Appendix A Study Brief

Appendix B Steering Committee

The Study is being conducted under the direction of a Steering Committee as listed in Table 1 below.

Table 1 Steering Committee Members

Name	Affiliation
Geoff Earl (Chair)	Goulburn Broken Catchment Management Authority
Pat Feehan	Goulburn-Murray Water
Rohan Hogan	North Central Catchment Management Authority
Andrea Joyce	Department of Sustainability and Environment
Paulo Lay	Department of Sustainability and Environment
Julia Reed	Department of Sustainability and Environment
Jolanta Skawinski	Murray Darling Basin Commission
Wayne Tennant	Goulburn Broken Catchment Management Authority
Bill Viney	Goulburn-Murray Water
Keith Ward	Goulburn Broken Catchment Management Authority

Valuable assistance to the Steering Committee was provided by those listed in Table 2 below.

Table 2 Other Contributors

Name	Affiliation
Bruce Duncan	Coliban Water
Graham Hall	North Central Catchment Management Authority
Barry James	Department of Sustainability and Environment
Guy Tierney	Goulburn Broken Catchment Management Authority

Appendix C Operation of Goulburn System

C.1 Goulburn Basin Overview

The Goulburn catchment covers 1.62 million hectares, or around 7% of Victoria. The Goulburn River rises in the Great Dividing Range in the catchment's south and flows predominately north entering the River Murray east of Echuca. Major tributaries of the Goulburn River include the Big, Delatite, Howqua and Jamieson Rivers upstream of Lake Eildon, the Acheron and Yea Rivers between Lake Eildon and Goulburn Weir, and the Broken River and Seven Creeks downstream of Goulburn Weir.

Lake Eildon (3,390 GL capacity) is the largest storage in the system, with the other major storage being Waranga Basin (412 GL capacity).

C.2 Goulburn Entitlements and Usage

Current irrigation entitlements in the Goulburn System total around 975 GL with an irrigated area of around 360,000 ha. Irrigation areas in the Goulburn System stretch from the Shepparton Irrigation Area in the east across to the Pyramid/Boort Irrigation Area which is in part to the west of the Loddon River. Table 3 gives the breakdown of irrigated area, entitlement and usage for the major irrigation areas in the Goulburn System.

- **Table 3 Goulburn System Irrigation (Goulburn-Murray Water, 2005)**

Irrigation Area	Irrigated Area (ha)	Entitlement (GL)[2]	2004/2005 Usage (GL)[1,2]
Shepparton	51,000	174	157
Central Goulburn	113,100	373	388
Rochester	61,700	162	190
Pyramid-Hill Boort	126,400	218	222
Goulburn Diverters	7,753	48	40
Total Goulburn	360,000	975	997

(1) Final allocation of 100% WR/LV
(2) From G-MW Annual Report

C.3 Goulburn System Losses

C.3.1 Loss Estimates in Resource Planning Models

The Goulburn Simulation Model (GSM) is used as the basis for long term modelling of the Goulburn System. The model incorporates losses for the Goulburn River between Lake Eildon and Goulburn Weir as:

- From Lake Eildon to Trawool transmission losses equal 5% of total Eildon outflow. The loss in the reach is limited to 500 ML/d when Eildon outflow exceeds 10,000 ML/d.
- From Trawool to Goulburn Weir groundwater losses equal 6% of the Eildon outflow. The loss in the reach is limited to 500 ML/d when Eildon outflow exceeds 10,000 ML/d.

Downstream of Goulburn Weir the Goulburn Simulation Model has no mechanisms to calculate and incorporate losses.

C.3.2 Seasonal Allocation Assessments

Seasonal allocations are a conservative assessment of the water available for irrigation and use the maximum estimated losses.

Current seasonal allocation assessments in the 2006/2007 season have a fixed minimum distribution system loss for the entire season of 255 GL. As seasonal allocation rise above 0% Water Right, loss for the season increase linearly until at a seasonal allocation of 60% the total distribution system loss equals 340 GL. If seasonal allocations approach 60% in the current season Goulburn-Murray Water will undertake an assessment to determine the loss function for higher allocations.

Transmission losses between Lake Eildon and Goulburn Weir used in seasonal allocations are the maximum of 8.7% of Lake Eildon release or 300 ML/d.

