 1 ML/Day is required to maintain DO above 6 mg/L (6 mg/L, although lower than the SEPP objective is a useful lower limit for native fish, with DO <6 mg/L representing a moderate risk to native fish, DO <4 mg/L representing a high risk to native fish and DO <2mg/L representing a very high risk to native fish). At Batesford a flow of 10 ML/d is generally required to maintain DO above 4 mg/L.

Electrical conductivity is generally low and complies with objectives in Reach 3a/3b, although it increased significantly from 2007-2010, during the drought. Further downstream (downstream of the She Oaks extraction point) salinity is much higher and consistently exceeds SEPP criteria elevated. The increases in salinity with decreased discharge is clearly evident in time series plots for both Morrison's and Batesford (Figure 5.10), also evident is the rapid decrease in salinity following increased flow in 2010, at the end of the drought. Also notable is that salinity is again starting to increase in 2014/15 as a period of low flow conditions returns, especially at Batesford.

Total nitrogen exceeds SEPP criteria in Reaches 3a/3b and Reach 4 while total phosphorus generally meets SEPP criteria in Reaches 3a/3b, but not in Reach 4. For both TN and TP, concentrations are higher in Reach 4 than Reach 3a/3b.

In summary, water quality is generally good in Reach 3a/3b and deteriorates in Reach 4. Dissolved oxygen decreases and salinity, TN and TP all increase. Releases from Lal Lal Reservoir are likely to help maintain good water quality in Reach 3a/3b (except during very low flow drought periods). Extraction at She Oaks is likely to contribute to the increased salinity in Reach 4 due to saline groundwater making a larger contribution to remaining flow. Tributary inputs (e.g. Moorabool River East Branch) are likely to be the main source of increase nutrient concentrations in Reach 4.

For sites where continuous water quality data is available, there is a significant correlation between discharge and both dissolved oxygen and salinity.

Table 5.8: Summary Water quality data for Moorabool River at Morrison's (site 232204)[1]. Cells shaded green meet SEPP (State Environmental Protection Policy water quality guidelines), cells shaded red exceed guidelines.

SEPP	pH		DO (%sat.)		Turbidity (NTU)	EC (µS/cm)	TN (mg/L)	TP (mg/L)	Discharge ML/d
	25th%ile	75th%ile	75th%ile	max	75th%ile	75th%ile	75th%ile	75th%ile	75th%ile
	>6.5	<8.3	<85	110	<10	<1500	<0.6	<0.045	
2000	7.2	7.5	72	112	3.9	1525	0.65	0.020	10.4
2001	7.8	7.8	83	113	2.4	1025	0.69	0.013	27.8
2002	7.5	7.8	75	113	2.5	1450	0.65	0.020	9.2
2003	7.5	7.8	81	98	1.5	813	0.61	0.010	40.5
2004	7.5	7.9	73	115	11.0	928	0.74	0.010	30.0
2005	7.4	7.7	83	108	5.8	1207	0.75	0.010	15.8
2006	7.5	7.9	79	134	3.6	1384	0.53	0.010	13.4
2007	7.4	7.9	66	104	4.7	2660	0.66	0.020	3.1
2008	7.7	8.4	92	129	18.2	2006	1.83	0.113	1.9
2009	7.8	8.1	75	118	12.5	2479	0.90	0.026	1.8
2010	7.6	7.8	69	95	9.3	2142	1.05	0.036	17.2
2011	7.3	7.6	80	116	19.1	581	1.23	0.060	137.0
2012	7.7	7.7	79	138	8.0	580	1.01	0.027	125.0
2013	7.7	7.7	82	110	4.6	670	0.79	0.018	24.7
2014	7.5	7.9	78	112	5.4	958	0.68	0.020	30.9

[1] http://data.water.vic.gov.au/monitoring.htm - Monthly data for site 232204)

Table 5.9: Summary Water quality data for Moorabool River at Batesford (site 232202). Cells shaded green meet SEPP (State Environmental Protection Policy water quality guidelines), cells shaded red exceed guidelines.

SEPP	pH		DO (%sat.		Turbidity (NTU)	EC (µS/cm)	TN (mg/L)	TP (mg/L)
	25th%ile	75th%ile	25th%ile	max	75th%ile	75th%ile	75th%ile	75th%ile
	>6.5	<8.3	>85	110	<10	<1500	<0.6	<0.045
2000	7.3	7.7	52	104	16.3	2600	1.3	0.06
2001	7.4	7.9	77	108	11	1850	1.9	0.075
2002	7.4	7.6	54	98	1.5	2600	0.915	0.04
2003	7.3	7.7	49	94	1.3	2750	0.98	0.073
2004	7.3	7.8	41	94	1.3	2450	0.86	0.098
2005	7.2	7.8	56	78	7.0	2860	1.47	0.105
2006	7.9	8.1	55	102	3.7	3391	0.898	0.08
2007	7.8	8.6	46	139	7.2	6028	1.3	0.158
2008	7.1	7.7	23	84	8.3	4530	2.29	0.185
2009	7.5	7.8	15	117	9.9	4995	1.39	0.21
2010	7.6	7.9	23	102	29.1	5731	1.79	0.17
2011	7.6	7.8	75	106	13.2	1583	1.8	0.106
2012	7.4	7.6	65	116	16.8	1394	1.34	0.1
2013	7.5	7.7	62	107	8.0	1606	0.86	0.048
2014	7.6	7.7	44	94	11.9	1906	0.87	0.088

[1] http://data.water.vic.gov.au/monitoring.htm - Monthly data for site 232202)

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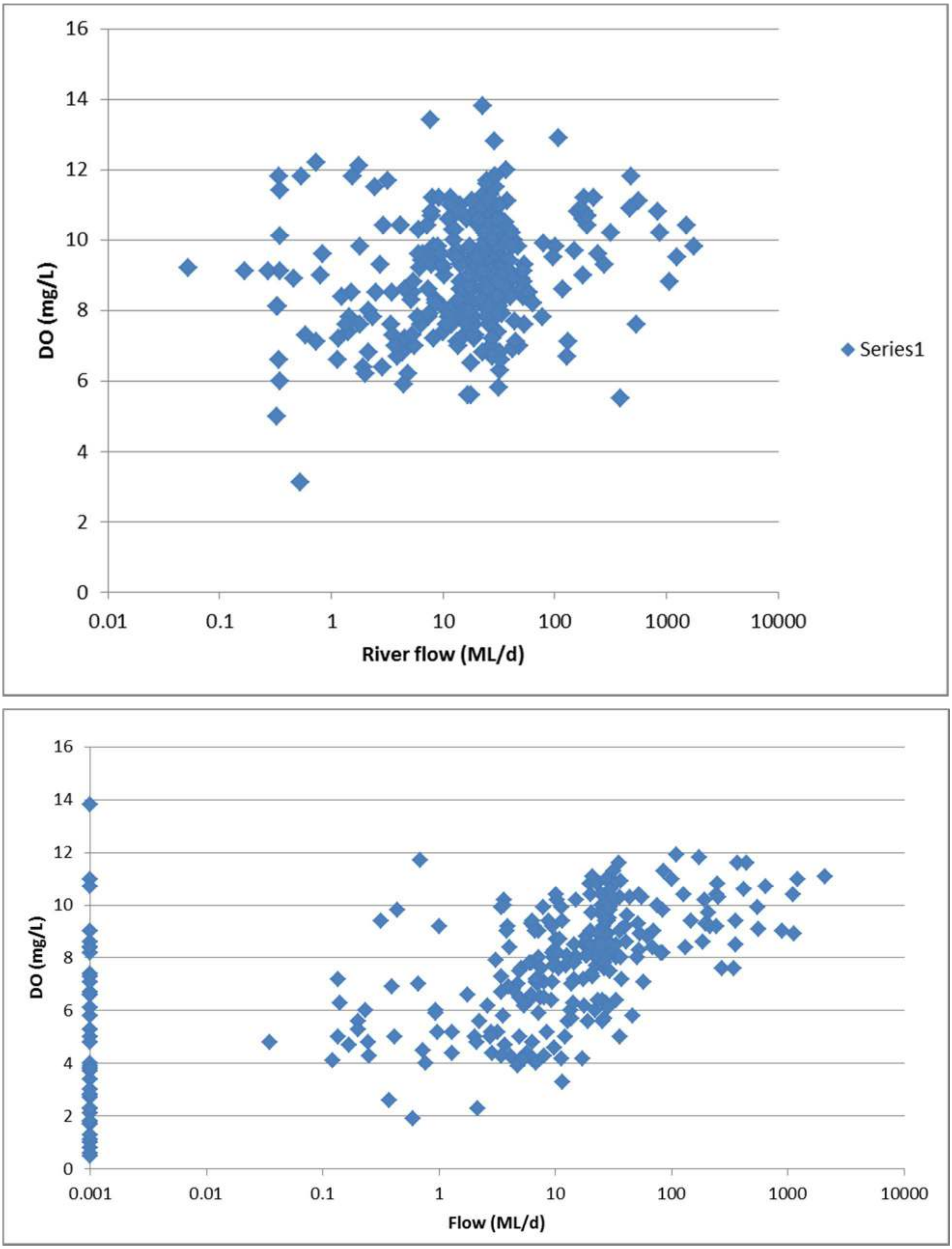
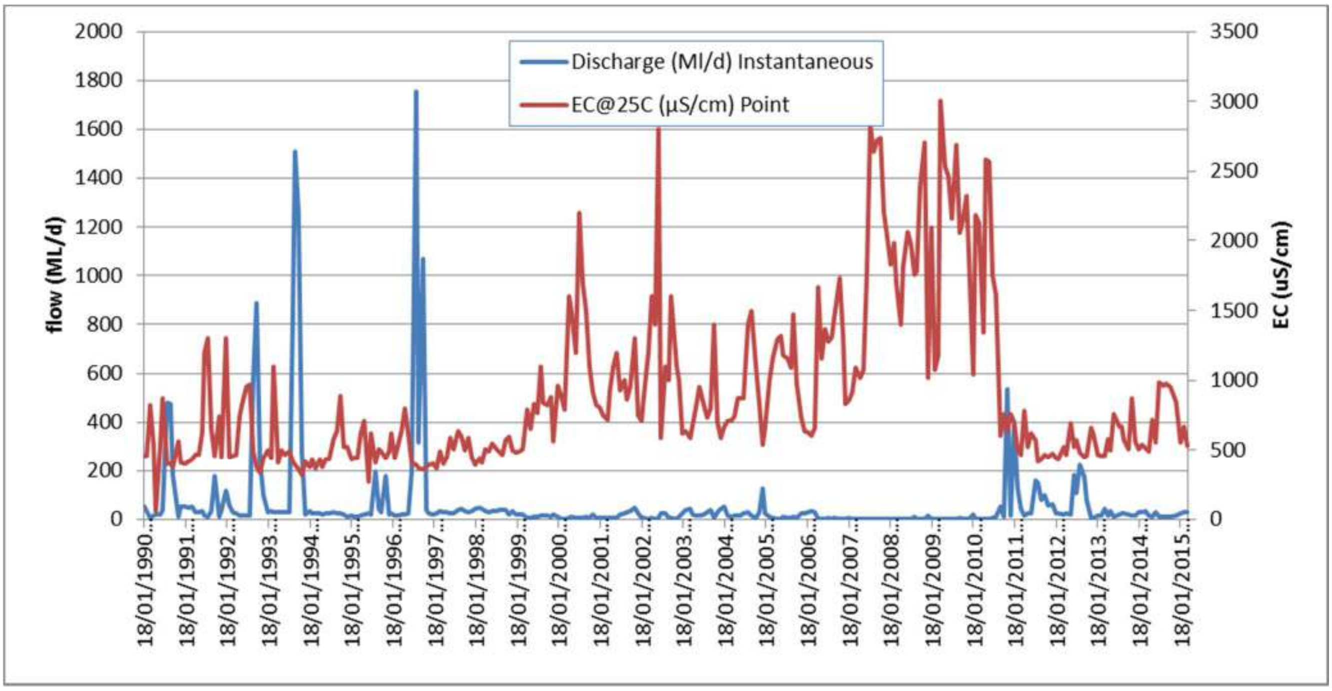


Figure 5.9: Correlation between flow and DO at Morrison's (upper panel) and Batesford (lower panel).



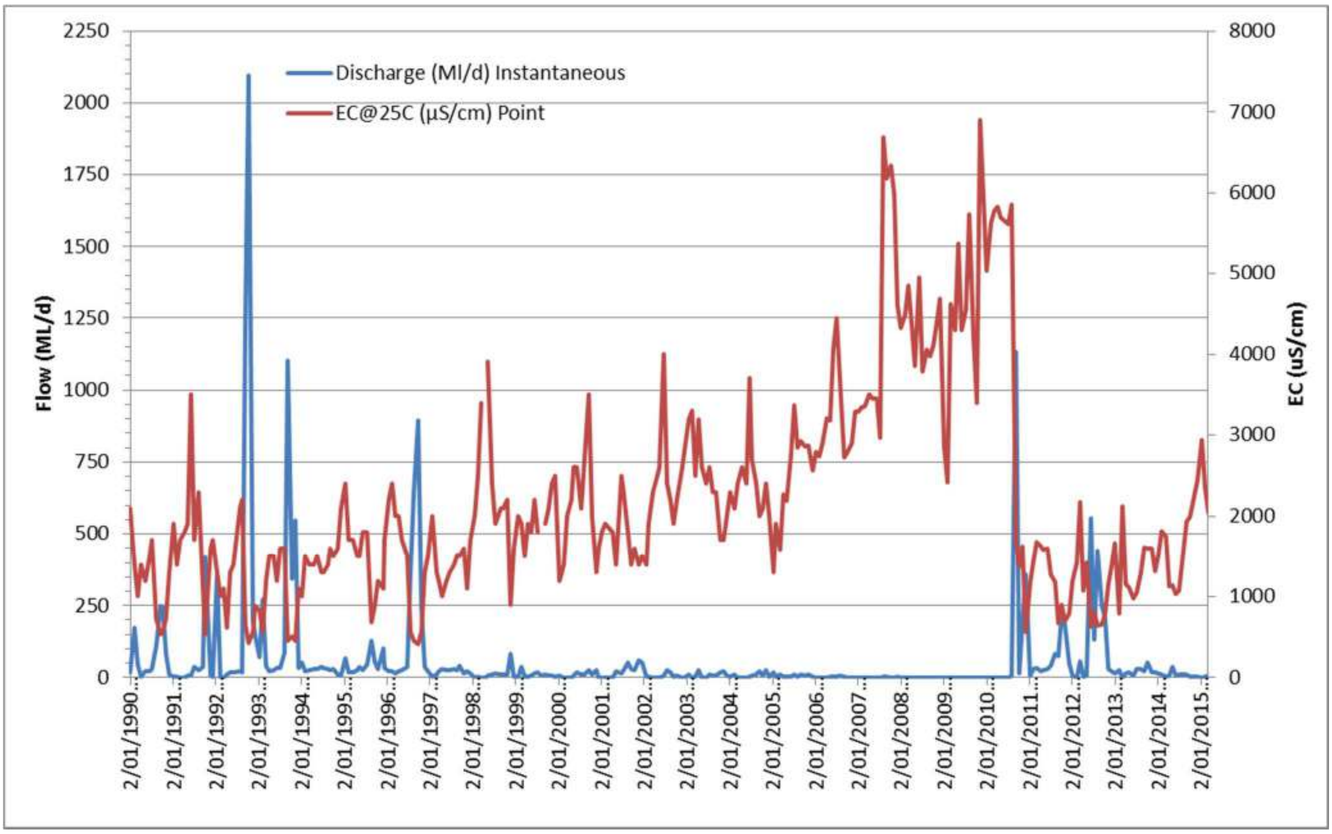


Figure 5.10: Time series of flow and EC at Morrison's (upper panel) and Batesford (lower panel).

5.6.2 Evaluation of existing objectives

Existing water quality objectives are to rehabilitate dissolved oxygen, nutrient and salinity concentrations (SKM 2004b). The existing objectives are not clear as to what rehabilitate means, presumably it relates to improving water quality with the objective of achieving relevant SEPP criteria. Flow components identified to achieve objectives are low flows and freshes.

Given the current catchment conditions, overall changes in flow (namely the extent of flow extraction) and the role that saline groundwater plays in contributing to stream flow, it is unlikely that SEPP objectives can be consistently achieved. However, the analysis in Section 5.6.1 shows that critical water quality variables (namely DO and salinity) are likely to be able to be managed via flow manipulation to avoid high risk conditions. On this basis it is recommended that water quality objective be revised to adopt a risk based approach that uses critical water quality thresholds to trigger flow releases that prevent high risk conditions from developing.

5.6.3 Revised ecological objectives

It is recommended that objectives for water quality adopt a risk a based approach based on monitoring of dissolved oxygen and salinity and use this information to trigger releases if dissolved oxygen declines to low levels or if salinity increases. Based on the available data continuous flow and occasional freshes should maintain dissolved oxygen levels above critical thresholds and minimise elevated salinity. At all reaches downstream of Lal Lal Reservoir, cease to flows are not recommended due to the potential for them to contribute to critical DO decline. Suitable thresholds for triggering flow releases are summarised in Table 5.10. Revised ecological objectives for water quality are presented in Table 5.11.

Table 5.10: Trigger levels for dissolved oxygen and salinity to avoid ecological risk (Corangamite CMA 2010).

Variable	Low risk	Moderate risk	High risk	Very high risk
Dissolved oxygen	6 mg/L	4-6 mg/L	2-4 mg/L	< 2 mg/L
Salinity	<1500 µs/cm	1500-3000 µs/cm	3000-5000 µs/cm	>5000 µs/cm

Table 5.11: Revised ecological objectives for water quality for selected FLOWS Reaches.

Reach	Ecological objective		Function	Required flow component	Timing	Expected response
1	W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
				Freshes	Summer	
	W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events
2	W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
				Freshes	Summer	
	W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events
3a	W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
				Freshes	Summer	
	W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events
3b	W1	Prevent low dissolved oxygen conditions and	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the

Reach	Ecological objective		Function	Required flow component	Timing	Expected response
		elevated EC conditions during low flow periods		Freshes	Summer	development of adverse water quality conditions.
	W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events
4	W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
				Freshes	Summer	
	W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events
				Freshes	Summer	

5.7 Water management goals

The Scientific Panel and Corangamite CMA drafted long term water management goals for the Moorabool River downstream from Lal Lal Reservoir, Moorabool River East Branch from Bostock Reservoir to West Moorabool River and the Moorabool River West Branch from Moorabool Reservoir to Lal Lal Reservoir. The management goals are described in Table 5.12.

Table 5.12: Water management goals for the Moorabool River FLOWS Reaches.

FLOWS Reach		Water Management Goal
1	Moorabool River East Branch: Bostock Reservoir to West Moorabool River	To maintain the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing protection to identified habitat refuges through land use management and securing water to maintain pools through dry periods.
2	Moorabool River West Branch: Moorabool River to Lal Lal Reservoir	To maintain the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing protection to identified habitat refuges through land use management and securing water to maintain pools through dry periods.
3a	Moorabool River: Lal Lal Reservoir to confluence with East Branch	To improve the distribution and resilience of flow dependant ecological values, particularly Platypus and native fish, by providing high quality breeding and feeding habitat; facilitate their movement through the provision of passage at artificial barriers; and restoration of native vegetation along the river.
3b	Moorabool River: East Moorabool River to Sharps Road	
4	Moorabool River: Sharps Road to Barwon River	

6. Development of Environmental Flow Recommendations

6.1 Method of revising environmental flow recommendations

Environmental flow recommendations for Moorabool River were updated by the Scientific Panel in a workshop conducted on 28 May 2015. The workshop was also attended by Saul Vermeeren and Robert Bone from Corangamite CMA.

The Scientific Panel worked through the process of updating the flow recommendations on a reach by reach basis. For each reach the revised ecological objectives and previous flow recommendations were discussed. Photos and field notes taken during the field assessment were examined along with transects from the hydraulic models in order to identify key habitat features (i.e. benches, pools, riffles, backwaters etc.).

Within each reach, each flow component was considered in turn. A range of criteria were used to determine suitable flows (i.e. depth in riffles and pool, water quality). These criteria are reach specific and vary according to the species present and channel features. For each flow component the desired volume threshold, frequency of occurrence and duration was determined. Consideration was given to the acceptable level of variability in flow components and differences between wet, average and dry years.

6.1.1 Flow seasons

Separate environmental flow recommendations are made for the Summer/Autumn and Winter/Spring. For the purposes of this project, Summer/Autumn flow recommendations apply to the whole period from the start of December to the end of May. Winter/Spring flow recommendations apply from the start of June to the end of November.

6.1.2 Tailoring flow recommendations for wet, average and dry years

To assist in the understanding of environmental flow recommendations, throughout this report there is reference to wet, average and dry years. This allows, for example, higher magnitude events in wet years compared to dry years, fewer freshes during dry years, or longer duration high flows during wet years.

The division of wet, average and dry years was based on the long-term rainfall record at Moorabool Reservoir, which has 102 years of record. Annual rainfall records were plotted and ranked from smallest to largest and visually inspected. There were no clear jumps observed in annual rainfall and therefore one third of the data is assigned to each climate condition (see Figure 6.1) and therefore we used those statistics as the threshold for wet, average and dry years. The specific years allocated to each category are shown in Table 6.1.

In wet years it is likely that streamflow will be higher than the recommended environmental flows. Under these circumstances it is not necessary to reduce flows to ‘meet’ or ‘comply with’ the flow recommendations. The flow recommendations are the minimum required to achieve ecological objectives and more flow than recommended (or longer duration freshes, even if it means fewer events above a particular threshold or flow events outside the suggested time intervals) is acceptable if it occurs naturally in response to wet climatic conditions.

To assist with developing the flow recommendations a range of flow statistics were examined for the current flow regime, these include spells plots to identify the pattern over time of flows above or below certain flow volume thresholds and spell duration statistics to summarise the frequency or number of events above or below a specified flow volume threshold per year, the duration in days of flow above or below the specified threshold volumes and the distribution of start month of flow events above or below specified threshold volumes

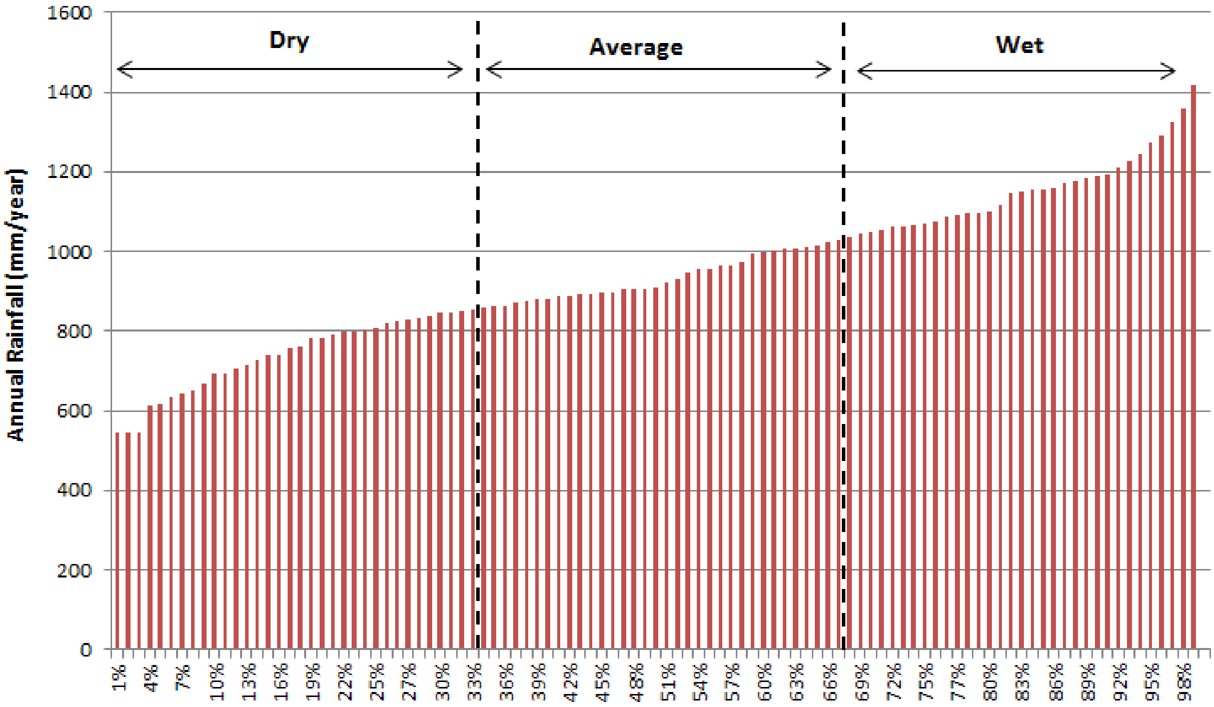


Figure 6.1: Plot showing how statistics were used to assign dry, wet and average years.

Table 6.1: Dry, Average, Wet assignment.

Dry		Average		Wet	
1912	1945	1936	1965	1966	1968
1913	1948	1921	1976	1916	1970
1914	1957	1923	1977	1917	1971
1915	1967	1928	1979	1924	1973
1918	1969	1929	1980	1935	1974
1919	1972	1931	1983	1939	1975
1920	1982	1932	1984	1942	1978
1922	1994	1933	1986	1947	1981
1925	1997	1934	1988	1951	1985
1926	1999	1941	1990	1952	1987
1927	2002	1946	1991	1953	1989
1930	2003	1949	1998	1954	1992
1937	2005	1950	2000	1955	1993
1938	2006	1958	2001	1956	1995
1940	2008	1959	2004	1960	1996
1943	2009	1961	2007	1963	2010
1944	2013	1962	2012	1964	2011

6.1.3 Setting of Minimum and Aspirational flow recommendations

For the Moorabool River FLOWS Reaches we have set minimum and aspirational flow recommendations. A minimum flow recommendation refers to the minimum amount of water that is required to meet the ecological objectives. Aspirational flow recommendations are those of a higher magnitude which are recognised as providing a greater benefit to the system and a higher likelihood of achieving river health outcomes.

For FLOWS Reaches 1 and 2 all of the flow recommendations are set as minimum flow recommendations. Aspirational flow recommendations have not been set for these FLOWS reaches as there is not considered sufficient justification to set higher aspirational flow recommendations.

For FLOWS Reaches 3a, 3b and 4, all of the Summer/Autumn flow recommendations are classified as minimum flow recommendations. A two staged approach has been followed in setting Winter/Spring flow recommendations, with the setting of minimum and aspirational flow recommendations. The minimum flow recommendations in the Winter/Spring season represent the minimum flow requirements to allow for fish and Platypus movement, maintain access to habitat and assist in scouring of biofilms and algae from the streambed and transport of organic matter. Minimum depths for movement of fish and Platypus is provided by the low flow and triggers for fish movement are provide by the smaller fresh events.

It is recognised that there would be greater benefit provided if a higher aspirational low flow was provided, with increased wetting of the perimeter of the channel, allowing more access to a greater area and diversity of instream habitat. Similarly, relative to the higher aspirational low flow, higher magnitude freshes with longer duration may be more beneficial in scouring biofilms from the bed, transporting organic matter and triggering fish migration. Aspirational flow recommendations are only likely to be achieved in very wet years at present.

6.1.4 Prioritisation of flows

In prioritising flows, the general rule followed is to provide base flows first and then give second priority to Summer/Autumn freshes followed by Winter/Spring freshes as third priority. The reasoning behind this is that aquatic systems are most stressed over Summer periods.

In the Moorabool Catchment, the general rule outlined above applies, however it is also recognised that there are often periods where there is limited water available to provide for a continuous recommended low flow. Given these constraints, the first priority is to provide a Summer/Autumn base flow that maintains suitable water quality. This may be lower than the recommended low flow. Should water conditions deteriorate a priority should be placed on the delivery of trigger based freshes to improve water quality conditions.

In the Moorabool Catchment, freshes in Summer/Autumn and Winter/Spring are important for triggering the movement and spawning of migratory fish species. The following prioritisation is applied to the delivery of freshes:

- In Summer/Autumn, a higher priority is recommended in delivering the April/May fresh to trigger downstream spawning migration of Grayling over the January/February fresh which triggers the downstream spawning migration of Short-finned Eel.
- In Winter/Spring, first priority is given to delivery of one fresh in September/October to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling followed by a fresh in June/July to trigger downstream spawning migration of adult Tupong as a second priority. An additional fresh in September/October is third priority, providing another opportunity for juvenile Galaxias, Tupong, Short-finned Eel and Grayling to move upstream.

6.1.5 Rates of rise and fall

The rates in which flows rise and fall are environmentally significant, particularly for short duration freshes and high flows. If rates of rise and fall are too fast they may exceed the ability of biota to adapt, thereby causing stress with fish stranded in backwater areas). Rapid falls in flow can increase the risk of bank failure leading to increased erosion and sediment loads.

The previous FLOWS study referred to median rates of rise and fall from flows data recorded at flow gauges downstream of all storages on the Moorabool River. The previously recommended rate of rise was 1.2 and 0.8 the rate of fall.

We have reviewed the flows data for each of the five FLOWS Reaches, noting that there is a significant range in rates of rise and fall. We have also considered in more detail what would be the relative water level changes associated with increasing flow from recommended low flows to freshes and high flows in each of the FLOWS Reaches.

On this basis, our recommended rate of rise is 2.0 and rate of fall is 0.7. It is expected that it would generally take 2-3 days for a flow to rise from base flow to the peak of a recommended Fresh, which approximates a 5-20 cm change in water level/day for flows less than 200 ML/Day. With a rate of fall of 0.7, flow levels would gradually drop down to base flow over four to six days.

Varying the rate of rise and fall could assist in reducing the amount of water required to deliver a recommended flow. It may be possible to reduce the number of days it takes for water levels to drop from the peak of the Fresh to base flows, perhaps to 3-4 days if water is limited, however risks to biota may be increased with higher rates of fall.

6.1.6 Uncertainty in flow recommendations

A range of uncertainties exist in the modelling of current flows and in HEC-RAS models. The models have been calibrated using the measured flow on the day of survey. HEC-RAS models should be accurate for flows that are relatively close to the calibrated flow magnitude, but will be less reliable for higher or lower flower magnitudes. Each model has been created so as to minimise this error, but it is not possible to avoid it entirely without surveying the water levels at each site over a wide range of different flows. An overview of the hydraulic models used to set flow recommendations is presented in Appendix C.

There are also uncertainties in the response of various physical and biological processes and functions to flow. For example, we know that some fish require an increase in flow at a particular time of the year to trigger migration or spawning, however we don't know whether the biological response is related to the rate of flow change or a specific flow threshold, whether the flow increase must be of a certain duration, or whether there are other confounding factors. These knowledge gaps introduce further uncertainties to the flow recommendations.

Many of the flow recommendations are based on maintaining elements of the current flow regime (i.e. the current magnitude, frequency and duration of various events), especially if there is no clear justification for a particular flow recommendation. For example, where there is an understanding of the general flow requirements (e.g. for fish spawning) but no site specific data to support a specific recommendation, we have resorted to using elements of the current regime to inform the recommendation.

The environmental flow recommendations presented in this report make use of the most up to date information that was available at the time of the assessment, but many information gaps remain. It is important that as our understanding of biological responses to flow improves (e.g. through monitoring and scientific research) the flow recommendations are amended to improve overall confidence.

6.2 FLOWS Reach 1 – Moorabool River East Branch: Bostock Reservoir to West Moorabool River

6.2.1 Ecological objectives

Based on information obtained from a review of the previous FLOWS study, monitoring reports, literature and the field inspection revised ecological objectives have been developed for Reach 1 (Refer to Appendix B, Table B.1). Objectives have still been set for the same migratory fish species as those found further downstream on the Moorabool River. We would expect the same migratory fish species to be present as in Reach 4, if She Oaks Weir was not present/or with provision of fish passage. To achieve objective of expansion of fish populations, removal of barriers or provision of fish passage is required. The sequence of barriers along the Moorabool River progressively reduces opportunities for upstream migration.

6.2.2 Environmental flow recommendations

The revised environmental flow recommendations for Reach 1 and specific objectives they aim to meet are summarised in Table 6.2. Figure 6.2 shows the range of flows that are recommended and how they relate to depths of flow and inundation of pool (Cross-Section 3) and riffle features (Cross-Section 6). A more detailed description of the flow recommendations is provided below. These flow recommendations are also presented in diagrammatic form, comparing the recommended flows against flows experienced in an example wet (Figure 6.3), average (Figure 6.4) and dry year (Figure 6.5). The flow recommendations for Reach 1 represent the minimum flows required to meet the ecological objectives.

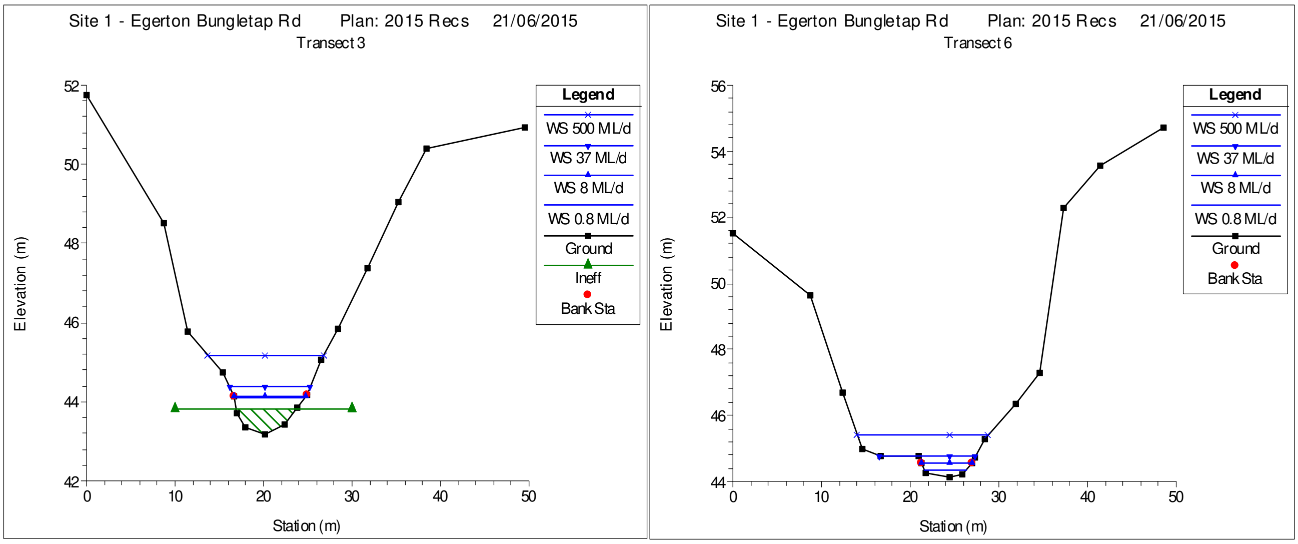


Figure 6.2: Cross-Section 3 and 6 showing influence changing flow levels has on inundation. Levels are shown for Summer/Autumn Low (0.8 ML/Day), a Winter/Spring Low Flow (8 ML/Day), Fresh (37 ML/Day) and High flow (500 ML/Day).

Summer/Autumn low flow

Summer/Autumn low flows are important in providing permanent habitat for fish, macroinvertebrates, Platypus and submerged aquatic vegetation as well as maintain water quality. It is estimated that groundwater contributes up to 50% of baseflow along the East Branch. This together with passing flows from Bostock Reservoir is considered sufficient to maintain the pool and riffle habitats.

Summer/Autumn fresh

Summer/Autumn freshes are important in providing greater depth of flow in all habitat areas that will allow fish and Platypus to move throughout the reach and maintain access to habitat. These higher flows will also water fringing vegetation. During wet/average years, groundwater contribution is considered sufficient to provide variability in flow over the Summer/Autumn period. In dry years, small freshes of 2 ML/Day with a duration of 2-3 days spaced 8 weeks apart are recommended to freshen pools and prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods.

Winter/Spring low

The Winter/Spring low flow should have a sufficient magnitude to allow fish movement through the reach, maintain a clear flow path and control intrusions by terrestrial vegetation. A higher continuous flow of 8 ML/Day from June to November would provide depth requirements for fish and wet the perimeter of the channel.

Winter/Spring fresh

Winter/Spring freshes assist in providing increased opportunities for movement of fish and Platypus throughout the reach and maintain access to habitat. Freshes are also required to trigger downstream spawning migration of adult Tupong (May to August) and upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (September/October). These freshes will also flush silt and scour biofilms and algae from the stream bed, transport organic matter and promote the growth and recruitment of native riparian vegetation. The recommended frequency and timing of freshes vary for wet/average and dry years:

- In wet/average years we recommend one fresh in May to August to trigger downstream spawning migration of Tupong and two freshes in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The recommendation is that each event has a magnitude of 37 ML/Day with a duration of 5 days.
- In dry years we recommend one fresh in May to August to trigger downstream spawning migration of adult Tupong and one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The recommendation is that each event has a magnitude of 37 ML/Day with a duration of 5 days.

In prioritising Winter/Spring freshes, in wet/average years first priority is given to delivery of one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling followed by a fresh in May to August to trigger downstream spawning migration of Tupong as a second priority. An additional fresh in September to November is given a third priority. In dry years, first priority is given to a September to November fresh with second priority to a fresh in May to August. It is recommended that the September to November freshes are linked with Barwon River high flows, during or just after to attract fish into the Moorabool River.

High flows

High flows approaching bankfull and overbank events help to maintain the channel form and dimensions as the velocity and shear stresses associated with these flows will scour the bed and banks of the channel, entraining sediments and deepening pools. These flows will also inundate benches, wetting riparian vegetation. We recommend a high flow of 500 ML/Day every 2 years with a duration of 1-2 days in wet/average years. These events are not expected to occur in dry years.

Table 6.2: Updated environmental flow recommendations for FLOWS Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River. Refer to Table B.1 in Appendix B for detailed account of ecological objectives for Reach 1.

Waterway	Moorabool River East Branch: Bostock Reservoir to West Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	All years	Passing flows (1.2 ML/Day) Minimum	December to May		
	Fresh	Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods (W1).	Wet / Average	Not required			
			Dry	2 ML/Day Minimum	Every 8 weeks	2-3 days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	All years	Passing flows (8 ML/Day) Minimum	June to November		
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	37 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	5 Days	2.0/0.7
			Dry	37 ML/Day Minimum	1 event May to August (Tupong) and 1 event September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	5 Days	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day Minimum	1 event every 2 to 3 years, preferably in Winter to avoid risks to Platypus (no control over timing)	2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, a 37 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 8 ML/Day it would take 3 days to ramp up flows to 37 ML/Day and then 4 days to fall down to 8 ML/Day.

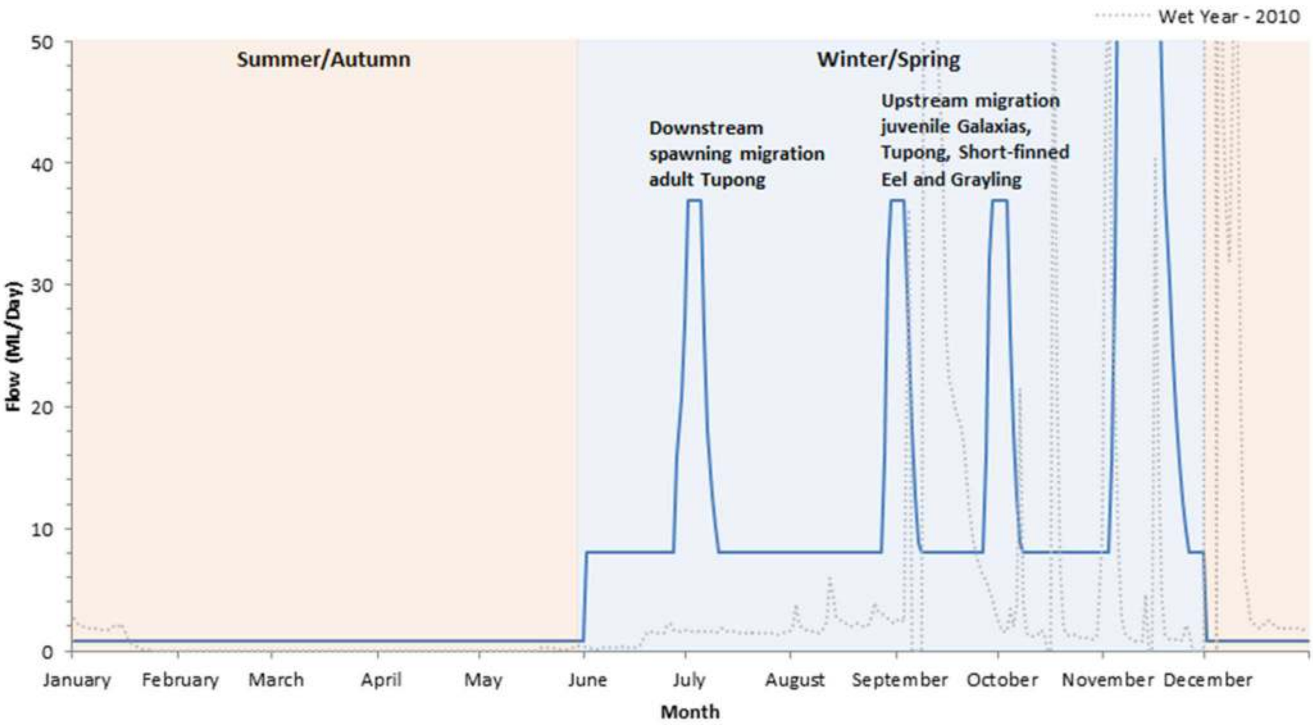


Figure 6.3: Plot showing Reach 1 updated environmental flow recommendations for a wet year. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions. Note the high flow recommendation of 500 ML/Day extends beyond the range of the scale shown on this plot.

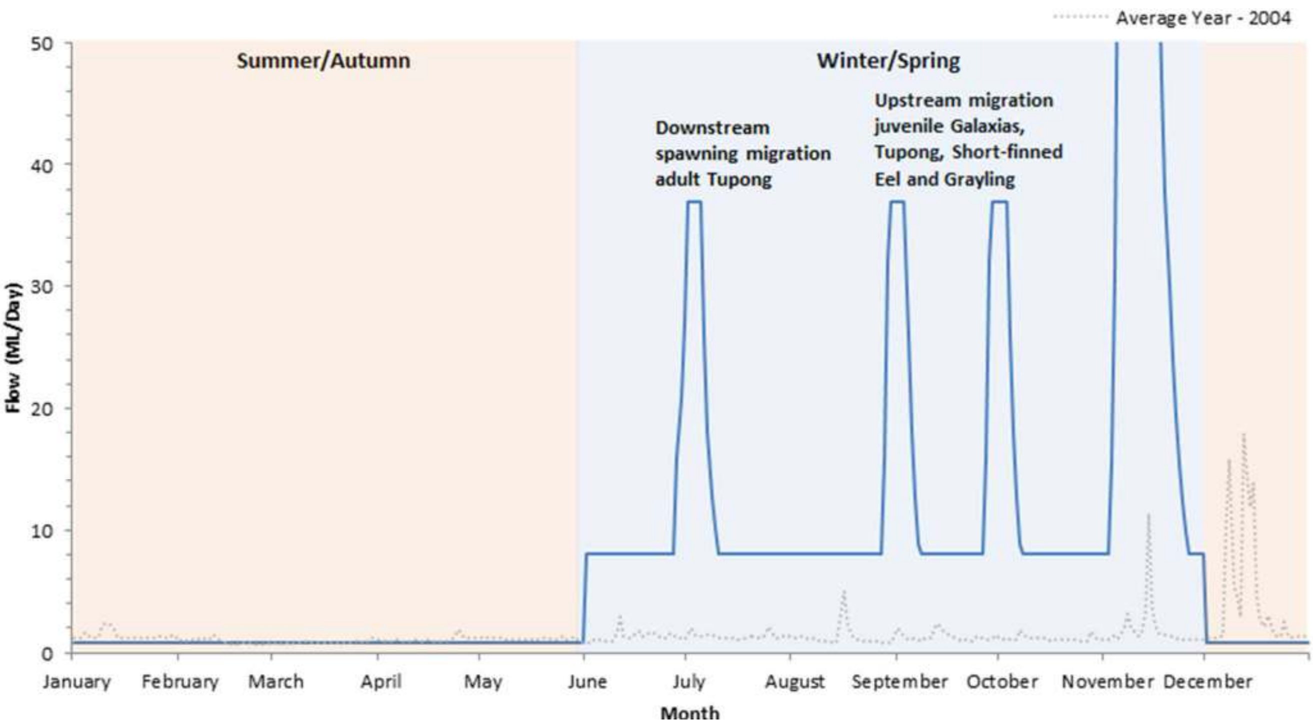


Figure 6.4: Plot showing Reach 1 updated environmental flow recommendations for an average year. The flow series for the year 2004 is shown as an example of a year experiencing average flow conditions. Note the high flow recommendation of 500 ML/Day extends beyond the range of the scale shown on this plot.