C.3.3 Loss Estimates in Operational Planning

A calculation of the total loss is generally not required in planning releases from Lake Eildon. Losses are incorporated in planning by determining the difference between Lake Eildon releases and the Goulburn Weir inflow.

- If Goulburn Weir inflow is greater than or equal Lake Eildon release then tributary inflows are providing for losses between Lake Eildon and Waranga Basin
- If Goulburn Weir inflow is less than Lake Eildon release the difference between the two gives and indication of the additional release required above tributary inflows to meet loss requirements.

Daily calculations of the difference between Eildon release and Goulburn Weir inflows provides an indication of the current catchment conditions.

The active storage volume available in Waranga Basin and Goulburn Weir provides a buffering capacity in the event that Goulburn Weir inflows are less or greater than planned due to changes in tributary inflows or operational errors. This means that there is generally no impact on operations.

C.4 Lake Eildon

C.4.1 General Information

At its full supply level of 288.90 mAHD, Lake Eildon holds 3,390,000 ML with a water surface area of 13,840 hectares. The water is impounded by an 85 metre high, 1,085 metre long rock and earthfill embankment and a spillway of a 45.72 metre high concrete gravity dam topped with three flood gates. The embankment has a crest level of 295.7 m AHD, topped by a 1.2 metre high parapet wall.

- **Figure 1 Lake Eildon Upstream of Spillway**

Below the main embankment the Lake Eildon Pondage allows the re-regulation of releases from a hydro station to the downstream release requirements to provide additional generation flexibility, refer to Figure 2. The Lake Eildon Pondage has a full supply level of 217.6 m AHD with an associated volume of 5,100 ML.

▪ **Figure 2 Eildon Pondage**

C.4.2 Outlet Works

The Lake Eildon outlet tower is situated between the original Sugarloaf Dam and the current embankment and is connected by a 400 metre long, 7 metre diameter tunnel to the hydro-electricity station and low level outlet. The low level outlet is 1.9 meter diameter cone dispersion valve while the hydro station is comprised 2 turbines having a maximum generation capacity of 60 MW and 2 turbines of 7.5 MW capacity. The smaller capacity turbines were relocated from the original Sugarloaf Dam and have a maximum head to which they can be operated. Table 4 details the maximum discharge at full supply level and the operating ranges of the various outlet works.

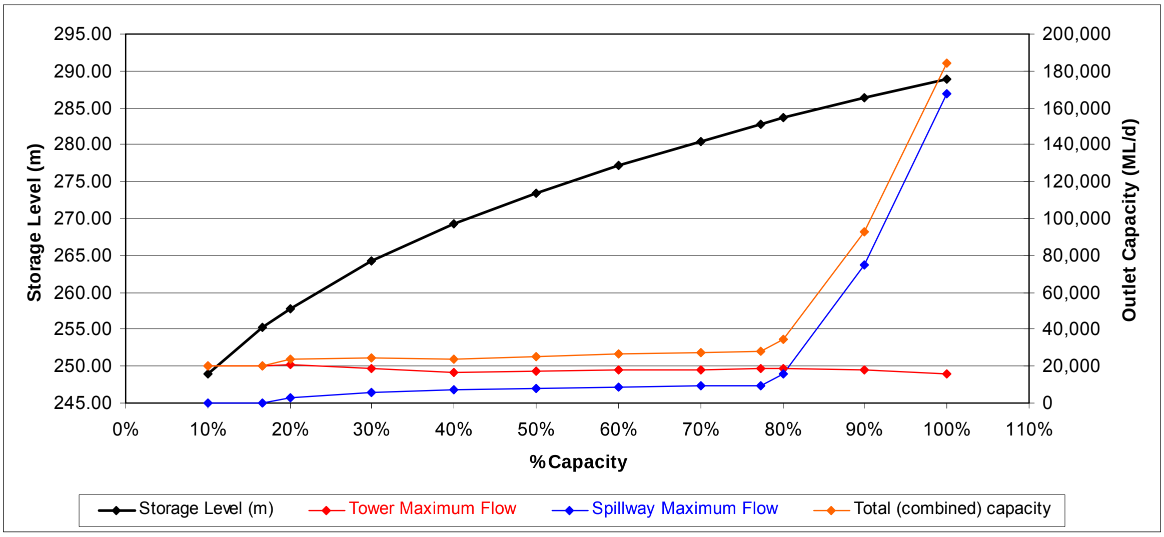
Releases can also be made at the spillway through two cone dispersions valves, each of 5,500 ML/d capacity at FSL, or through 3 spillway gates with a total capacity of 157,000 ML/d at FSL. The spillway valves require the storage to be holding around 17% of capacity to operate, and the spillway gates require the storage to be holding 77.4% capacity to enable releases.