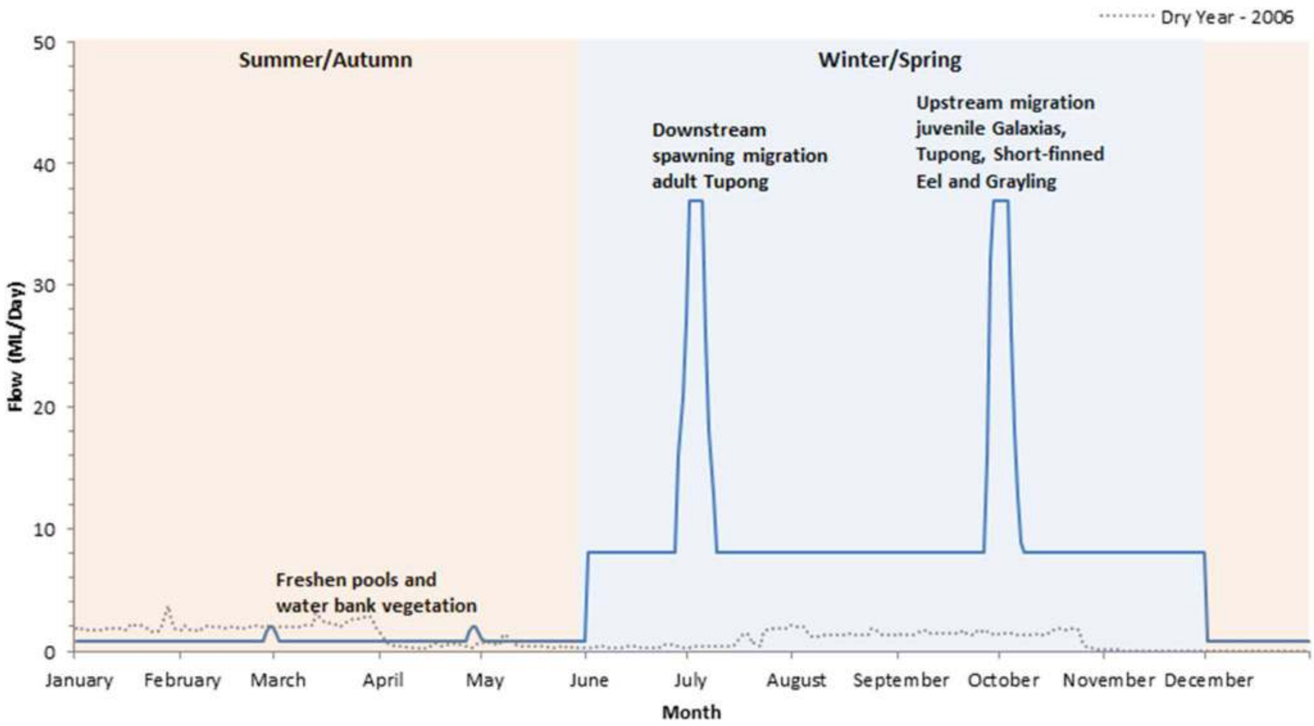


Figure 6.5: Plot showing Reach 1 updated environmental flow recommendations for a dry year. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

6.3 FLOWS Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir

6.3.1 Ecological objectives

Based on information obtained from a review of the previous FLOWS study, monitoring reports and literature revised ecological objectives have been developed for Reach 2 (Refer to Appendix B, Table B.2). For Reach 2 we would not expect migratory fish species to be present, due to Lal Lal Reservoir. The magnitude of flow recommendations for this reach have been reduced by 50% from those recommended in Reach 3a based on a comparison of catchment area between Reach 2 and 3a.

6.3.2 Environmental flow recommendations

The revised environmental flow recommendations for Reach 2 and specific objectives they aim to meet are summarised in Table 6.3. As no survey or hydraulic modelling was undertaken in this reach, the updated flow recommendations for Reach 2 have been developed with reference to Reach 3a. A more detailed description of the flow recommendations is provided below. The flow recommendations for Reach 2 represent the minimum flows required to meet the ecological objectives.

Summer/Autumn low flow

Summer/Autumn low flows are important in providing permanent habitat for fish, macroinvertebrates, Platypus and submerged aquatic vegetation as well as maintain water quality. A continuous low flow of 5 ML/Day is recommended in wet/average years and 2.5 ML/Day in dry years. A low flow of 2.5 ML/Day is considered the bare minimum to maintain water quality conditions.

Summer/Autumn fresh

Summer/Autumn freshes are important in providing greater depth of flow in all habitat areas that will allow fish and Platypus to move throughout the reach and maintain access to habitat. These higher flows will also flush silt and scour biofilms and algae from the stream bed and water fringing vegetation. In wet/average years we recommend three freshes of 30 ML/Day with a duration of 3 days. In dry years we recommend one fresh of 30 ML/Day with a duration of 3 days every two to three years.

Winter/Spring low

The Winter/Spring low flow should have a sufficient magnitude to allow fish movement through the reach, maintain a clear flow path and control intrusions by terrestrial vegetation. A Winter/Spring low flow of 5 ML/Day in wet/average years and 2.5 ML/Day in dry years is recommended.

Winter/Spring fresh

Winter/Spring freshes assist in providing increased opportunities for movement of fish and Platypus throughout the reach and maintain access to habitat. These freshes will also flush silt and scour biofilms and algae from the stream bed, transport organic matter and promote the growth and recruitment of native riparian vegetation. In wet/average years we recommend three freshes of 40 ML/Day with a duration of 3 days. In dry years we recommend one fresh of 40 ML/Day with a duration of 3 days.

High flows

High flows approaching bankfull and overbank events help to maintain the channel form and dimensions as the velocity and shear stresses associated with these flows will scour the bed and banks of the channel, entraining sediments and deepening pools. These flows will also inundate benches, wetting riparian vegetation. We recommend a high flow of 250 ML/Day every 2 years with a duration of 1-2 days in wet/average years. These events are not expected to occur in dry years.

Table 6.3: Updated environmental flow recommendations for FLOWS Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir. Refer to Table B.2 in Appendix B for detailed account of ecological objectives for Reach 2.

Waterway	Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	5 ML/Day Minimum			NA
			Dry	2.5 ML/Day Minimum			NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1).	Wet / Average	30 ML/Day Minimum	3 events	3 Days	2.0/0.7
			Dry	30 ML/Day Minimum	1 event every 2 to 3 years	3 Days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	5 ML/Day Minimum	June to November		
			Dry	2.5 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	40 ML/Day Minimum	3 events	3 Days	2.0/0.7
			Dry	40 ML/Day Minimum	1 event	3 Days	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4).	Wet / Average	250 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus (no control over timing)	1-2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, a 40 ML/Day Winter/Spring Fresh has a recommended duration of 3 days at its peak. If flow started at 5 ML/Day it would take 3 days to ramp up flows to 40 ML/Day and then 6 days to fall down to 5 ML/Day .

6.4 FLOWS Reach 3 – Moorabool River: Lal Lal Reservoir to Sharps Road

6.4.1 FLOWS Reach 3a - Moorabool River: Lal Lal Reservoir to confluence with East Branch

6.4.1.1 Ecological objectives

The sequence of barriers along the Moorabool River progressively reduces opportunities for upstream migration. For example, if She Oaks Weir was not present, or if there was a fishway built into the weir, we would expect the same migratory fish species to be present in Reach 3a as in Reach 4. To achieve objective of expansion of fish populations along the river, removal of barriers or provision of fish passage is required. Based on information obtained from a review of the previous FLOWS study, monitoring reports, literature and field inspections, revised ecological objectives have been developed for Reach 3a (Refer to Table B.3 in Appendix B).

6.4.1.2 Environmental flow recommendations

The revised environmental flow recommendations for Reach 3a and specific objectives they aim to meet are summarised in Table 6.4. Figure 6.6 shows the range of flows recommended and how they relate to depths of flow and inundation of channel features in the deepest pool at Cross-Section 6 and riffle habitat at Cross-Section 7. A more detailed description of the flow recommendations is provided below. These flow recommendations are also presented in diagrammatic form, comparing the recommended flows against flows experienced in an example wet (Figure 6.7), average (Figure 6.8) and dry year (Figure 6.9).

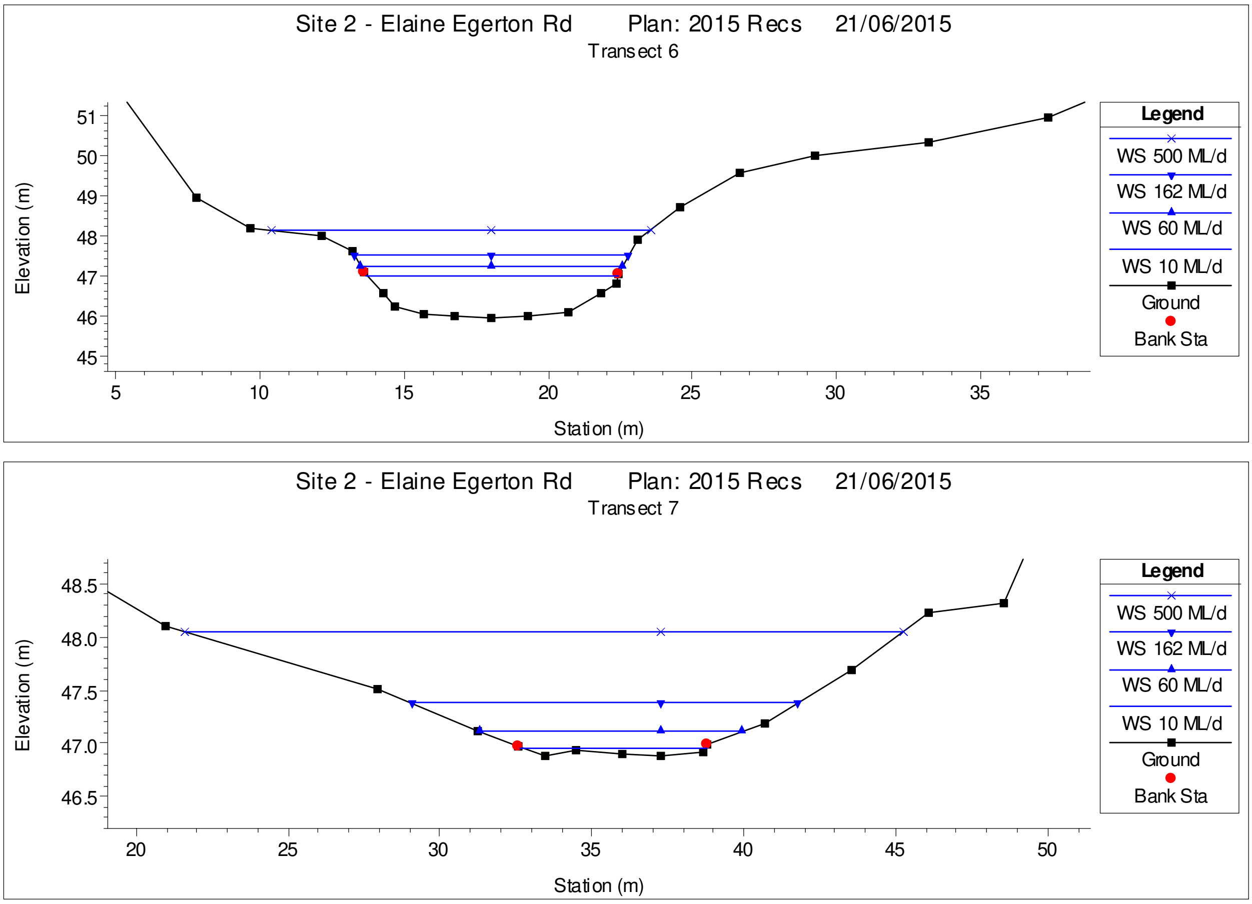


Figure 6.6: Cross-Section 6 (top) and 7 (bottom) showing influence changing flow levels have on inundation and flow depth. Levels are shown for a Summer/Autumn Low Flow (10 ML/Day), a Winter/Spring Low Flow (60 ML/Day), Fresh (162 ML/Day) and High flow (500 ML/Day).

Summer/Autumn low flow

Summer/Autumn low flows are important in providing permanent habitat for fish, macroinvertebrates, Platypus and submerged aquatic vegetation as well as maintain water quality. A continuous low flow of 10 ML/Day is recommended in wet/average years and 5 ML/Day in dry years. 5 ML/Day is considered the bare minimum to maintain water quality conditions.

Summer/Autumn fresh

Summer/Autumn freshes are important in providing greater depth of flow in all habitat areas that will allow fish and Platypus to move throughout the reach and maintain access to habitat. These higher flows will also flush silt and scour biofilms and algae from the stream bed and water fringing vegetation. Freshes are also required to trigger downstream spawning migration of Short-finned Eel (January/February) and Grayling (April/May). The recommended frequency and timing of freshes vary for wet/average and dry years:

- We recommend two freshes of 60 ML/Day in January/February and April/May in wet/average years, with each event having a duration of 5 days. An additional smaller fresh of 30 ML/day with a duration of 3 days is recommended in February/March to water fringing vegetation.
- We recommend one fresh of 60 ML/Day every two to three years in dry years with a duration of 5 days in April/May to trigger downstream spawning migration of Grayling. Over dry periods Short-finned Eels will survive.

A higher priority is recommended in delivering the April/May fresh to trigger downstream spawning migration of Grayling over the January/February fresh which triggers the downstream spawning migration of Short-finned Eel.

Winter/Spring low

A two staged approach has been followed in setting Winter/Spring flow recommendations, based on what is considered aspirational if a greater volume of water was available from that which is considered a minimum flow requirement.

The Winter/Spring low flow should have a sufficient magnitude to allow fish movement through the reach, maintain a clear flow path and control intrusions by terrestrial vegetation. A higher continuous flow of 60 ML/Day from June to November would inundate the full extent of the channel bed. We recommend this as an aspirational low flow recommendation. A lower Winter/Spring low flow of 10 ML/Day in wet/average years and 5 ML/Day in dry years is considered the minimum flow. These lower flows will still provide for fish movement through the reach, however, this will not be effective in controlling intrusions by terrestrial vegetation.

Winter/Spring fresh

Winter/Spring freshes assist in providing increased opportunities for movement of fish and Platypus throughout the reach and maintain access to habitat. Freshes are also required to trigger downstream spawning migration of adult Tupong (May to August) and upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (September to November). These freshes will also flush silt and scour biofilms and algae from the stream bed, transport organic matter and promote the growth and recruitment of native riparian vegetation. The recommended frequency and timing of freshes vary for wet/average and dry years:

- In wet/average years we recommend one fresh in May to August to trigger downstream spawning migration of Tupong and two freshes in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.
- In dry years we recommend one fresh in May to August to trigger downstream spawning migration of adult Tupong and one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.

In prioritising Winter/Spring freshes, in wet/average years first priority is given to delivery of one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling followed by a fresh in May to August to trigger downstream spawning migration of adult Tupong as a second priority. An additional fresh in September to November is given a third priority. In dry years, first priority is given to a September to November fresh with second priority to a fresh in May to August. It is recommended that the September to November freshes are linked with Barwon River high flows, during or just after to attract fish into the Moorabool River.

High flows

High flows approaching bankfull and overbank events help to maintain the channel form and dimensions as the velocity and shear stresses associated with these flows will scour the bed and banks of the channel, entraining sediments and deepening pools. These flows will also inundate benches, wetting riparian vegetation. We recommend a high flow of 500 ML/Day every 2 years with a duration of 1-2 days in wet/average years. These events are not expected to occur in dry years.

Table 6.4: Updated environmental flow recommendations for FLOWS Reach 3a - Moorabool River West Branch: Lal Lal Reservoir to confluence with East Branch. Refer to Table B.3 in Appendix B for detailed account of ecological objectives for Reach 3a.

Waterway	Moorabool River West Branch: Lal Lal Reservoir to East Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	10 ML/Day Minimum	December to May		NA
			Dry	5 ML/Day Minimum	December to May		NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, April/May (Grayling) and January/February (Short-finned Eel)	5 Days	2.0/0.7
				30 ML/Day Minimum	1 event in February/March to water fringing vegetation	3 Days	2.0/0.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet/Average	60 ML/Day Aspirational 10 ML/Day Minimum	June to November		
			Dry	60 ML/Day Aspirational 5 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 2 events September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/0.7

Waterway	Moorabool River West Branch: Lal Lal Reservoir to East Moorabool River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
		recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event May to August (Tupong) and 1 event September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/0.7
	High	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day Minimum	1 event every 2-3 years, preferably in Winter to avoid risks to Platypus (no control over timing)	1 to 2 Days	2.0/0.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day .

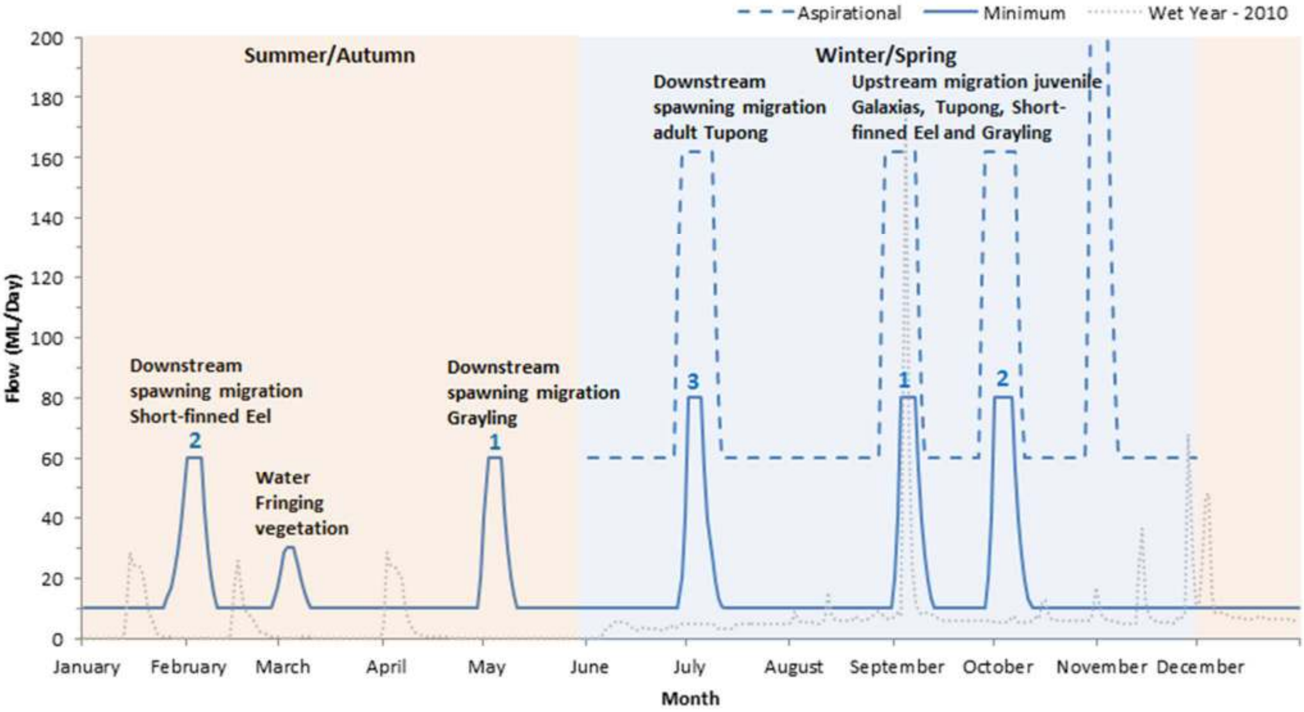


Figure 6.7: Plot showing Reach 3a updated environmental flow recommendations for a wet year. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions. Note the high flow recommendation of 500 ML/Day extends beyond the range of the scale shown on this plot.

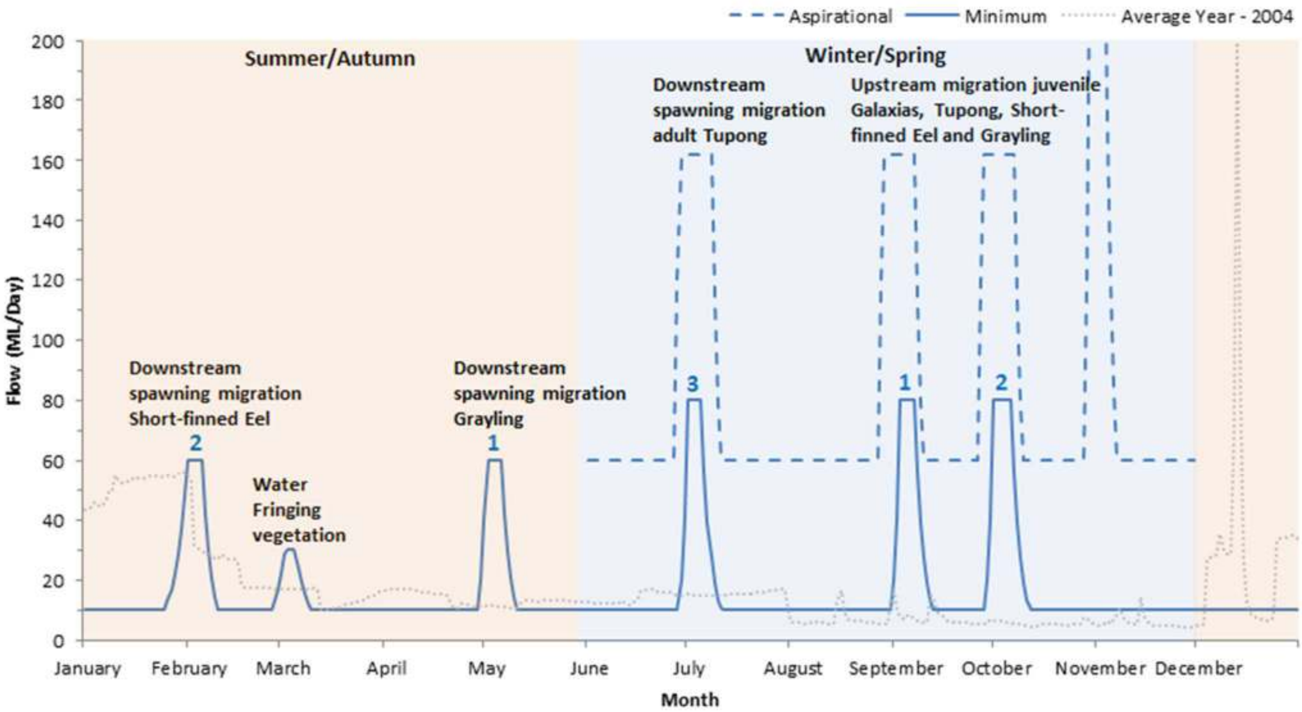


Figure 6.8: Plot showing Reach 3a updated environmental flow recommendations for an average year. The flow series for the year 2004 is shown as an example of a year experiencing average flow conditions. Note the high flow recommendation of 500 ML/Day extends beyond the range of the scale shown on this plot.

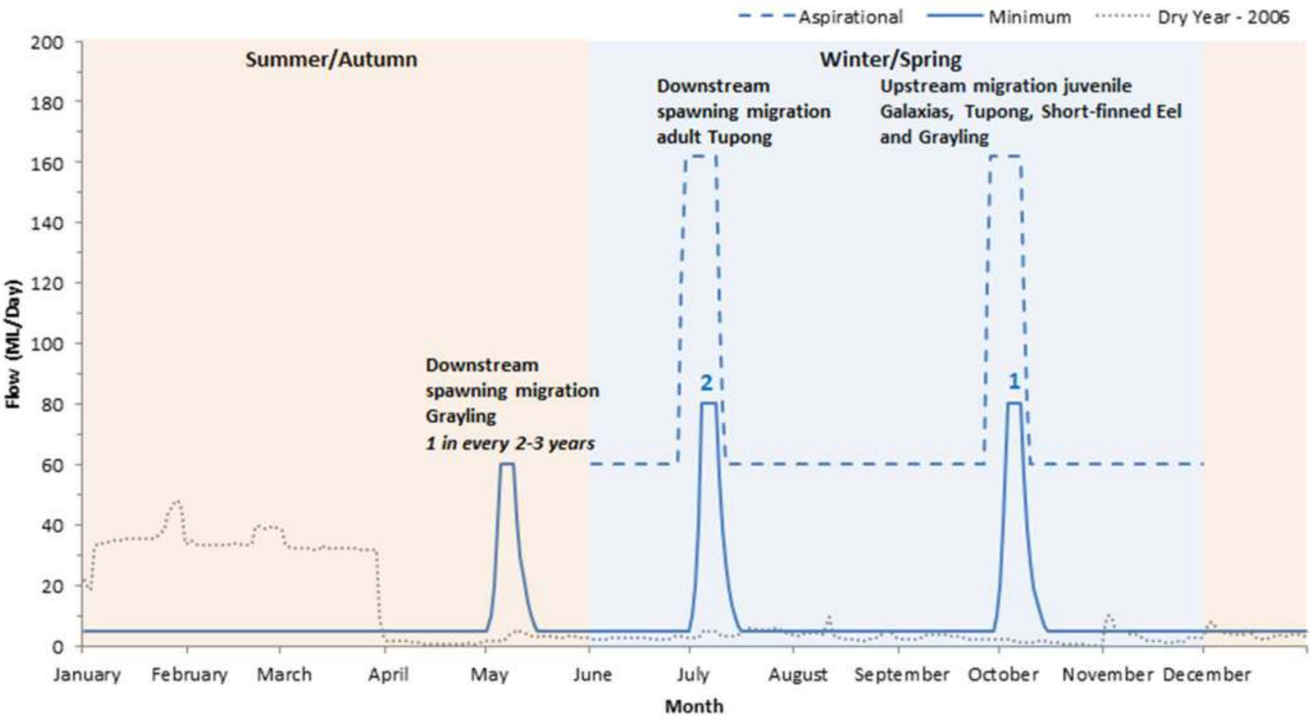


Figure 6.9: Plot showing Reach 3a updated environmental flow recommendations for a dry year. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

6.4.2 FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road

6.4.2.1 Ecological objectives

The sequence of barriers along the Moorabool River progressively reduces opportunities for upstream migration. For example, if She Oaks Weir was not present, or if there was a fishway built into the weir, we would expect the same migratory fish species to be present in Reach 3b as in Reach 4. To achieve objective of expansion of fish populations along the river, removal of barriers or provision of fish passage is required. Based on information obtained from a review of the previous FLOWS study, monitoring reports, literature and field inspections, revised ecological objectives have been developed for Reach 3b (Refer to Table B.4 in Appendix B).

6.4.2.2 Environmental flow recommendations

The revised environmental flow recommendations for Reach 3b and specific objectives they aim to meet are summarised in Table 6.5. Figure 6.10 presents selected cross-sections of the channel to show the range of flows that are recommended and how they relate to depths of flow and inundation of channel features. A more detailed description of the flow recommendations is provided below. These flow recommendations are also presented in diagrammatic form, comparing the recommended flows against flows experienced in an example wet (Figure 6.11), average (Figure 6.12) and dry year (Figure 6.13).

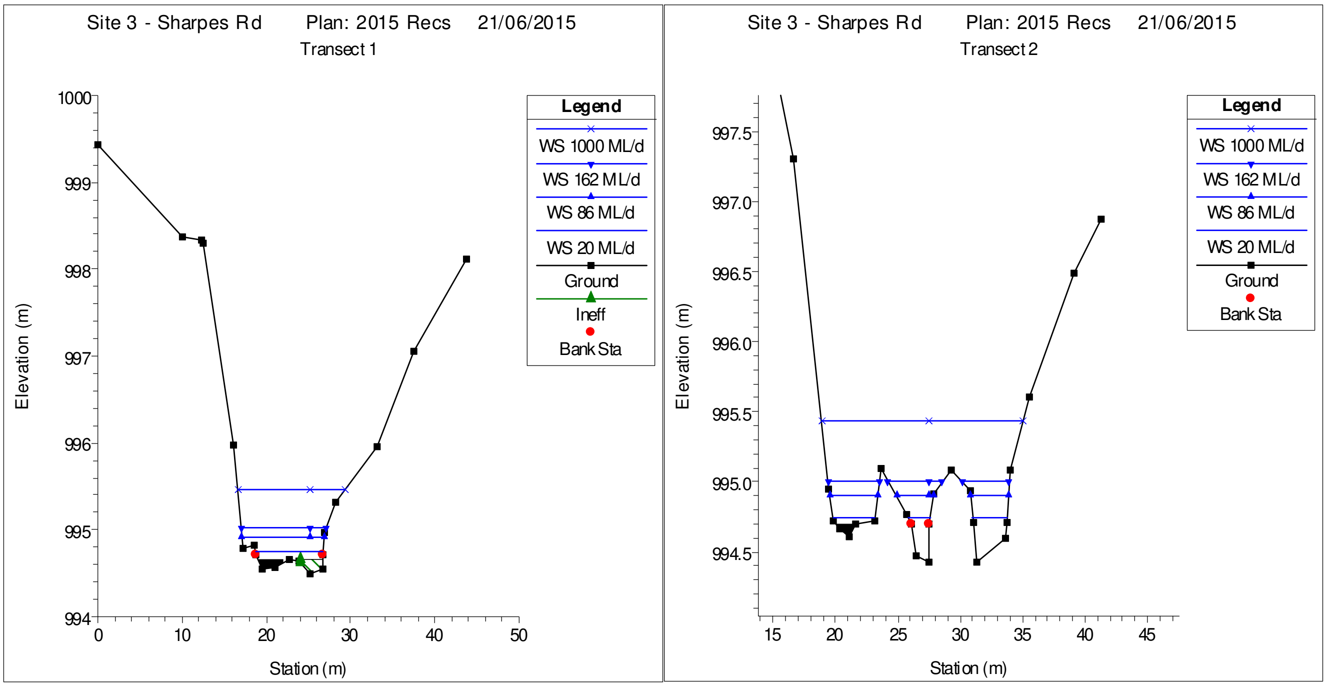


Figure 6.10: Cross-Section 1 and 2 showing influence changing flow levels have on inundation and flow depth. Levels are shown for a Summer/Autumn Low Flow (20 ML/Day), a Winter/Spring Low Flow (86 ML/Day), Fresh (162 ML/Day) and High flow (1000 ML/Day).

Summer/Autumn low flow

Summer/Autumn low flows are important in providing permanent habitat for fish, macroinvertebrates, Platypus and submerged aquatic vegetation as well as maintain water quality. A continuous low flow of 20 ML/Day is recommended in wet/average years and 10 ML/Day in dry years. A low flow of 10 ML/Day is considered the bare minimum to maintain water quality conditions.

Summer/Autumn fresh

Summer/Autumn freshes are important in providing greater depth of flow in all habitat areas that will allow fish and Platypus to move throughout the reach and maintain access to habitat. These higher flows will also flush silt and scour biofilms and algae from the stream bed and water fringing vegetation. Freshes are also required to trigger downstream spawning migration of Short-finned Eel (January/February) and Grayling (April/May). The recommended frequency and timing of freshes vary for wet/average and dry years:

- We recommend two freshes of 60 ML/Day in January/February and April/May in wet/average years, with each event having a duration of 5 days. An additional smaller fresh of 30 ML/day with a duration of 3 days is recommended in February/March to water fringing vegetation.
- We recommend one fresh of 60 ML/Day every two to three years in dry years with a duration of 5 days in April/May to trigger downstream spawning migration of Grayling. Over dry periods Short-finned Eels should survive. Trigger based freshes of 30 ML/Day are also recommended to freshen water quality when DO drops below 5 mg/L.

A higher priority is recommended in delivering the April/May fresh to trigger downstream spawning migration of Grayling over the January/February fresh which triggers the downstream spawning migration of Short-finned Eel.

Winter/Spring low

A two staged approach has been followed in setting Winter/Spring flow recommendations, based on what is considered aspirational if a greater volume of water was available from that which is considered a minimum flow requirement.

The Winter/Spring low flow should have a sufficient magnitude to allow fish movement through the reach, maintain a clear flow path and control intrusions by terrestrial vegetation. A higher continuous flow of 86 ML/Day from June to November would inundate the full extent of the channel bed. We recommend this as an aspirational low flow recommendation. A lower Winter/Spring low flow of 20 ML/Day in wet/average years and 10 ML/Day in dry years is considered the Minimum flow recommendation. These lower flows will still provide for fish movement through the reach, however, this will not be effective in controlling intrusions by terrestrial vegetation.

Winter/Spring fresh

Winter/Spring freshes assist in providing increase opportunities for movement of fish and Platypus throughout the reach and maintain access to habitat. Freshes are also required to trigger downstream spawning migration of adult Tupong (May to August) and upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (September to November). These freshes will also flush silt and scour biofilms and algae from the stream bed, transport organic matter and promote the growth and recruitment of native riparian vegetation. The recommended frequency and timing of freshes vary for wet/average and dry years:

- In wet/average years we recommend one fresh in May to August to trigger downstream spawning migration of adult Tupong and two freshes in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.
- In dry years we recommend one fresh in May to August to trigger downstream spawning migration of adult Tupong and one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.

In prioritising Winter/Spring freshes, in wet/average years first priority is given to delivery of one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling followed by a fresh in May to August to trigger downstream spawning migration of adult Tupong as a second priority. An additional fresh in September to November is given a third priority. In dry years, first priority is given to a September to November fresh with second priority to a fresh in May to August. It is recommended that the September to November freshes are linked with Barwon River high flows, during or just after to attract fish into the Moorabool River.

High flows

High flows help to maintain the channel form and dimensions as the velocity and shear stresses associated with these flows will scour the bed and banks of the channel, entraining sediments and deepening pools. These events may also engage billabongs in the lower reaches. We recommend a high flow of 1000 ML/Day every 2 years with a duration of 1-2 days in wet/average years. These events are not expected to occur in dry years.

Table 6.5: Updated environmental flow recommendations for FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road. Refer to Table B.4 in Appendix B for detailed account of ecological objectives for Reach 3b.

Waterway	Moorabool River: East Moorabool River to Sharps Road		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	20 ML/Day Minimum	December to May		NA
			Dry	10 ML/Day Minimum	December to May		NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, January/February (Short-finned Eel) and April/May (Grayling)	5 Days	2.0/1.7
				30 ML/Day Minimum	1 event in February/March to water fringing vegetation	3 Days	2.0/1.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/1.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	30 ML/Day Minimum	1 event as required	3 Days	2.0/1.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	All years	86 ML/Day Aspirational 20 ML/Day Minimum	June to November		
			Dry	86 ML/Day Aspirational 10 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event in May to August (Tupong) and 2 events in September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
			Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event in May to August (Tupong) and 1 event in September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
	High	Scour pools and maintain channel form and dimensions (G1). Maintain inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	1000 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus	1 to 2 Days	2.0/1.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day.

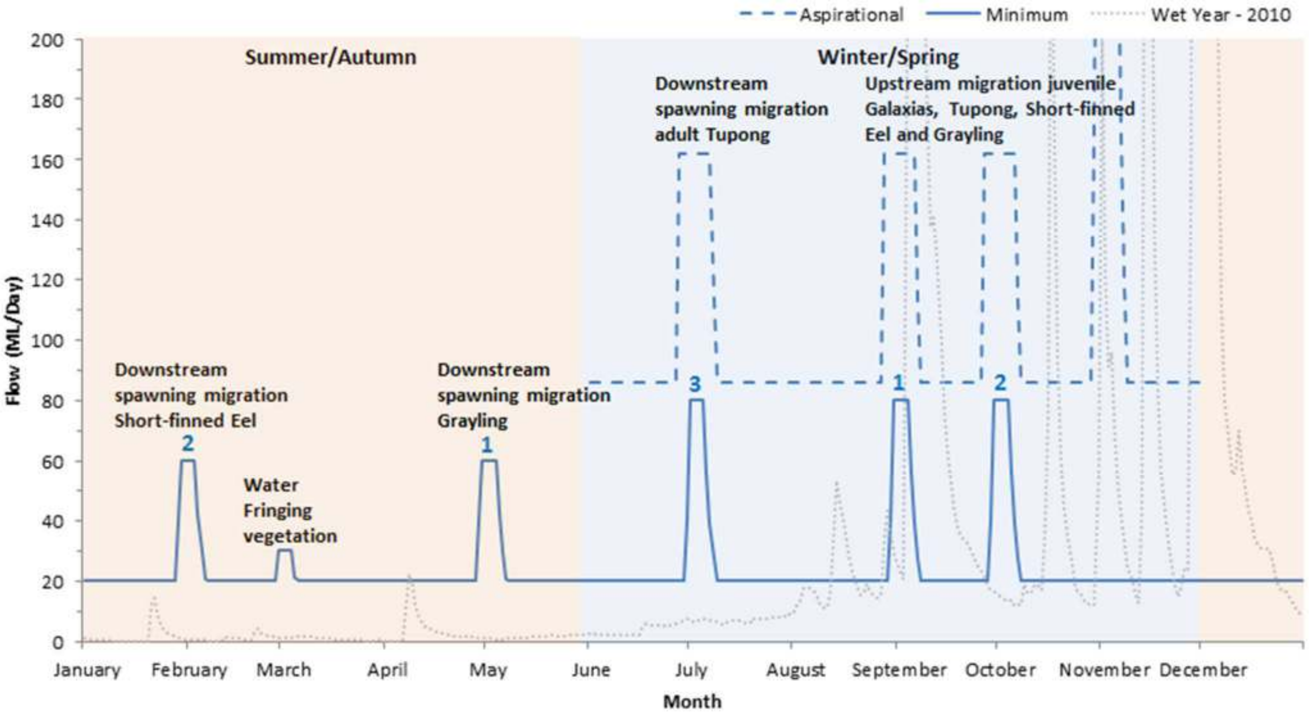


Figure 6.11: Plot showing Reach 3b updated environmental flow recommendations for a wet year and prioritisation of freshes. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions. Note the high flow recommendation of 1000 ML/Day extends beyond the range of the scale shown on this plot.

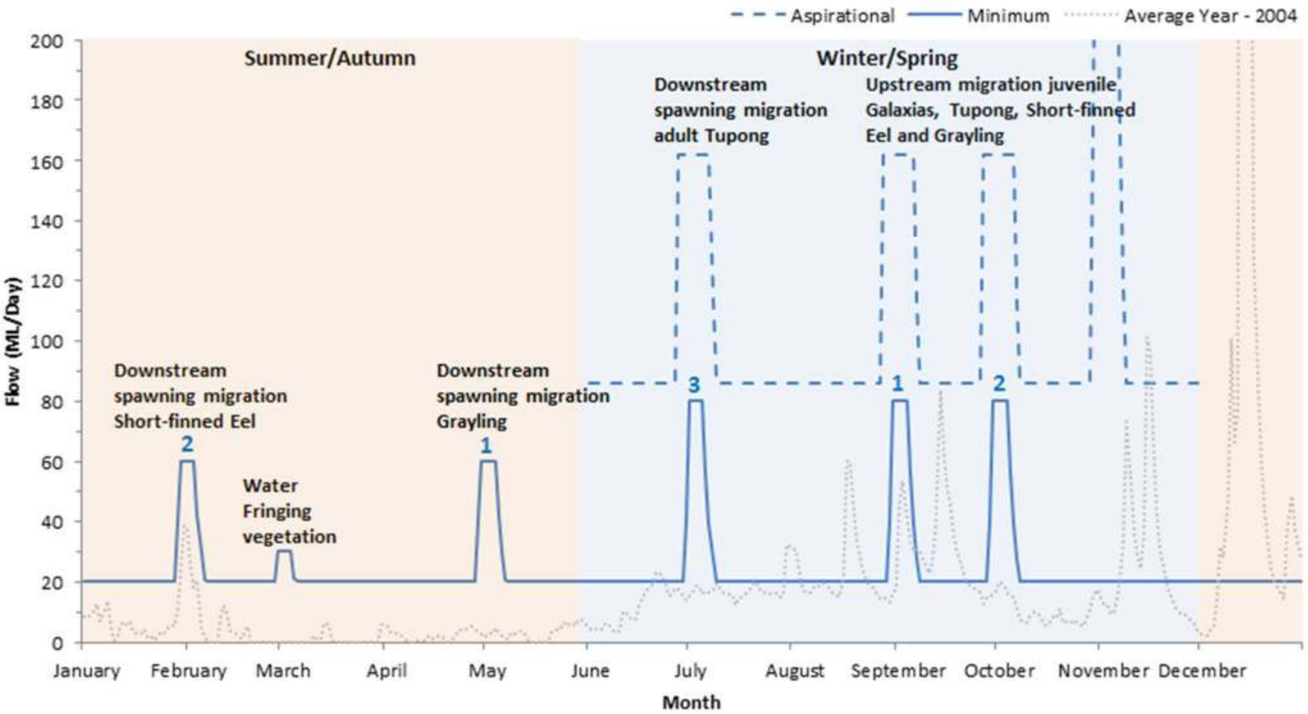


Figure 6.12: Plot showing Reach 3b updated environmental flow recommendations for an average year and prioritisation of freshes. The flow series for the year 2004 is shown as an example of a year experiencing average flow conditions. Note the high flow recommendation of 1000 ML/Day extends beyond the range of the scale shown on this plot.

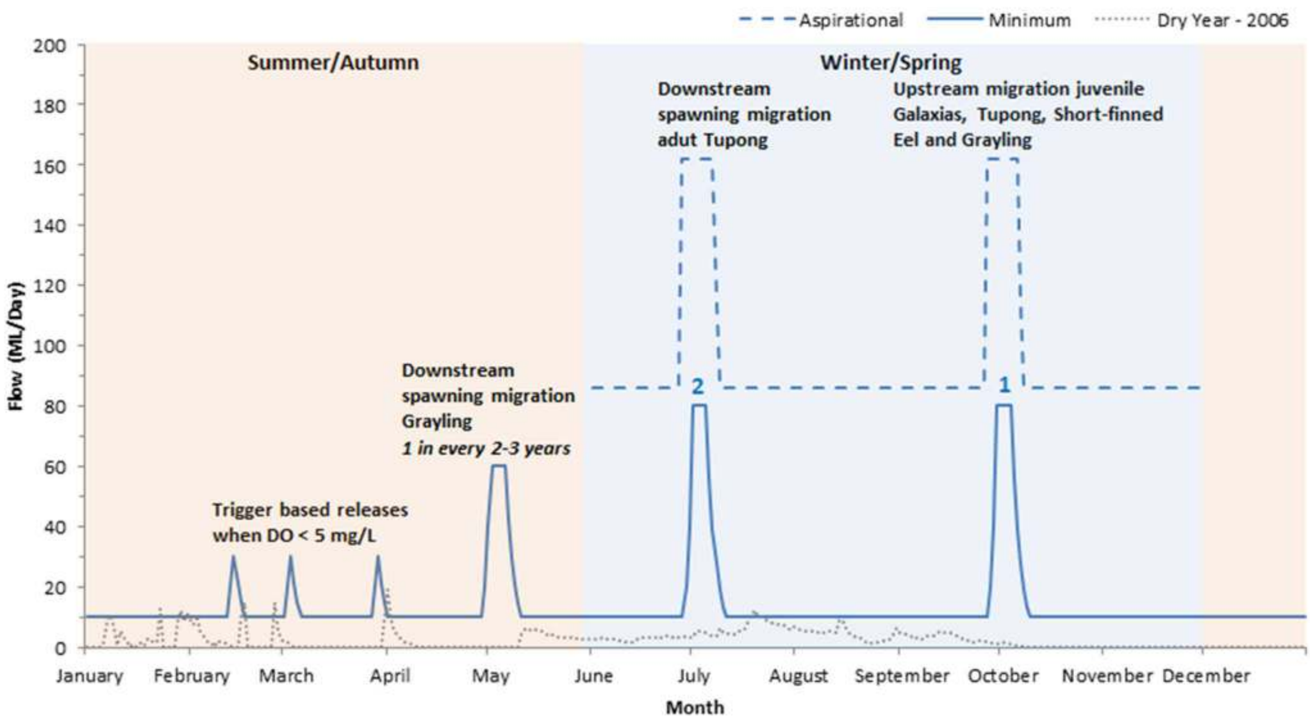


Figure 6.13: Plot showing Reach 3b updated environmental flow recommendations for a dry year and prioritisation of freshes. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

6.5 FLOWS Reach 4 - Moorabool River: Sharps Road to Barwon River

6.5.1 Ecological objectives

Based on information obtained from a review of the previous FLOWS study, monitoring reports, literature and the field inspection revised ecological objectives have been developed for Reach 4 (Refer to Table B.5 in Appendix B).

6.5.2 Environmental flow recommendations

The revised environmental flow recommendations for Reach 4 and specific objectives they aim to meet are summarised in Table 6.6. Figure 6.14 presents a selected cross-section of the channel to show the range of flows that are recommended and how they relate to depths of flow and inundation of channel features. A more detailed description of the flow recommendations is provided below. These flow recommendations are also presented in diagrammatic form, comparing the recommended flows against flows experienced in an example wet (Figure 6.15), average (Figure 6.16) and dry year (Figure 6.17).

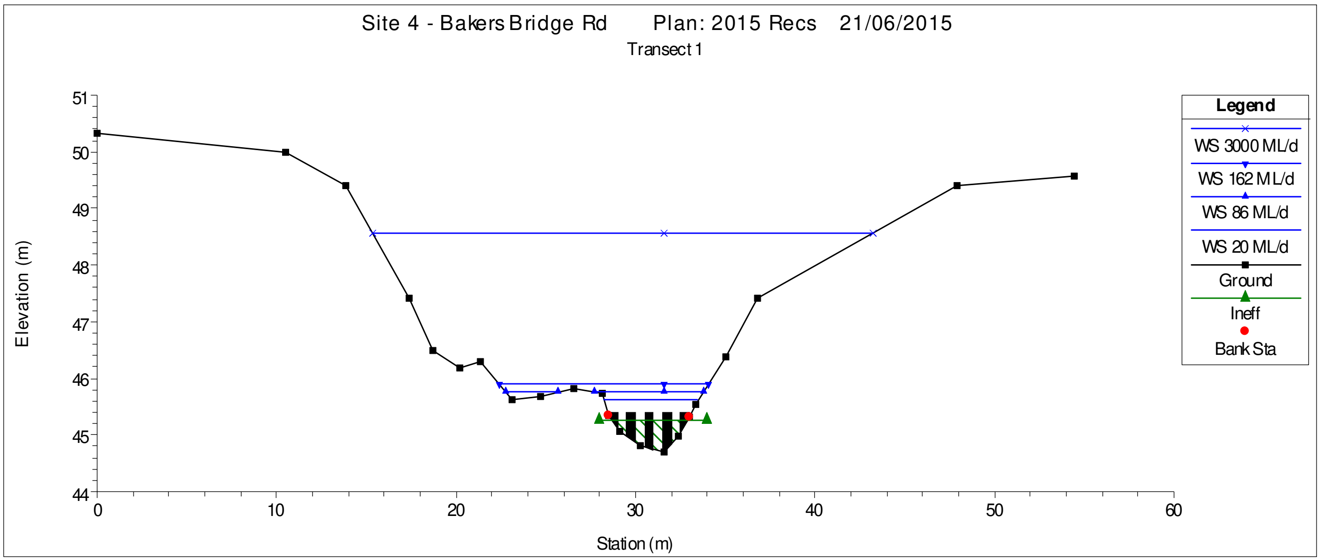


Figure 6.14: Cross-Section 1 showing influence changing flow levels has on inundation and flow depth. Levels are shown for a Summer/Autumn Low Flow (20 ML/Day), a Winter/Spring Low Flow (86 ML/Day), Fresh (162 ML/Day) and High flow (3000 ML/Day).

Summer/Autumn low flow

Summer/Autumn low flows are important in providing permanent habitat for fish, macroinvertebrates, Platypus and submerged aquatic vegetation as well as maintain water quality. A continuous low flow of 20 ML/Day is recommended in wet/average years and 10 ML/Day in dry years. 10 ML/Day is considered the bare minimum to maintain water quality conditions.