▪ Table 4 Lake Eildon Outlet Works: Discharge Capacities and Operating Ranges

Outlet	Discharge Capacity at FSL (ML/d)	Operating Range	
		Minimum m AHD (%Capacity)	Maximum m AHD (%Capacity)
Low Level Irrigation Outlet	8,600	237.09 (2.7)	288.90 (FSL)
Turbines 1&2	-	248.00 (9.1)	263.00 (27.9)
Turbines 3&4	16,150[1]	248.00 (9.1)	288.90 (FSL)
Spillway Gates	157,000[2]	282.81 (77.4)	288.90 (FSL)
Spillway Valves	5,500 each	255.30 (16.6)	288.90 (FSL)

1. Maximum release capacity of 18,400 ML/d occurs below FSL.
2. Reflects capacity at FSL, discharge would increase if level increased above FSL. The design discharge rate is 415,190 ML/d .

▪ Figure 3 Lake Eildon – Outlet Release Capacities



Releases from the Lake Eildon Pondage can be made through 3 flood gates having a total capacity of 194,000 ML/d at FSL, two low level sluice outlets, or a power station at the pondage embankment. Table 5 shows the discharge capacities of the flood gates and low level sluices. The hydro station on the pondage can pass 2,000 ML/d to 6,000 ML/d, with a minimum operating head of 4.5 metres and a maximum operating head of 10.2 metres.

■ **Table 5 Lake Eildon Regulating Pondage: Discharge Capacities and Operating Ranges**

Outlet	Discharge Capacity at FSL (ML/d)	Operating Range	
		Minimum m AHD	Maximum m AHD
Low Level Sluices	1,000 (each)[1]	206.75	217.6
Flood Gates	194,000	210.38	217.6

1. Estimate only

C.4.3 Lake Eildon Releases

The minimum flow immediately downstream of the Lake Eildon Pondage is established by Clause 11 of the Goulburn Bulk Entitlement Conversion Order 1995. The general minimum flow requirement is 120 ML/d, however if 24 month inflows exceed trigger levels, additional passing flows described in Clause 6 of the Bulk Entitlement become available. Under these provisions, minimum flows increase to 250 ML/d, and an additional 80 GL can be passed downstream during November, to provide water to effluent lagoons for the period of 1 day up to a maximum release of 16,000 ML/d.

During the irrigation season releases to satisfy downstream requirements will generally exceed the minimum flow requirements. G-MW bases its requirements for Lake Eildon releases on:

- Daily assessment of release requirements:
  - for supply of bulk water orders for irrigation areas, diversion customers or other authorities, including inter-valley transfers;
  - to minimise unregulated releases at Goulburn Weir by taking into account irrigation demand, natural catchment inflow below Eildon and weather conditions;
  - to supply transmission losses; and
  - for release requirements downstream of Goulburn Weir.
- Target operating levels at Waranga Basin, to avoid long periods of high release from Eildon.
- Maximum regulated release from Lake Eildon, which is 10,000 ML/d.

Inter-valley transfers have resulted from net trade from the Goulburn to the Murray systems. At different times of the years water may be called out from Eildon to assist in meeting Murray system requirements. The transfer of water from the Goulburn System (which is held in Eildon) to the Murray system can be done through the following river systems:

- Goulburn River, utilising the reach downstream of Goulburn Weir;
- Broken Creek, utilising the East Goulburn Main Channel to outfall water to Broken Creek through to Rice’s Weir;

- Campaspe River, utilising the Waranga Western Channel to outfall water to the Campaspe downstream of Campaspe Siphon.

C.4.4 Regulated Release Operations

When Lake Eildon is being operated to meet a downstream release requirement, Goulburn-Murray Water places an order for the flow required downstream of the regulating pondage with AGL Hydro. AGL Hydro will then operate the power station and regulating pondage to best meet its requirements (within agreed pondage operating limits), whilst passing the ordered flow downstream. This will include communicating what flows can be passed through the pondage hydro station with the power station operator.

If the Lake Eildon power station is unavailable then G-MW will regulate water using the low level outlet, spillway valves or spillway gates, into the pondage. AGL Hydro will continue to manage releases from the pondage to meet downstream flows.