Summer/Autumn fresh

Summer/Autumn freshes are important in providing greater depth of flow in all habitat areas that will allow fish and Platypus to move throughout the reach and maintain access to habitat. These higher flows will also flush silt and scour biofilms and algae from the stream bed and water fringing vegetation. Freshes are also required to trigger downstream spawning migration of Short-finned Eel (January/February) and Grayling (April/May). The recommended frequency and timing of freshes vary for wet/average and dry years:

- We recommend two freshes of 60 ML/Day in January/February and April/May in wet/average years, with each event having a duration of 5 days. An additional smaller fresh of 30 ML/day with a duration of 3 days is recommended in February/March to water fringing vegetation.

- We recommend one fresh of 60 ML/Day every two to three years in dry years with a duration of 5 days in April/May to trigger downstream spawning migration of Grayling. Over dry periods Short-finned Eels will survive. Trigger based freshes of 20 ML/Day are also recommended to freshen water quality when DO drops below 5 mg/L.

A higher priority is recommended in delivering the April/May fresh to trigger downstream spawning migration of Grayling over the January/February fresh which triggers the downstream spawning migration of Short-finned Eel.

Winter/Spring low

A two staged approach has been followed in setting Winter/Spring flow recommendations, based on what is considered aspirational if a greater volume of water was available from that which is considered a minimum flow requirement.

The Winter/Spring low flow should have a sufficient magnitude to allow fish movement through the reach, maintain a clear flow path and control intrusions by terrestrial vegetation. A higher continuous flow of 86 ML/Day from June to November would inundate the full extent of the channel bed. We recommend this as an aspirational low flow recommendation. A lower Winter/Spring low flow of 20 ML/Day in wet/average years and 10 ML/Day in dry years is considered the minimum flow. These lower flows will still provide for fish movement through the reach, however, this will not be effective in controlling intrusions by terrestrial vegetation.

Winter/Spring fresh

Winter/Spring freshes assist in providing increased opportunities for movement of fish and Platypus throughout the reach and maintain access to habitat. Freshes are also required to trigger downstream spawning migration of adult Tupong (May to August) and upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (September to November). These freshes will also flush silt and scour biofilms and algae from the stream bed, transport organic matter and promote the growth and recruitment of native riparian vegetation. The recommended frequency and timing of freshes vary for wet/average and dry years:

- In wet/average years we recommend one fresh in May to August to trigger downstream spawning migration of Tupong and two freshes in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.
- In dry years we recommend one fresh in May to August to trigger downstream spawning migration of Tupong and one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong , Short-finned Eel and Grayling. The aspirational recommendation is that each event has a magnitude of 162 ML/Day with a duration of 10 days. The minimum flow recommendation is that each event has a magnitude of 80 ML/Day with a duration of 5 days.

In prioritising Winter/Spring freshes, in wet/average years first priority is given to delivery of one fresh in September to November to trigger upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling followed by a fresh in May to August to trigger downstream spawning migration of Tupong as a second priority. An additional fresh in September to November is given a third priority. In dry years, first priority is given to a September to November fresh with second priority to a fresh in May to August. It is recommended that the September to November freshes are linked with Barwon River high flows, during or just after to attract fish into the Moorabool River.

High flows

High flows help to maintain the channel form and dimensions as the velocity and shear stresses associated with these flows will scour the bed and banks of the channel, entraining sediments and deepening pools. These events may also engage billabongs in the lower reaches. We recommend a high flow of 3000 ML/Day every 2 years with a duration of 1-2 days in wet/average years. These events are not expected to occur in dry years.

Table 6.6: Updated environmental flow recommendations for FLOWS Reach 4 - Moorabool River: Sharps Road to Barwon River. Refer to Table B.5 in Appendix B for detailed account of ecological objectives for Reach 4.

Waterway	Moorabool River: Moorabool River: Sharps Road to Barwon River		Regime	Flow recommendations			
Season	**Flow**	**Objective**	**Wet/Average/Dry**	**Magnitude**	**Frequency and timing**	**Duration**	**Rise/Fall***
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet/Average	20 ML/Day Minimum	December to May		NA
			Dry	10 ML/Day Minimum	December to May		NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of Short-finned Eel and Grayling (F1).	Wet / Average	60 ML/Day Minimum	2 events, January/February (Short-finned Eel) and April/May (Grayling)	5 Days	2.0/1.7
				30 ML/Day Minimum	1 event, February/March to water fringing vegetation	3 Days	2.0/1.7
			Dry	60 ML/Day Minimum	1 event every 2 to 3 years, April/May (Grayling)	5 Days	2.0/1.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	20 ML/Day Minimum	1 event as required	2 Days	2.0/1.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet/Average	86 ML/Day Aspirational 20 ML/Day Minimum	June to November		
			Dry	86 ML/Day Aspirational 10 ML/Day Minimum			
	Fresh	Allow fish and Platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	162 ML/Day Aspirational 80 ML/Day Minimum	1 event in May to August (Tupong) and 2 events in September to November (Galaxias, Tupong Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
			Dry	162 ML/Day Aspirational 80 ML/Day Minimum	1 event in May to August (Tupong) and 1 event in September to November (Galaxias, Tupong, Short-finned Eel and Grayling)	10 Days Aspirational 5 Days Minimum	2.0/1.7
	High	Scour pools and maintain channel form and dimensions (G1). Flushing of sediment to improve spawning sites (F2). Inundate billabongs (G1, G2, V4).	Wet / Average	3000 ML/Day Minimum	1 event every 2 years, preferably in Winter to avoid risks to Platypus	1 to 2 Days	2.0/1.7
			Dry	Not expected			

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow. For example, an 80 ML/Day Winter/Spring Fresh has a recommended duration of 5 days at its peak. If flow started at 10 ML/Day it would take 3 days to ramp up flows to 80 ML/Day and then 6 days to fall down to 10 ML/Day.

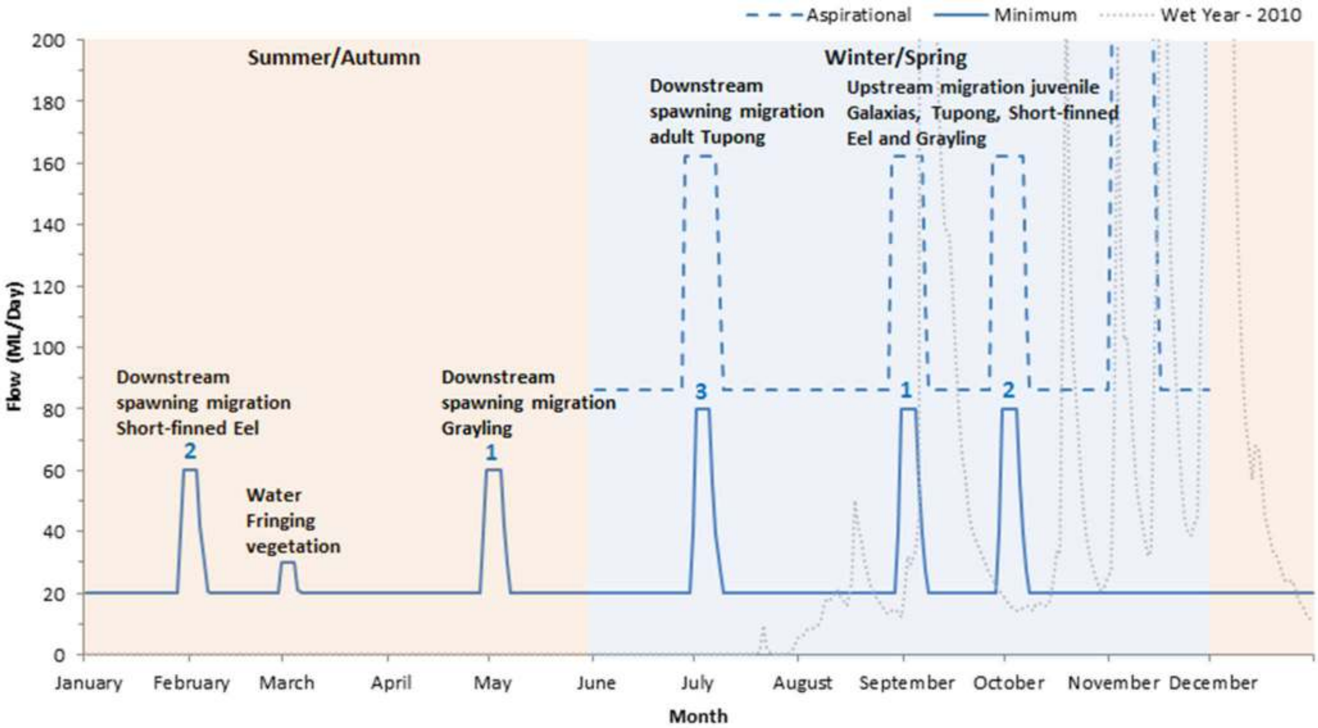


Figure 6.15: Plot showing Reach 4 updated environmental flow recommendations for a wet year and prioritisation of freshes. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions. Note the high flow recommendation of 3000 ML/Day extends beyond the range of the scale shown on this plot.

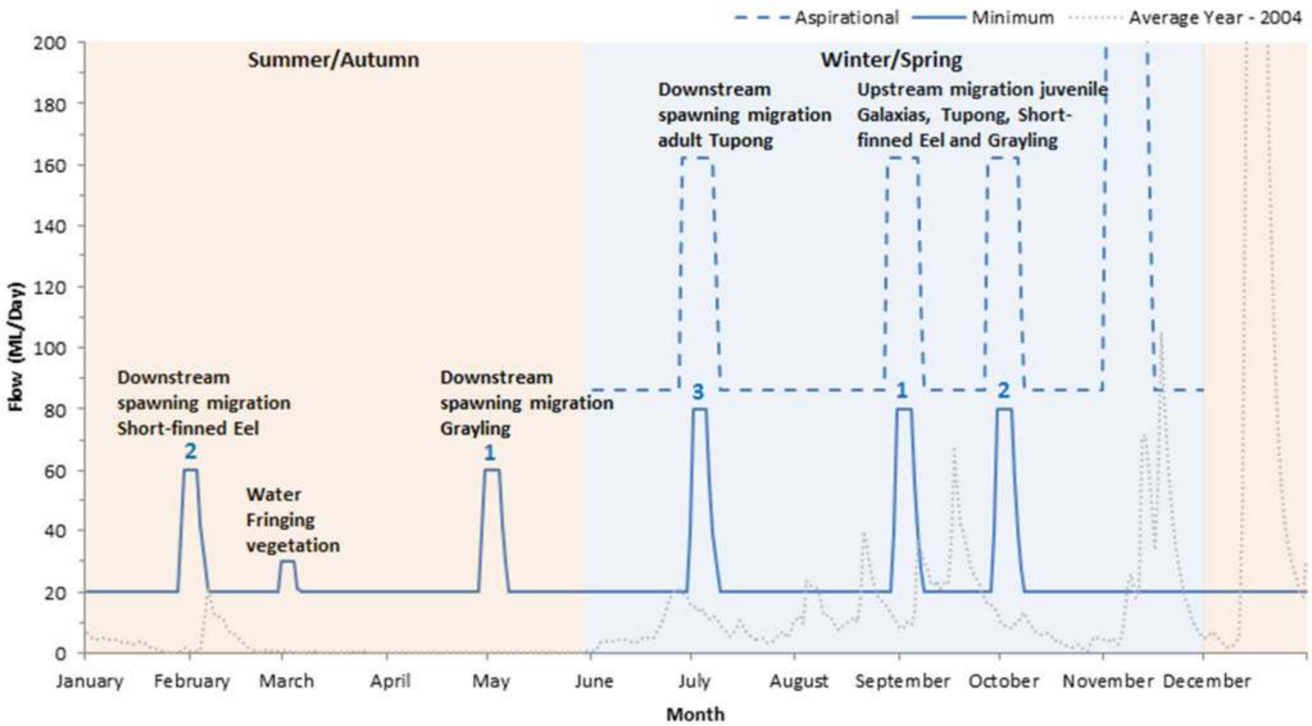


Figure 6.16: Plot showing Reach 4 updated environmental flow recommendations for an average year and prioritisation of freshes. The flow series for the year 2004 is shown as an example of a year experiencing average flow conditions. Note the high flow recommendation of 3000 ML/Day extends beyond the range of the scale shown on this plot.

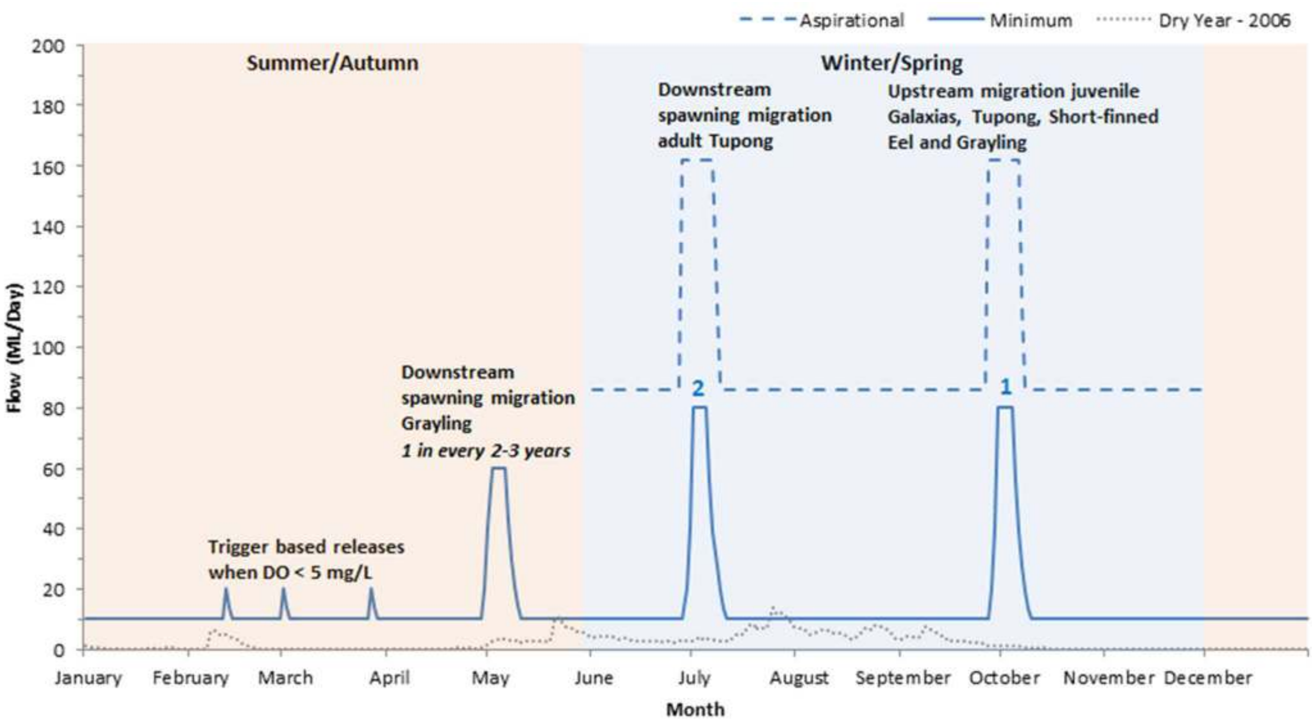


Figure 6.17: Plot showing Reach 4 updated environmental flow recommendations for a dry year and prioritisation of freshes. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

7. Prioritisation of flow components

Given the limitations on the amount of water that is available to deliver the recommended environmental flows, some further advice is provided in this section on what is considered a realistic and appropriate prioritisation of flow components. The volumes of water that have been recommended for high flows (500-3,000 ML/day) for FLOWS Reaches 3a, 3b and 4 cannot be realistically provided for within the existing Environmental Entitlement and the delivery constraints at Lal Lal Reservoir. These events will occur naturally in wet/average years and are not expected to occur in dry years.

Table 7.1 and Table 7.2 document the estimated volumes of water required to meet the minimum and aspirational low flow recommendations for these FLOWS Reaches. It is noted that the amount of water needed to meet the minimum low flow recommendations in these FLOWS Reaches would exceed the total amount of water that is available for environmental flows in an average year (2500 ML), with the exception of dry years (910 to 1820 ML). Furthermore, the volume of water needed to meet the aspirational low flow recommendations for Winter/Spring (10,920 to 15,652 ML) far exceeds the total amount of water available.

Table 7.1: Minimum low flow recommendations and estimated volumes of water for FLOWS Reach 3a, 3b and 4.

Season	Regime	FLOWS Reach 3a		FLOWS Reach 3b and 4	
(Months)	Wet/Average/Dry	Magnitude (ML/Day)	Volume (ML)	Magnitude (ML/Day)	Volume (ML)
Summer/ Autumn (Dec-May)	Wet/Average	10	1,820	20	3,640
	Dry	5	910	10	1,820
Winter/ Spring (Jun-Nov)	Wet/Average	10	1,820	20	3,640
	Dry	5	910	10	1,820

Table 7.2: Aspirational low flow recommendations and estimated volumes of water for FLOWS Reach 3a, 3b and 4.

Season	Regime	FLOWS Reach 3a		FLOWS Reach 3b and 4	
(Months)	Wet/Average/Dry	Magnitude (ML/Day)	Volume (ML)	Magnitude (ML/Day)	Volume (ML)
Winter/ Spring (Jun-Nov)	Wet/Average/Dry	60	10,920	86	15,652

Table 7.3 and Table 7.4 document the estimated volumes of water to meet the minimum and aspirational flow recommendations for freshes to facilitate fish migration/spawning in the Moorabool River. The prioritisation of freshes within each season is also documented. It is noted that the volume of water needed to deliver multiple freshes may exceed the total amount of water available in the Environmental Entitlement.

Table 7.3: Minimum flow recommendations for freshes and estimated volumes of water to facilitate fish migration/spawning in Moorabool River FLOWS Reaches 3a, 3b and 4. Prioritisation of freshes within each season is also shown.

					Volume (ML)	
Season	Timing	Fresh	Priority	Magnitude (ML/Day)	Reach 3a	Reach 3b and 4
Summer/ Autumn	January/February	Downstream spawning migration Short-finned Eel	2	60	485	470
	April/May	Downstream spawning migration Grayling	1	60	485	470
Winter/ Spring	May to August	Downstream spawning migration adult Tupong	3	80	650	600
	September to November	Upstream migration juvenile Galaxias, Tupong, Short-finned Eel and Grayling	1	80	650	600
	September to November	Upstream migration juvenile Galaxias, Tupong, Short-finned Eel and Grayling	2	80	650	600
				Total	2,920	2,740

Table 7.4: Aspirational flow recommendations for freshes and estimated volumes of water to facilitate fish migration/spawning in Moorabool River FLOWS Reaches 3a, 3b and 4. Prioritisation of freshes for the Winter/Spring season is also shown.

					Volume (ML)	
Season	Timing	Fresh	Priority	Magnitude (ML/Day)	Reach 3a	Reach 3b and 4
Winter/ Spring	May to August	Downstream spawning migration adult Tupong	3	162	2,050	1,900
	September to November	Upstream migration juvenile Galaxias, Tupong, Short-finned Eel and Grayling	1	162	2,050	1,900
	September to November	Upstream migration juvenile Galaxias, Tupong, Short-finned Eel and Grayling	2	162	2,050	1,900
				Total	6,150	5,700

For fish migration/spawning freshes to be effective, it is critical that there is connectivity in delivery of flows between FLOWS Reaches 3a, 3b and 4. To be stated more simply, the magnitude of the fresh as an event needs to be protected along the length of the Moorabool River. Additional work will also be needed to modify existing weir structures to maximise opportunities for movement of fish along the Moorabool River.

We understand that Corangamite CMA's current flow release strategy with managing low flows is to aim for an average flow rate over an extended period, as opposed to maintaining a constant flow, with the delivery of trigger based freshes as required to maintain water quality conditions. This is an appropriate flow release strategy given the limitations in the amount of water available in the Environmental Entitlement and it is recommended that this strategy is continued.

The following recommendations are made regarding the prioritisation of flow components. The first priority is to provide base flows that are aimed at achieving an average flow rate commensurate with the seasonal minimum low flow recommendation, with trigger based freshes as required to maintain water quality conditions. Second priority is then the Summer/Autumn freshes followed by the Winter/Spring freshes as third priority.

This prioritisation of flow components is informative for the management of the existing Environmental Entitlement. The prioritisation of flow components would remain the same should there be an increase in the volume of the Environmental Entitlement: the first priority would be to provide base flows, followed by Summer/Autumn freshes as second priority and Winter/Spring freshes as third priority.

8. Conclusions and management recommendations

8.1 Environmental flow recommendations

This report documents an updated assessment of the environmental flow requirements of the Moorabool River system. The report provides updated ecological objectives and flow recommendations for five FLOWS Reaches, with the section previously referred to as FLOWS Reach 3 now broken into two sections:

- FLOWS Reach 3a - Moorabool River: Lal Lal Reservoir to confluence with East Branch; and
- FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road

In the time since the 2004 Moorabool River Environmental Flows Assessment, the Moorabool River Environmental Entitlement has been implemented, which can be used to deliver environmental flows to FLOWS Reaches 3a, 3b and 4. The 7086 ML Environmental Entitlement is subject to delivery rules (a maximum of 7500 ML over three years) with an average of 2500 ML per year available to be used to deliver environmental flows.

Table 8.1 provides a summary of the estimated volumes of water that are required to meet the minimum and aspirational flow recommendations set for FLOW Reaches 3a, 3b and 4 in wet/average and dry climate years. These totals include all of the recommended flow components (low flows, freshes and high flows). It is clear in reviewing these totals that the current Environmental Entitlement does not provide sufficient volume of water to meet the environmental needs.

The 7086 ML Environmental Entitlement falls far short of the volume of water required to achieve the aspirational flow recommendations (14,600 to 36,000 ML). Even the minimum flow recommendations, which range from 3,300 to 9,000 ML, cannot be realistically achieved with the existing allocation of water provided in the Environmental Entitlement.

It is our recommendation that the volume of the Environmental Entitlement is increased. A volume of 15,000 ML over three years, with an average of 5,000 ML in each year would go a long way towards meeting the minimum flow recommendations documented in this FLOWS update. This roughly equates to the volume of water required to meet the minimum flow recommendations in a dry year. In order to achieve the aspirational flow recommendations, this would require a more significant increase in the volume of the Environmental Entitlement, upwards of 20,000 to 30,000 ML over three years.

Table 8.1: Estimated annual volume of water (ML) required to meet minimum and aspirational flow recommendations in FLOW Reaches 3a, 3b and 4.

FLOWS	Wet/Average		Dry	
Reach	Minimum	Aspirational	Minimum	Aspirational
3a	6,150	18,970	3,380	14,620
3b	9,000	25,700	5,140	19,630
4	9,000	36,050	5,140	19,630

8.2 Future environmental investigations

Assessment of fish barriers

Further understanding is required on the condition of natural and artificial barriers along the Moorabool River, the extent to which they pose a barrier to fish migration and what additional works are required to improve fish passage. Clearly, She Oaks Weir is the largest barrier impacting on fish movement and major works would be needed to provide fish passage. There are also a number of smaller barriers downstream (SKM 2004a). The Corangamite CMA in their Waterway Management Strategy (Corangamite CMA 2014) have committed to undertake an assessment of fish barriers in the Barwon and Moorabool catchments.

Identification of refuges

To assist Platypus survival in future severe drought periods, it is recommended that substantial pools that are likely to serve as important refuges for Platypus during natural cease-to-flow events should be identified, mapped and managed appropriately (e.g. by fencing out livestock). It is possible that the best (or only) reasonably drought-proof pool in some parts of Reach 4 may be associated with an on-stream weir. If so, consideration should be given to installing a mechanism to facilitate fish passage around or over the weir, as opposed to removing the weir entirely.