The pondage provides AGL Hydro with some flexibility to make higher releases during periods of higher electricity demand without additional water being releases downstream of the pondage. However there are times when releases for electricity generation will exceed the pondage's ability to regulate the water. AGL Hydro has up to 80 GL a year that it can pass downstream of the pondage in addition to Goulburn-Murray Water's downstream requirements.

Variations in releases downstream of the pondage have restrictions placed on them:

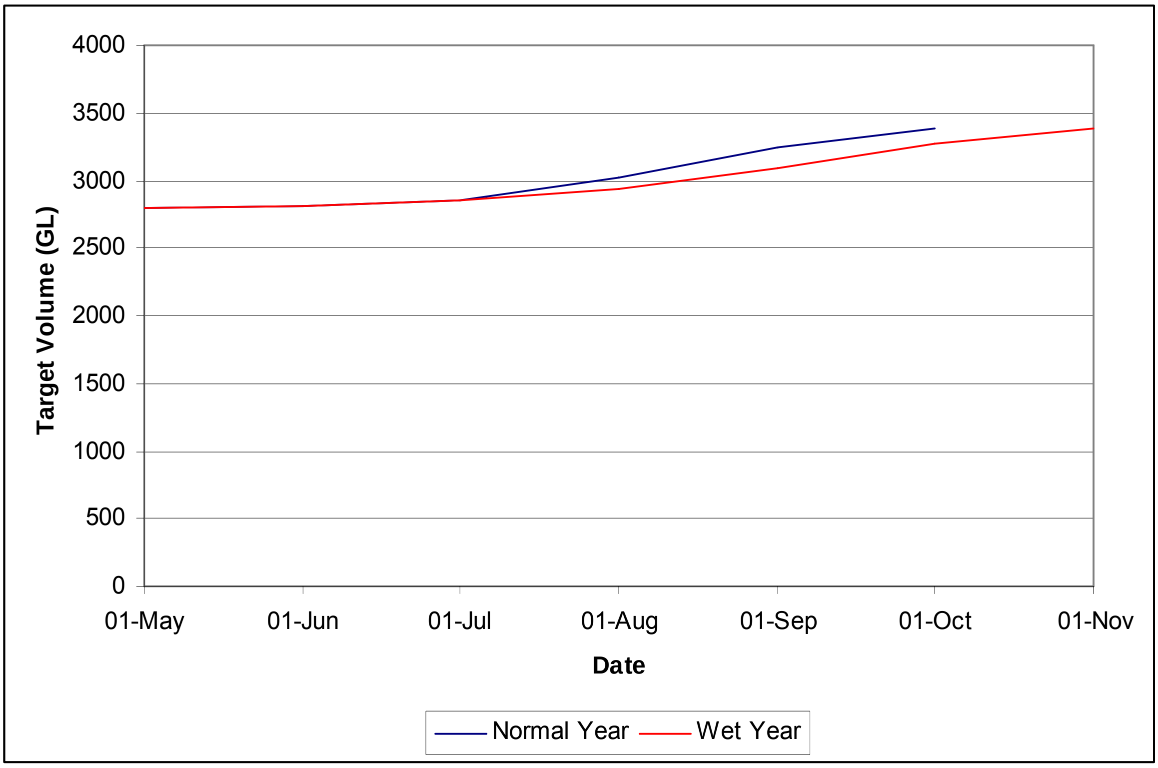
- Maximum rate of rise is 150 mm/h with a maximum flow increase of 3,500 ML/d.
- Maximum rate of fall is an instantaneous fall of 150 mm and then 30 mm/h to a maximum of 450 mm/d for the first day, with 30 mm/h and 300 mm/d thereafter.

C.4.5 Flood Operations

The two target curves in Schedule 5 of the Goulburn-Murray Water Goulburn Bulk Entitlement 1995 (G-MW 1995) form the basis of the flood operating procedures for Lake Eildon (refer Figure 4). The two curves represent the target filling for normal and wet years, with the wet year curve used where G-MW considers that wet conditions will continue, and the risk of Lake Eildon not filling is low.