Investigate issues associated with Batesford Quarry

Seepage and losses of stream flow into Batesford Quarry is an ongoing issue, which has the potential to impact on the connectivity of flows and fish passage. Options to address this seepage losses should be further investigated (discharge at upstream site). Degradation of concrete channel lining works has also led to the creation of potential barriers for fish and Platypus movement.

The spurs found on the ankles of male Platypus (used to establish dominance when competing for territories and mates) are likely to be abraded in a very untimely manner if animals have to travel repeatedly along a concrete-lined channel. Further investigations are required to assess the condition of the river in this section, the nature of instability issues and options to improve the stability of the channel and habitat areas for aquatic organisms.

Investigate sand slugs

Further investigations are recommended into the extent of sand slugs in the Moorabool Catchment and the potential threats that these pose to instream habitat. Sand slugs tend to dramatically simplify channel morphology, replacing complex structure and substrate with flat sheets of sand and gravel. The ecologically obvious result is that pools are filled in, and habitat is lost (Rutherfurd et al. 2000).

8.3 Monitoring recommendations

This FLOWS study has made use of the most up to date information that was available at the time of the assessment, but information gaps remain. It is important that as our understanding of biological responses to flow improves (e.g. through monitoring and scientific research) the flow recommendations are revised and updated accordingly.

Water quality monitoring

It is recommended that addional water quality monitoring stations are installed in the lower sections of Reach 1 to confirm that recommended flow rates at the FLOWS assessment site do meet the minimum flow depths and acceptable water quality conditions further downstream.

Groundwater and Surface Water Interactions

Further investigation and monitoring is recommended of groundwater and surface water interactions in FLOWS Reach 1 to confirm the contribution of groundwater to low flow and freshes. This may require the installation of additional bore holes adjacent to the river to provide a greater understanding of the influence of fluctuations in groundwater levels on surface water.

Fish movement and habitat studies

Fish movement studies are required to develop a greater understanding of fish movement along the Moorabool River. This is needed to confirm that fish are moving past barriers and to provide a greater understanding of the specific magnitude and timing of flows required to facilitate movement for different fish species. While flow freshes have been recommended to trigger upstream migration of juvenile diadromous fish, our understanding of the influence of flow on the upstream migration of these diadromous fishes is limited at present. Further information is also required on where along the Moorabool River the fish are moving to and what habitat they are using.

Platypus monitoring

It is recommended that a database should be established to consistently record Platypus and Rakali sightings by landholders or management agency staff, as this is the most cost-effective method to identify where these species occur.

8.4 Management actions

Environmental flows are one of a range of management strategies that need to be considered when managing the environmental flows of a catchment. It is rare that all of the environmental issues and threats within a catchment can be resolved by only providing an appropriate flow regime. In most catchments, other management actions need to be implemented in combination with flow management to meet the stated environmental flow objectives.

Land use, particularly clearing and uncontrolled stock access is contributing to degradation of riparian vegetation. The Corangamite CMA in their Waterway Management Strategy (Corangamite CMA 2014) have identified a number of management activities that are focused on protecting the stream-side zone along the Moorabool River. These include installation of riparian fencing, establishment of native indigenous vegetation, weed control and the establishment of stewardship/management agreements.

Acronyms

APC	Australian Platypus Conservancy
ARI	Arthur Rylah Institute for Environmental Research
AUSRIVAS	Australian River Assessment System
CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
EC	Electrical Conductivity
EPA	Environmental Protection Authority
EFTP	Environmental Flow Technical Panel
EVC	Ecological Vegetation Class
ISC	Index of Stream Condition
EWMP	Environmental Water Management Plan
MSAC	Moorabool Stakeholder Advisory Committee
PCG	Project Control Group
SEPP	State Environment Protection Policy
SIGNAL	Stream Invertebrate Grade Number – Average Level
SKM	Sinclair Knight Merz
VEWH	Victorian Environmental Water Holder

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Appendix A. Vegetation identified at FLOWS Assessment Sites

Table A.1: Vegetation identified at FLOWS Assessment Sites.

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
FLOWS Reach 1, Moorabool River East Branch: Bostock Reservoir to West Moorabool River				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Ranunculus amphitrichus	Small River Buttercup	x	
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton (Abundant)			
Marginal	**Rorippa nasturtium-aquatica*	Water Cress		
	Apium prostratum	Sea Celery	x	
	Carex appressa	Tall Sedge		
	Carex fascicularis	Tassel Sedge		
	Crassula helmsii	Swamp Crassula		
	Eleocharis acuta	Common Spike-sedge		
	Glyceria australis	Austral Sweet Grass		
	Isolepis cernua	Nodding Club-sedge	x	
	Schoenoplectus tabernaemontani	River Club-sedge		
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Hemlock		
	**Nasella trichotoma*	Serrated Tussock		
	**Phalaris aquatica*	Toowoomba Canary-grass		
	**Rubus anglocandicans*	Blackberry		
	Acacia dealbata	Silver Wattle		
	Acacia mearnsii	Black Wattle		
	Acacia melanoxylon	Blackwood		
	Acaena novae-zeelandiae	Bidgee Widgee		
	Callistemon sieberi	River Bottlebrush		
	Geranium sp. 2	Variable Crane's-bill		
	Hemarthria uncinata	Mat Grass		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Leptospermum lanigerum	Woolly Tea-tree		
	Poa labillardierei	Common Tussock-grass		
	Pteridium esculentum	Bracken		
	Rumex brownii	Slender Dock		
	Senecio minimus	Shrubby Fireweed		
	Total salt or groundwater indicator species		3	
Reach 3a, Moorabool River: Lal Lal Reservoir to confluence with East Branch				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton (Abundant)			
Marginal	*Carex appressa*	Tall Sedge		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Carex fascicularis	Tassel Sedge		
	Carex gaudichaudii	Fen Sedge		
	Crassula helmsii	Swamp Crassula		
	Glyceria australis	Austral Sweet Grass		
	Isolepis inunudata	Swamp Club-sedge		
	Persicaria decipiens	Slender Knotweed		
	Phragmites australis	Common Reed		
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Tall Sedge		
	**Rosa rubiginosa*	Tassel Sedge		
	**Rubus anglocandicans*	Fen Sedge		
	Acacia dealbata	Swamp Crassula		
	Acacia melanoxylon	Austral Sweet Grass		
	Acaena novae-zeelandiae	Swamp Club-sedge		
	Bursaria spinosa subsp. spinosa	Slender Knotweed		
	Eucalyptus viminalis	Common Reed		
	Gynatrix pulchella s.s.	Narrow-leaf Cumbungi		
	Hymenanthera dentata var. dentata			
	Juncus pauciflorus			
	Leptospermum lanigerum	Hemlock		
	Poa labillardierei	Sweet Briar		
	Pomaderris aspera	Blackberry		
	Pteridium esculentum	Silver Wattle		
	Senecio minimus	Blackwood		
	Total salt or groundwater indicator species		0	
Reach 3b, Moorabool River: Confluence with East Branch to Sharps Road				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Triglochin procerum (broad erect leaves)	Common Water-ribbons		
	Periphyton- abundant			
Marginal	**Juncus acutus*	Spiny Rush		
	**Juncus articulatus*	Jointed Rush		
	**Salix fragilis*	Crack Willow		
	Carex appressa	Tall Sedge		
	Carex gaudichaudii	Fen Sedge		
	Crassula helmsii	Swamp Crassula		
	Glyceria australis	Austral Sweet Grass		
	Isolepis cernua	Nodding Club-sedge	x	
	Juncus caespiticius	Grassy Rush	x	
	Lobelia anceps	Angled Lobelia		
	Persicaria decipiens	Slender Knotweed		
	Phragmites australis	Common Reed		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Schoenoplectus tabernaemontani	River Club-sedge		
	Triglochin striatum	Streaked Arrow-grass	x	
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Hemlock		
	**Ulex europaeus*	Gorse		
	Acacia dealbata	Silver Wattle		
	Acacia mearnsii	Black Wattle		
	Acacia melanoxylon	Blackwood		
	Acaena novae-zeelandiae	Bidgee Widgee		
	Bursaria spinosa subsp. spinosa	Sweet Bursaria		
	Coprosma quadrifida	Prickly Currant-bush		
	Dichondra repens	Kidney Weed		
	Eucalyptus camaldulensis	River Red Gum		
	Eucalyptus leucoxylon	Yellow Gum		
	Eucalyptus viminalis	Manna Gum		
	Ficinia nodosa	Knobby Club-sedge	x	
	Gynatrix pulchella s.s.	Hemp Bush		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Leptospermum lanigerum	Woolly Tea-tree		
	Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Poa labillardierei	Common Tussock-grass		
	Senecio minimus	Shrubby Fireweed		
	Total salt or groundwater indicator species		**5**	
Reach 4, Moorabool River: Sharps Road to Barwon River				
Aquatic	*Azolla filiculoides*	Pacific Azolla		
	Chara sp	Stonewort		
	Landoltia punctata	Thin Duckweed		
	Lemna tricusularia	Ivy-leaf Duckweed		poorly known
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton- locally common in shallow areas			
Marginal	**Cyperus eragrostis*	Drain Flat-sedge		
	**Paspalum distichum*	Water Couch		
	**Polypogon monspeliensis*	Annual Beard-grass		
	Bolboschoenus caldwelii	Sea Club-sedge	x	
	Crassula helmsii	Swamp Crassula		
	Isolepis inunudata	Swamp Club-sedge		
	Lachnagrostis filiformis s.l.	Common Blown-grass		
	Lilaeopsis polyantha	Australian Lilaeopsis	x	
	Mimulus repens	Creeping Monkey-flower	x	
	Persicaria decipiens	Slender Knotweed		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Phragmites australis	Common Reed		
	Rumex bidens	Mud Dock		
	Schoenoplectus tabernaemontani	River Club-sedge		
	Triglochin striatum	Streaked Arrow-grass	x	
Damp	*Chenopodium glaucum*	Glaucous Goosefoot	x	
	Duma florulenta	Tangled Lignum		
	Eucalyptus camaldulensis	River Red Gum		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Poa labillardierei	Common Tussock-grass		
	Rorippa laciniata	Jagged Bitter-cress		
	Total salt or groundwater indicator species		**5**	

* Denotes introduced species

Appendix B. Revised ecological objectives

Table B.1: Revised ecological objectives for FLOWS Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River.

Ecological objective		Function	Required flow component	Timing	Expected response
F1	Rehabilitate migratory species (Short-finned Eel, Common Galaxias, Spotted Galaxias, Short-headed Lamprey, Australian Grayling)				
	- Maintain opportunities for occupancy of migratory species	Upstream migration	Freshes	Spring/Early Summer	Increased distribution, abundance and diversity of migratory fish species
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40 cm in pool and 20 cm in riffles)	Low Flows	All seasons	
			Freshes	All seasons	
F2	Maintain and expand non-migratory fish species (Mountain Galaxias, Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40 cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species
	- Flush sediments	Clean substrate areas	Freshes	All seasons	
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae
V1	Maintain aquatic zone species (Varied Water-milfoil, Small River Buttercup and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
		Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
V2	Maintain marginal zone species (Tall Sedge, Tassel Sedge, River Club-sedge and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
V3	Maintain damp zone species (Blackwood, River Bottlebrush, Woolly Tea-tree and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
V4	Maintain inset benches	Maintain diversity of vegetation	High flows	All seasons	
P1	Maintain Platypus population, particularly in refuge pools during dry years	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality.	Low flows	All seasons (Summer critical)	Should be capable of supporting populations of Platypus in refuge pools
			Freshes	All seasons	
G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
		Maintain channel and scour pools	High flows	Anytime	
G2	Maintain inset floodplains	Engage and maintain floodplain process	High flows	Anytime	Maintain floodplain features
W1	Prevent low dissolved oxygen conditions and	Connecting flow sufficient to maintain water	Low flow	All seasons	Continuously flowing water and occasional freshes will

Ecological objective		Function	Required flow component	Timing	Expected response
	elevated EC conditions during low flow periods	quality	Freshes	Summer	prevent the development of adverse water quality conditions.
W1	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events

Table B.2: Revised ecological objectives for FLOWS Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir.

Ecological objective		Function	Flow component	Timing	Expected response
F1	Maintain and expand non-migratory fish species (Mountain Galaxias, Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species
	- Flush sediments	Clean substrate areas	Freshes	All seasons	
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae
V1	Maintain aquatic zone species	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
		Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
V2	Maintain marginal zone species	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
V3	Maintain damp zone species	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
V4	Maintain inset benches	Maintain diversity of vegetation	High flows	All seasons	
P1	Maintain Platypus population, particularly in refuge pools during dry years	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality.	Low flows	All seasons (Summer critical)	Should be capable of supporting populations of Platypus in refuge pools
			Freshes	All seasons	
G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
		Maintain channel and scour pools	High flows	Anytime	
G2	Maintain inset floodplains	Engage and maintain floodplain process	High flows	Anytime	Maintain floodplain features
W1	Prevent low dissolved oxygen conditions and	Connecting flow sufficient to maintain water	Low flow	All seasons	Continuously flowing water and occasional freshes will

Ecological objective		Function	Flow component	Timing	Expected response
	elevated EC conditions during low flow periods	quality	Freshes	Summer	prevent the development of adverse water quality conditions.
W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events

Table B.3: Revised ecological objectives for FLOWS Reach 3a - Moorabool River West Branch: Lal Lal Reservoir to confluence with East Branch.

Ecological objective		Function	Required flow component	Timing	Expected response
F1	Rehabilitate migratory species (Short-finned Eel, Common Galaxias, Spotted Galaxias, Short-headed Lamprey, Australian Grayling)				
	- Provide opportunities for upstream migration of adult anadromous and juvenile catadromous and amphidromous fish	Upstream migration	Freshes	Spring/Early Summer	Increased distribution, abundance and diversity of migratory fish species
	- Trigger downstream spawning migration of adult catadromous and amphidromous fish	Downstream spawning migration	Freshes	April-May - Australian Grayling May-Aug - Tupong Summer - Short-finned Eel	
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	
			Freshes	All seasons	
F2	Maintain and expand non-migratory fish species (Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae
V1	Maintain aquatic zone species (Varied Water-milfoil and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
		Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	
V2	Maintain marginal zone species (Tall Sedge, Tassel Sedge, Fen Sedge, Common Reed and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
V3	Maintain damp zone species (Manna Gum, Hazel Pomaderris, Blackwood, Hemp Bush, Woolly Tea-tree and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
V4	Maintain inset floodplains	Maintain diversity of vegetation	High flows	All seasons	
P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus. Avoid flows higher than Winter

Ecological objective		Function	Required flow component	Timing	Expected response
		water quality.	Freshes	All seasons	flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth to support dispersal.	Low flows	All seasons (April-June critical)	
G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
		Maintain channel and scour pools	High flows	Anytime	
G2	Maintain inset floodplains	Engage and maintain floodplain process	High flows	Anytime	Maintain floodplain features
W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
			Freshes	Summer	
W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events

Table B.4: Updated ecological objectives for FLOWS Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road.

Ecological objective		Function	Required flow component	Timing	Expected response
F1	Rehabilitate migratory species (Short-finned Eel, Common Galaxias, Spotted Galaxias, Short-headed Lamprey, Australian Grayling)				
	- Provide opportunities for upstream migration of adult anadromous and juvenile catadromous and amphidromous fish	Upstream migration	Freshes	Spring/Early Summer	Increased distribution, abundance and diversity of migratory fish species
	- Trigger downstream spawning migration of adult catadromous and amphidromous fish	Downstream spawning migration	Freshes	April-May - Australian Grayling May-Aug - Tupong Summer - Short-finned Eel	
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	
			Freshes	All seasons	
F2	Maintain and expand non-migratory fish species (Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae
V1	Maintain aquatic zone species (Varied Water-milfoil and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
		Limit terrestrial encroachment, scour periphyton and flush Elodea	Freshes	All seasons	

Ecological objective		Function	Required flow component	Timing	Expected response
V2	Maintain marginal zone species (Tall Sedge, Fen Sedge, Streaked Arrow-grass, River Club-rush, Common Reed and Narrow-leaf Cumbungi)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
V3	Maintain damp zone species (River Red Gum, Manna Gum, Blackwood, Hemp Bush, Woolly Tea-tree, Prickly Currant-bush, Knobby Club-sedge and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
V4	Maintain inset floodplains	Maintain diversity of vegetation	High flows	All seasons	
P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality.	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus. Avoid flows higher than Winter flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
			Freshes	All seasons	
P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth for dispersal.	Low flows	All seasons (April-June critical)	
G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
		Maintain channel and scour pools	High flows	Anytime	
G2	Maintain inset floodplains	Engage and maintain floodplain process	High flows	Anytime	Maintain floodplain features
W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
			Freshes	Summer	
W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events

Table B.5: Updated ecological objectives for FLOWS Reach 4 - Moorabool River: Sharps Road to Barwon River.

Ecological objective		Function	Flow component	Timing	Expected response
F1	Rehabilitate migratory species (Short-finned Eel, Common Galaxias, Spotted Galaxias, Short-headed Lamprey, Australian Grayling)				
	- Provide opportunities for upstream migration of adult anadromous and juvenile catadromous and amphidromous fish	Upstream migration	Freshes	Spring/Early Summer	Increased distribution, abundance and diversity of migratory fish species
	- Trigger downstream spawning migration of adult catadromous and amphidromous fish	Downstream spawning migration	Freshes	April-May - Australian Grayling May-Aug - Tupong Summer - Short-finned Eel	
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20cm in riffles)	Low Flows	All seasons	
			Freshes	All seasons	
F2	Maintain and expand non-migratory fish species (Flat-headed Gudgeon, Australian Smelt, Southern Pygmy Perch, River Blackfish)				

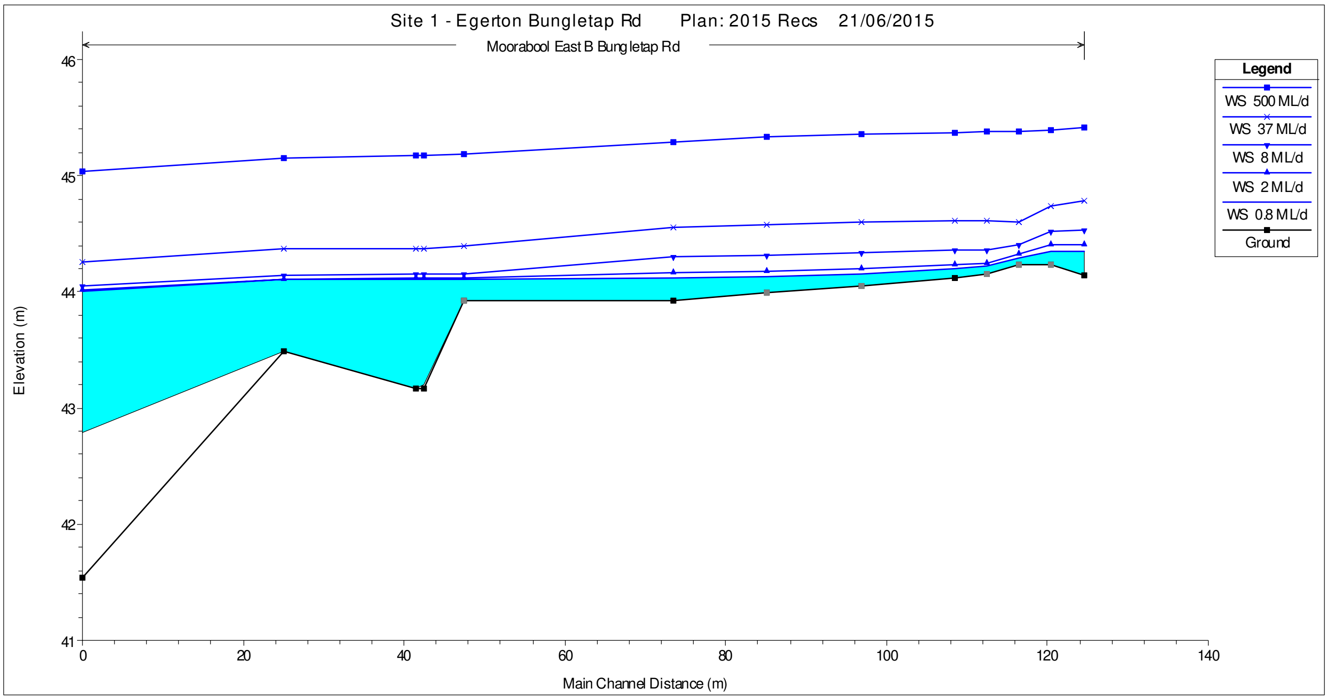
Ecological objective		Function	Flow component	Timing	Expected response
	- Maintain access to habitat (pools, riffles, LWD)	Provide minimum flow depths for movement and dispersal (40cm in pool and 20 cm in riffles)	Low Flows	All seasons	Increased distribution, abundance and diversity of non-migratory fish species
			Freshes	All seasons	
	- Flushing of sediment to improve availability of spawning sites	Spawning	High flow	Spring	
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Low flow	All seasons	Maintain abundance and biomass of macroinvertebrates
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Freshes	All seasons	Maintain a diverse mix of cleared areas and areas with benthic algae
V1	Maintain aquatic zone species (Stonewort, Ivy-leaf Duckweed and Common Water-ribbons)	Provide sufficient depth of water to maintain instream vegetation	Low flow	All seasons	Maintain diversity of instream vegetation
		Limit terrestrial encroachment and flush Azolla	Freshes	All seasons	
V2	Maintain marginal zone species (Creeping Monkey-flower, Sea Club-rush, Streaked Arrow-grass, River Club-rush, Common Reed and Mud Dock)	Provide flow variability to maintain species diversity of fringing vegetation	Freshes/High flow	All seasons	Maintain and promote growth of fringing vegetation
V3	Maintain damp zone species (River Red Gum, Tangled Lignum, Broad-leaf Tree-violet, Jagged Bitter-cress and Common Tussock-grass)	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Freshes/High flows	All seasons	Maintain riparian zones plus successful recruitment of juveniles into the population.
V4	Maintain floodplain wetlands	Maintain diversity of vegetation	High flows	All seasons	
P1	Restore self-sustaining breeding population of Platypus	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality.	Low flows	All seasons (Summer critical)	Should be capable of supporting self-sustaining breeding population of Platypus. Avoid flows higher than Winter flow in Spring and Summer (September to February) to minimise risk of inundating nests/drowning juveniles. Keep rise in flow < 1m.
			Freshes	All seasons	
P2	Support dispersal of juvenile Platypus to/from the Barwon River	Provide sufficient flow depth for dispersal.	Low flows	All seasons (April-June critical)	
P3	Support movement of adult males to/from the Barwon River	Provide sufficient flow depth for movement.	Low flows	All seasons (July-October critical)	
G1	Maintain channel form and processes	Engage benches	Freshes/High flows	Anytime	Maintain channel complexity, pools and benches
		Maintain channel and scour pools	High flows	Anytime	
G2	Maintain inset floodplains	Engage and maintain floodplain process	High flows	Anytime	Maintain floodplain features
W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Low flow	All seasons	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.
			Freshes	Summer	
W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over Winter and Summer periods	Freshes	Winter	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events

Appendix C. Hydraulic Modelling Report

The models adopted for the 2015 FLOWS update were developed during the original 2004 FLOWS project. During the project, these models were assessed and compared to the conditions of the river. It was observed that the river channels had not changed between 2004 and 2015 and therefore the 2004 models were adopted. The roughness coefficient was updated where required (only for Reach 4) and the downstream boundary condition was reviewed, and deemed acceptable for all models. No additional calibration data was collected and therefore the models were not re-calibrated or verified to surveyed water level data during this project.

C.1 Site 1: Egerton Bungletap Road (FLOWS Reach 1)

The long section is presented below.



The table below represents the cross sections with the model and shows the Mannings adopted for each section.

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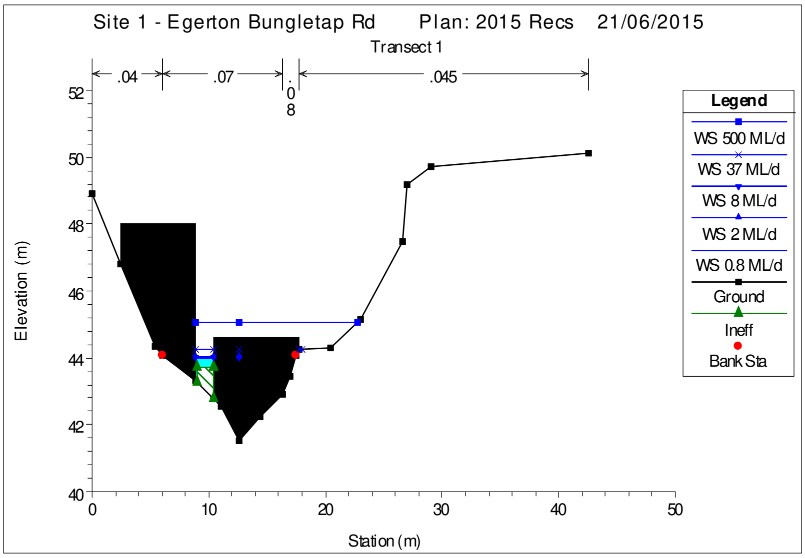
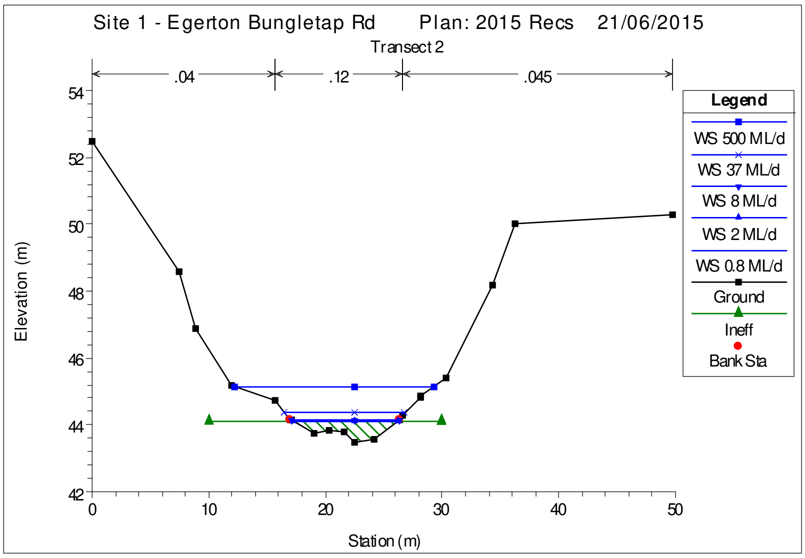
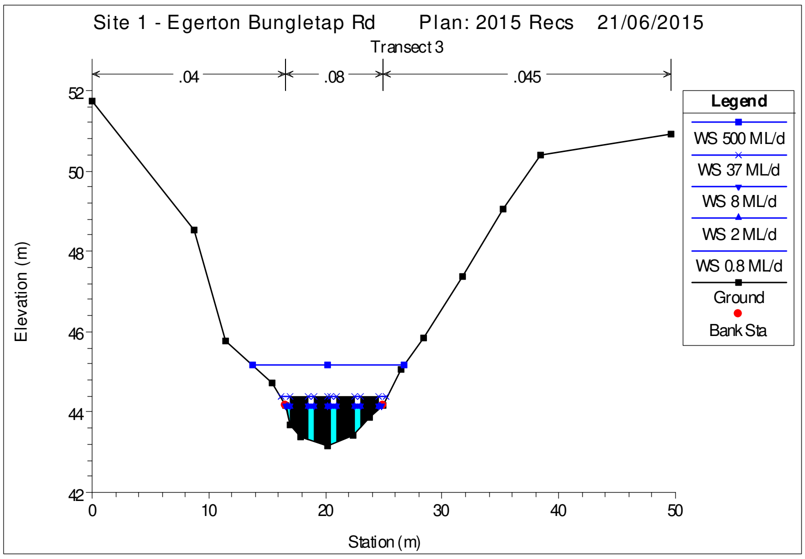
<tr><td>1 (most downstream)</td><td>
</td></tr>
<tr><td>2</td><td>
</td></tr>
<tr><td>3</td><td>
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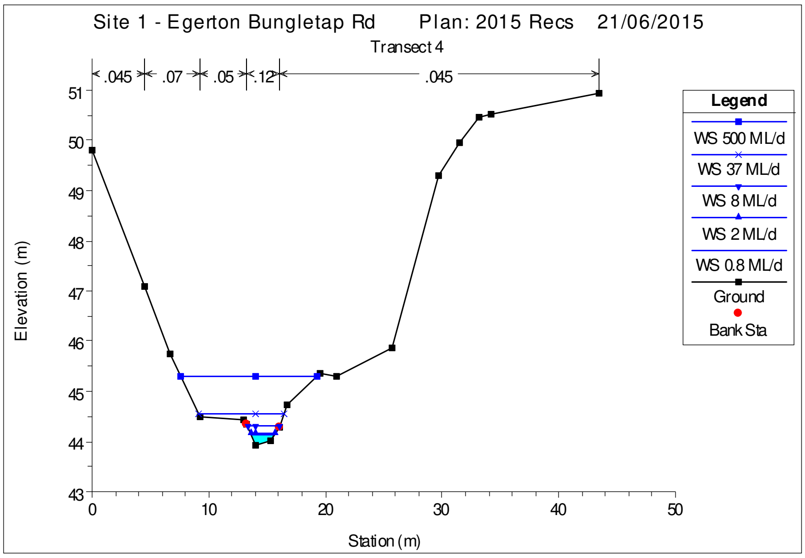
<table>
<tr><th>Cross section number</th><th></th></tr>
<tr><td>4</td><td>
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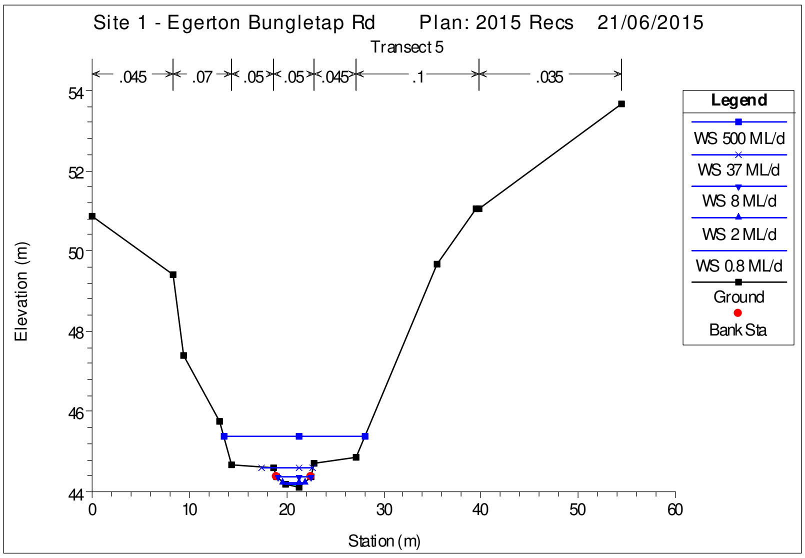
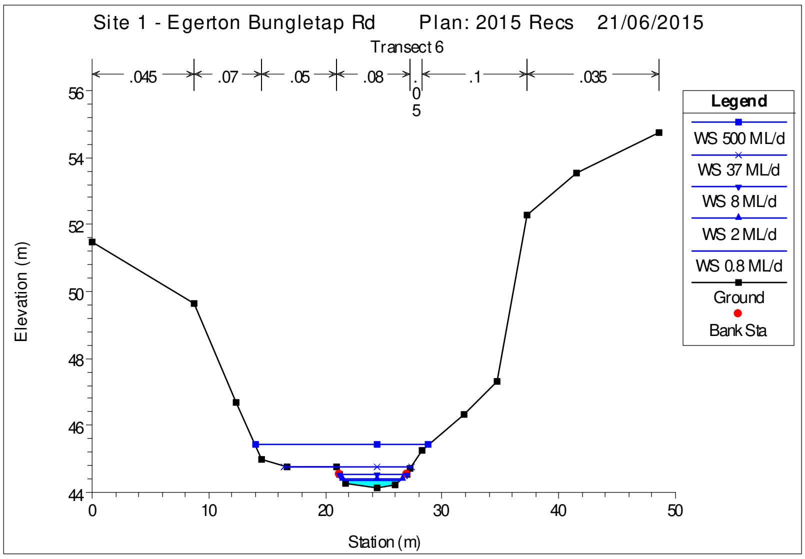
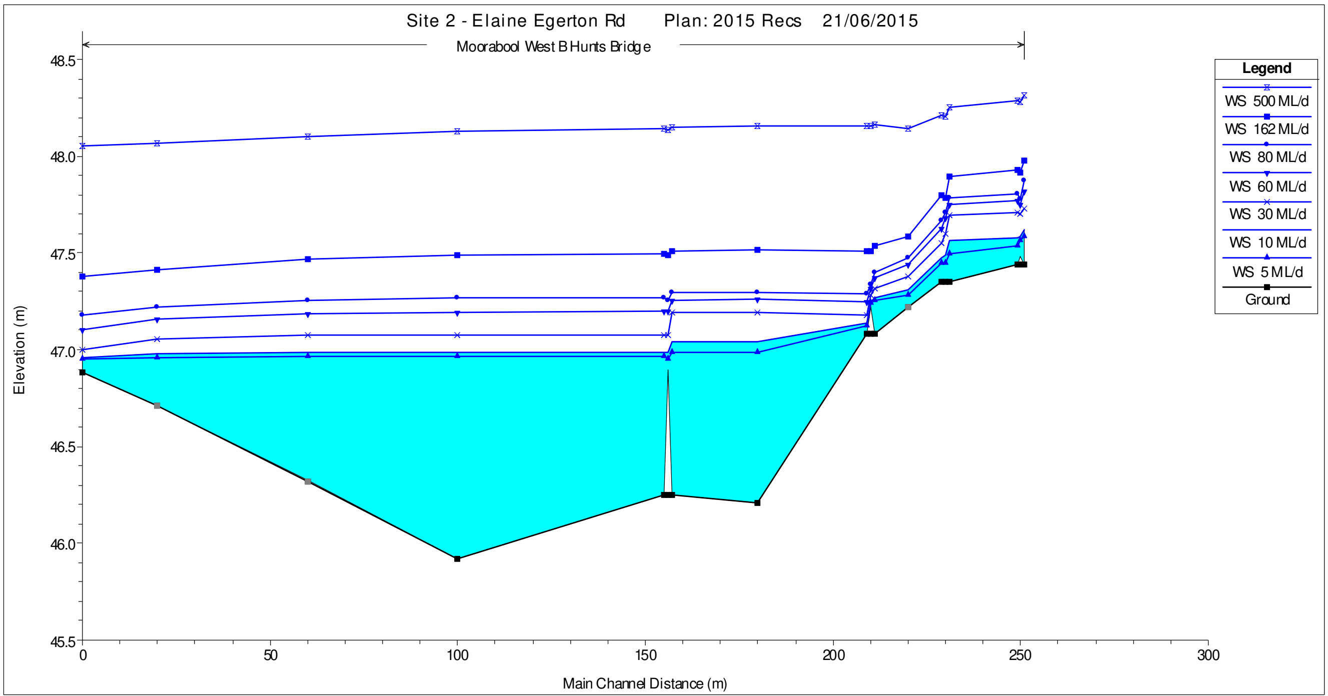
<tr><td>5</td><td>
</td></tr>
<tr><td>6 (most upstream)</td><td>
</td></tr>
</table>

The downstream boundary condition adopted was a rating curve.

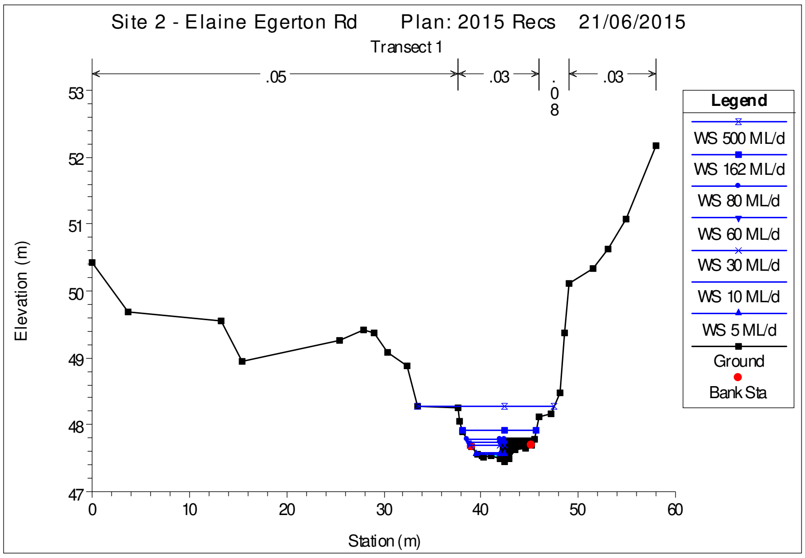
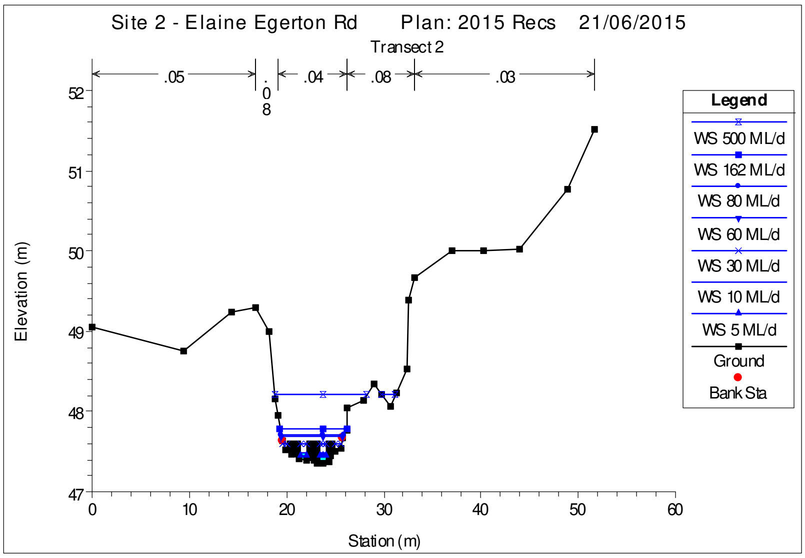
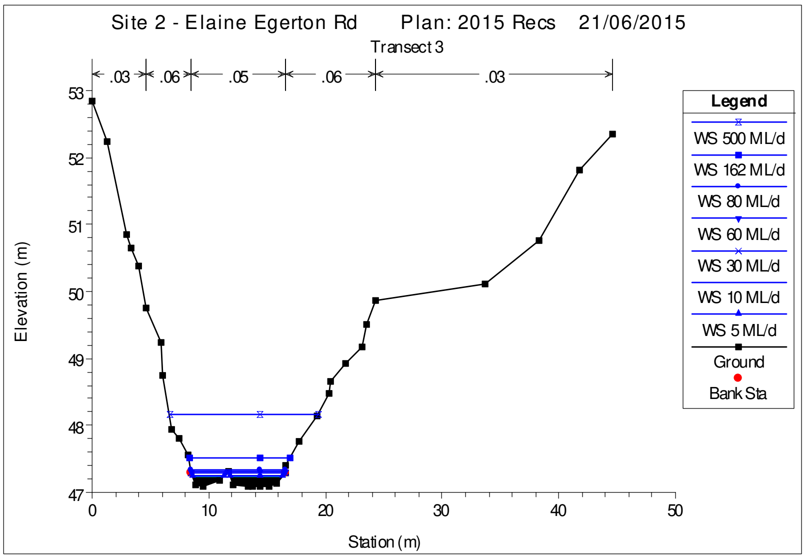
Stage (m)	Flow (m^3/s)
44	0
44.075	0.15
44.3	0.5
45	5
45.8	20
48.5	100

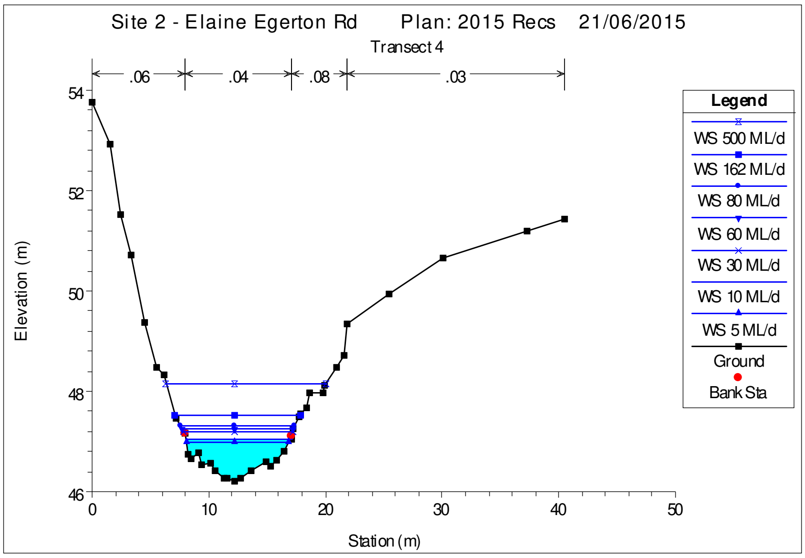
C.2 Site 2: Elaine Egerton Road (FLOWS Reach 3a)

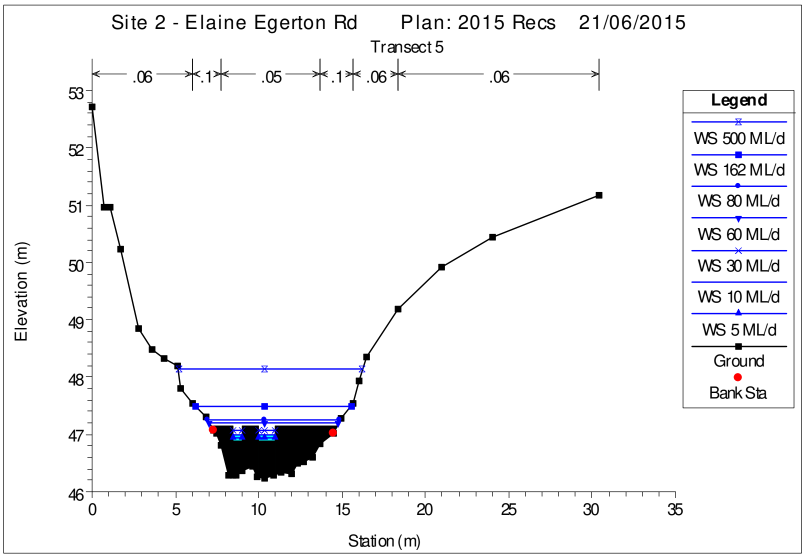
The long section is presented below

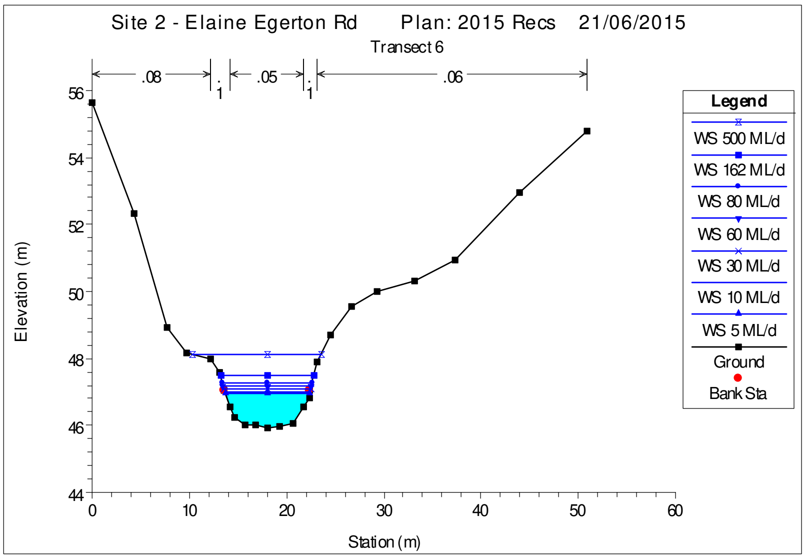


The table below represents the cross sections with the model and shows the Mannings adopted for each section.

Cross section number	
1 (most upstream)	
2	
3	

<table>
<tr><th>Cross section number</th><th></th></tr>
<tr><td>4</td><td>


</td></tr>
<tr><td>5</td><td>


</td></tr>
<tr><td>6</td><td>


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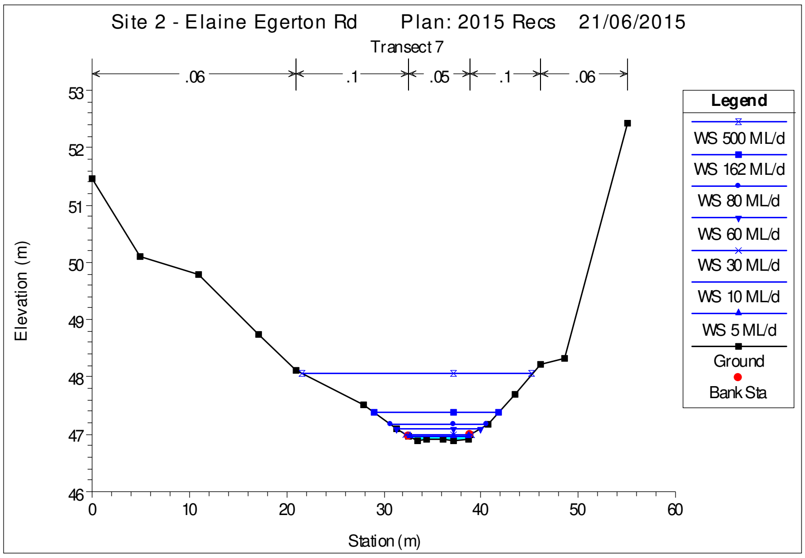
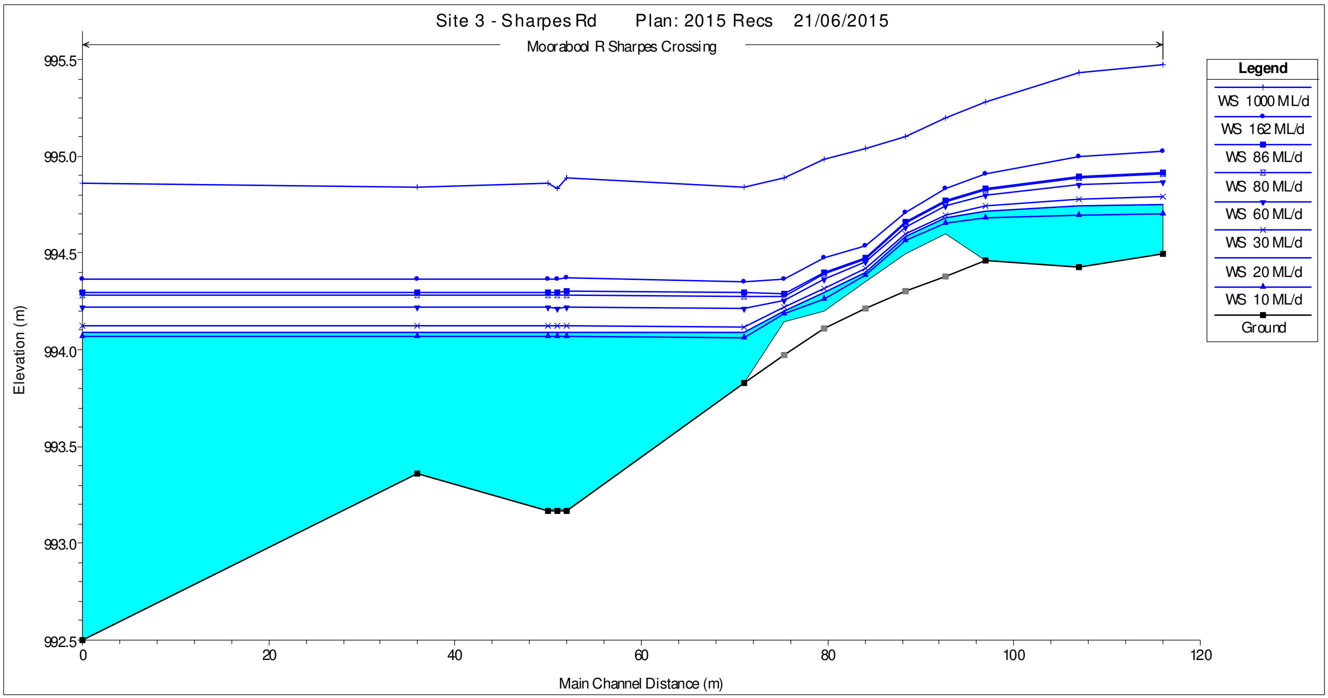
Cross section number	
7	

The downstream boundary condition adopted was a rating curve.

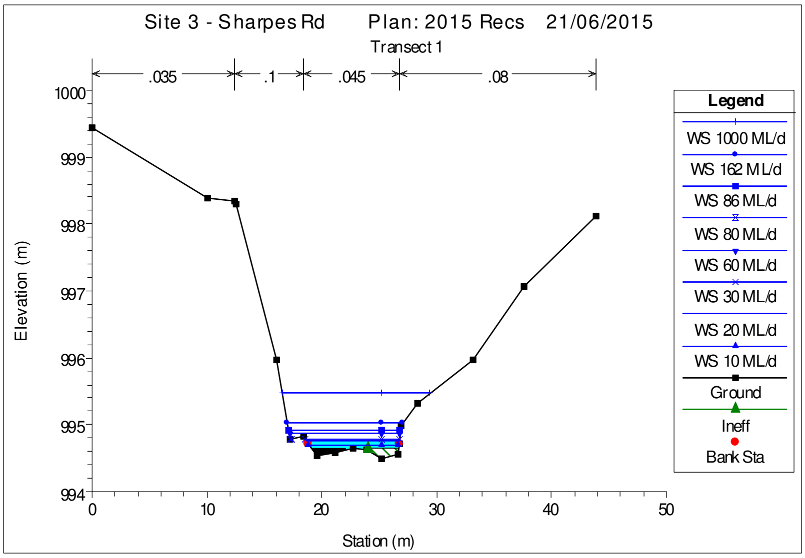
Stage (m)	Flow (m^3/s)
46.95	0
46.97	0.25
47.2	1
48	5
49	20
51.6	100

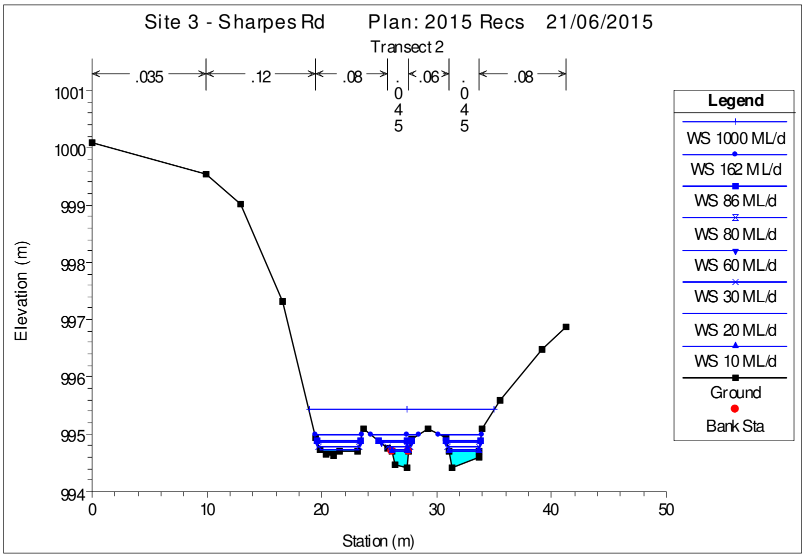
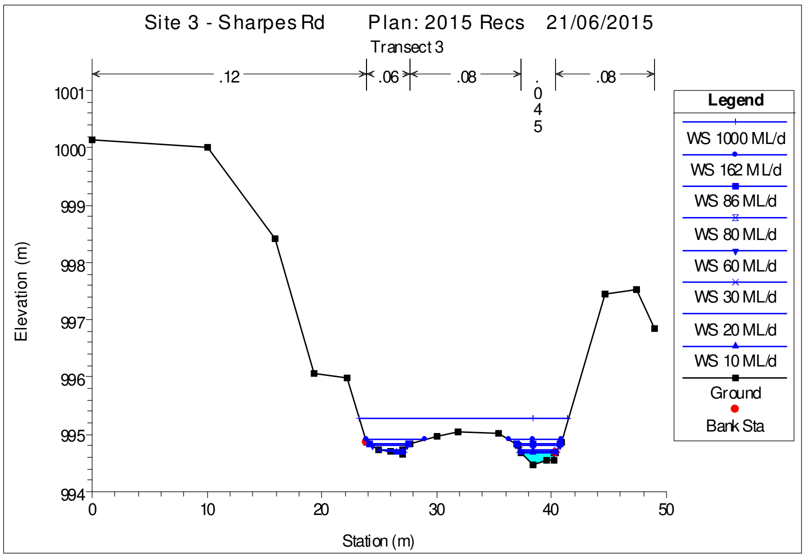
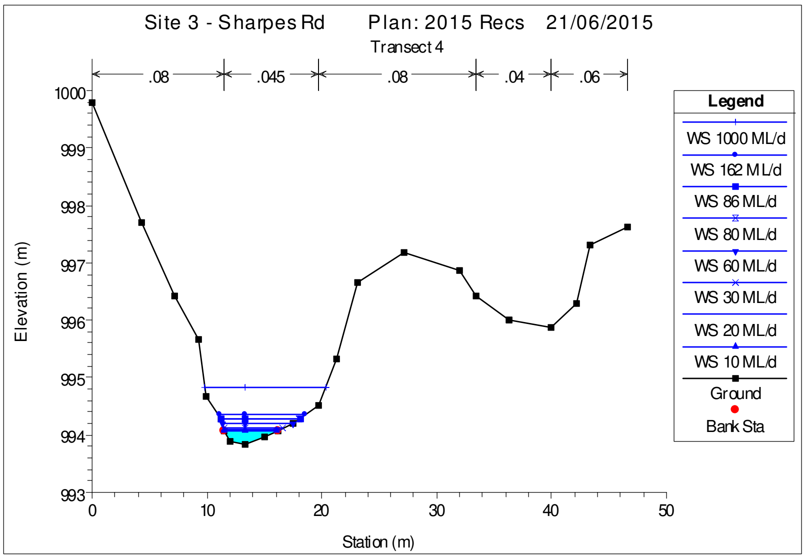
C.3 Site 3: Sharpes Road (FLOWS Reach 3b)

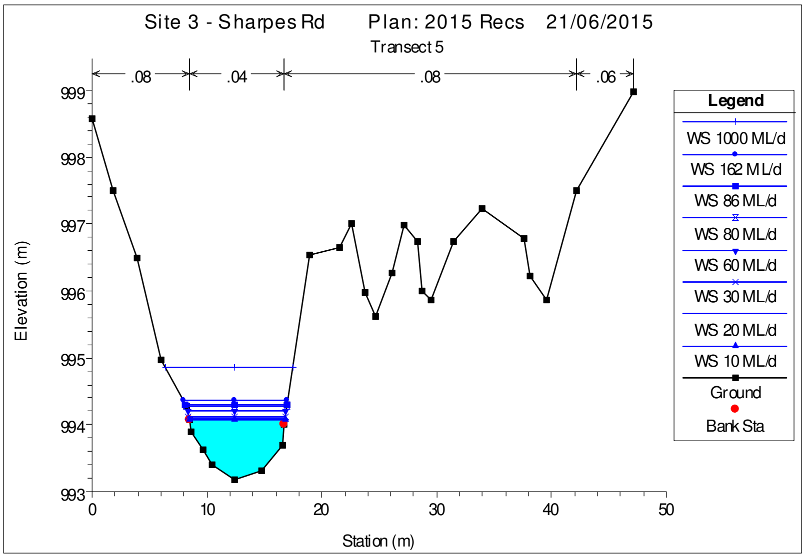
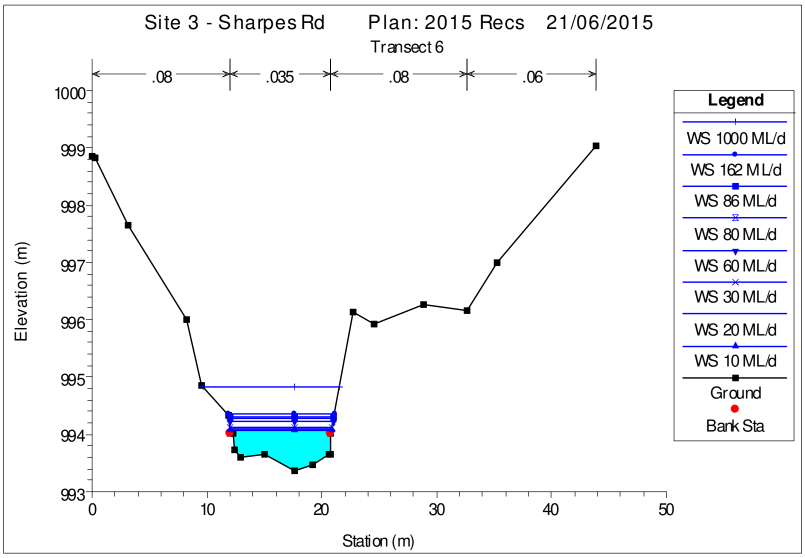
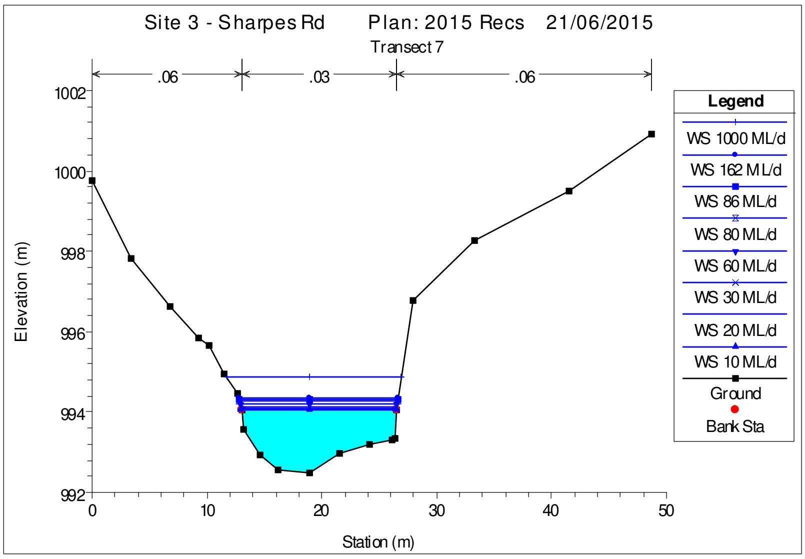
The long section is presented below



The table below represents the cross sections with the model and shows the Mannings adopted for each section.

Cross section number	
1 (most upstream)	

Cross section number	
2	
3	
4	

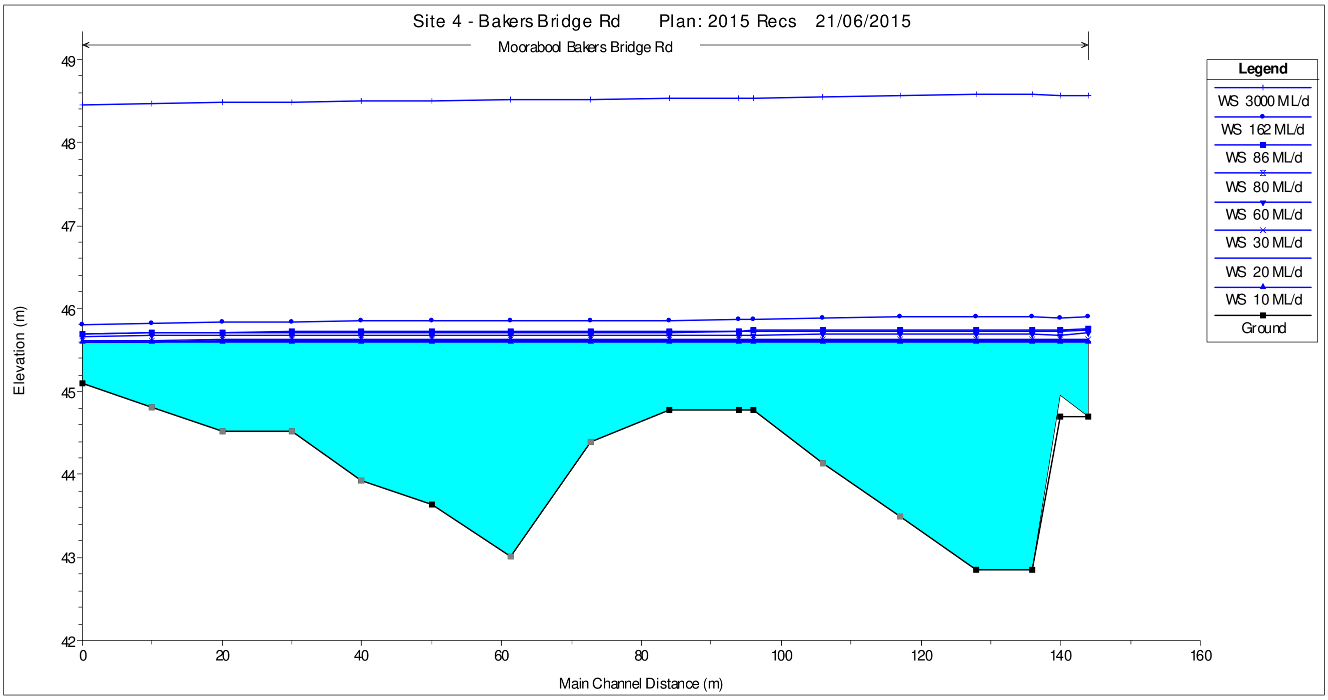
Cross section number	
5	
6	
7	

The downstream boundary condition adopted was a rating curve.

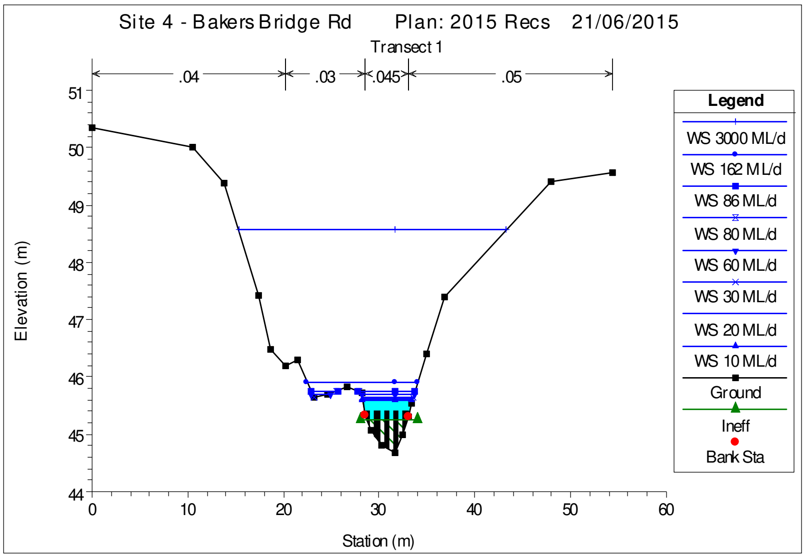
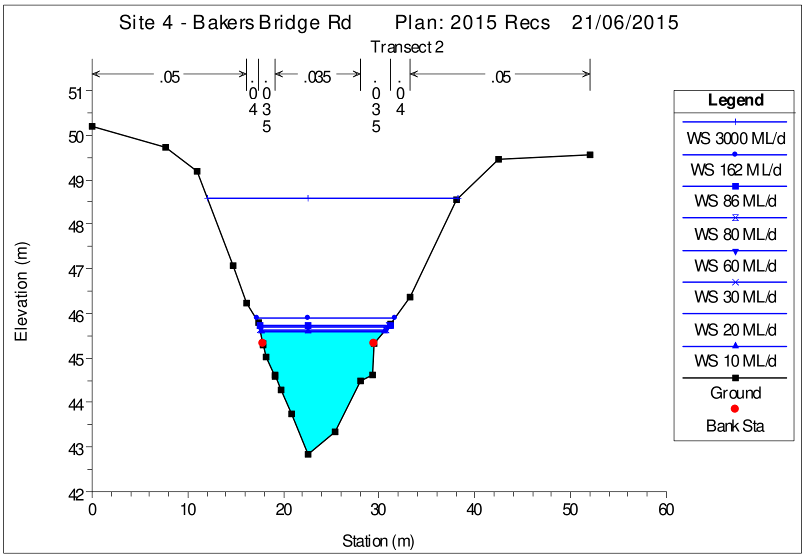
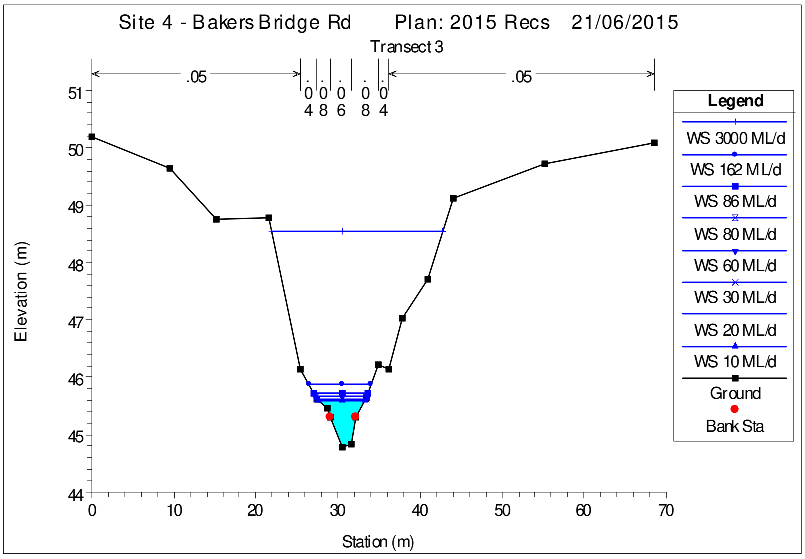
Stage (m)	Flow (m^3/s)
994.05	0
994.07	0.15
994.3	1
994.6	5
995.2	20
997.5	80
999	200

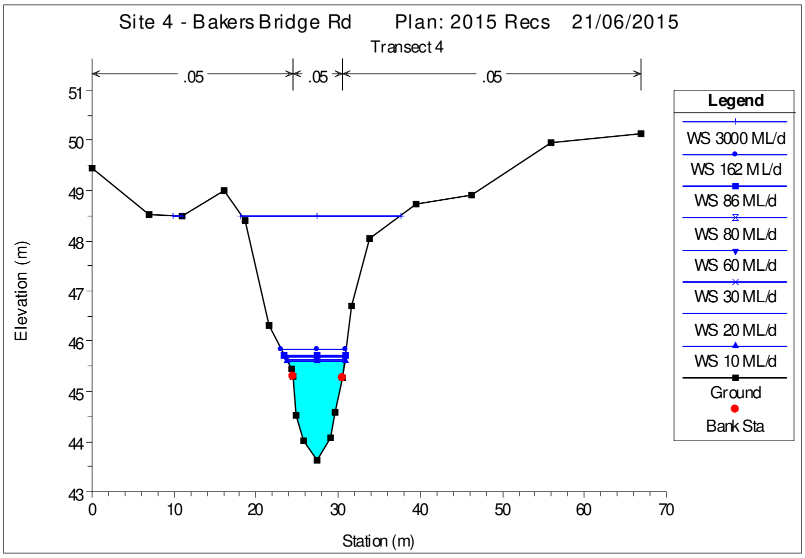
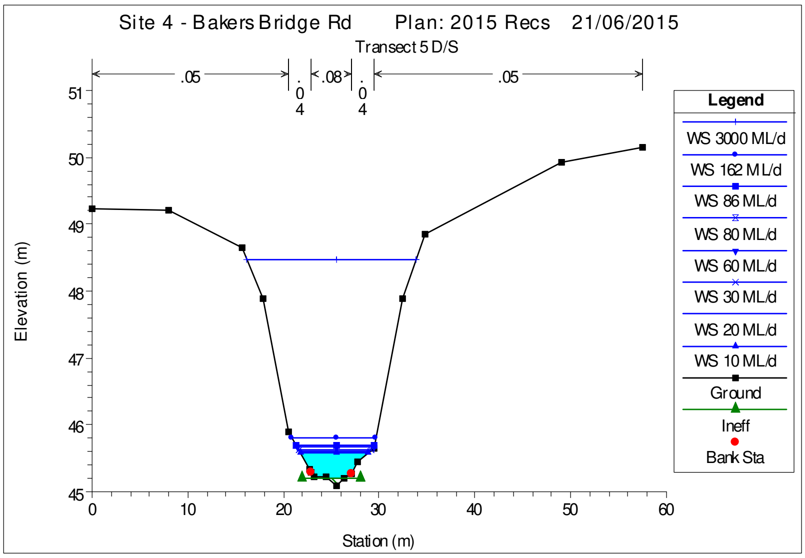
C.4 Site 4: Bakers Bridge Road (FLOWS Reach 4)

The long section is presented below



The table below represents the cross sections with the model and shows the Mannings adopted for each section.

Cross section number	
1 (most upstream)	
2	
3	

Cross section number	
4	
5	

The downstream boundary condition adopted was a rating curve.

Stage (m)	Flow (m^3/s)
45.26	0
45.58	0.05
45.7	1
48	20
50.5	100
52	260