Operations will initially allow Lake Eildon to fill to the selected target curve. Once the target curve has been reached, releases will be made up to downstream channel capacity to endeavour to keep to the target curve. During periods of high inflows the storage may be allowed to exceed the target curve to provide some flood mitigation. Releases will then be made to return the storage to the target storage level. The magnitude and timing of releases will need to be based on the rate of inflow to the storage, any ability to surcharge the storage, downstream inflows and flooding, and the potential for further significant inflows.

▪ **Figure 4 Lake Eildon Filling Targets – Schedule 5 of the G-MW Bulk Entitlement**



C.5 Goulburn Weir

C.5.1 General Information

Goulburn Weir, which forms Lake Nagambie, is a concrete and masonry structure that provides a sufficient water level to allow diversions to the Stuart-Murray Canal, Cattanach Canal and the East Goulburn Main Channel. At its full supply level of 124.24 m AHD, its capacity is 25,000 ML, and it has a surface area of 1,130 hectares. Lake Nagambie is used extensively for recreation.

C.5.2 Outlet Works

Regulation of water downstream of Lake Nagambie is controlled by 9 radial gates installed in 1987 and two overshot gates based on the original gate design. The radial gates have been designed to be above the 1 in 100 year flood (170,000 Ml/d).

The offtake to the Stuart-Murray Canal is located immediately west of the weir structure, while offtakes to the East-Goulburn Main Channel (east side of the weir) and Cattanach Canal (west side of the weir) are located further upstream of the weir.

SKM

C.5.3 Release Requirements for Downstream Demand

The Goulburn Bulk Entitlement sets minimum flow criteria at two points downstream of Goulburn Weir. The first immediately downstream of Goulburn Weir requires a weekly average of 250 ML/d, and a minimum daily rate of 200 ML/d. The second passing flow requirement occurs at McCoy's Bridge and varies over the year. Requirements are:

- For November to June inclusive a minimum average monthly flow of 350 ML/d and a daily requirement of no less than 300 ML/d; and
- For July to October inclusive a minimum average monthly flow of 400 ML/d with a daily requirement of not less than 350 ML/d.

Other demands downstream of Goulburn Weir include in-valley consumptive demand from rural and urban customers, and any inter-valley transfer volumes to be passed to the Murray River. Demands downstream of Goulburn Weir and minimum passing flows at McCoy's Bridge can be met fully or in part by unregulated tributary inflows, including inflows from the Broken River.

C.5.4 Goulburn Weir Operation Guidelines

Goulburn Weir operations need to consider meeting downstream requirements, maintaining discharge capacities from the weir and maximising the volume of unregulated inflows that can be harvested to Waranga Basin.

During the June to September period, with no or low demand requirements, the operating level of Goulburn Weir is generally varied within 300 mm below Full Supply Level (FSL) to increase harvesting capacity. However as irrigation demand and the need to allow the offtakes to operate at or near capacity increases, the ability to vary the level at Goulburn Weir diminishes. In addition the community around Lake Nagambie would generally prefer the pool level to remain near FSL for public amenity reasons.

Inflows exceeding the diversion capacity to Goulburn Weir can be harvested up to FSL, however once the storage reaches FSL all additional inflows above diversion capacity are passed downstream.

C.5.5 East Goulburn Main Channel

The East Goulburn Main (EGM) Channel runs for 95 km from Lake Nagambie to the Broken Creek at Katandra Weir. It supplies the Shepparton Irrigation District and up to 40,000 ML of regulated outfall to the Broken Creek.

Channel capacity at the offtake is 2,590 ML with capacity falling to around 300 ML/d where the EGM outfalls into the Broken Creek. The channel capacity at Broken River siphon is over 2,000 ML/d. During periods of peak demand there is negligible spare capacity in the EGM.

C.5.6 Stuart Murray Canal

Diversions to the Stuart-Murray Canal are controlled by two radial gates in a structure adjacent to Goulburn Weir. Diversions to the Stuart-Murray Canal are either passed through to Waranga Basin or diverted into the Central Goulburn system via the 1,2,3,4 and 6 offtakes. Potentially up to 2,435 ML/d can be diverted from the Stuart-Murray Canal into the Central Goulburn Irrigation Area. Apart from the offtake, regulated levels are controlled in the Stuart-Murray Canal at two regulating structures, the No 1 (Punt Rd) regulator and the inlet regulator to Waranga Basin. The regulators and offtake were automated in 2005.

The capacity of the Stuart Murray Canal at the Goulburn Weir offtake regulator is 3500 ML/d. This capacity is available under normal conditions but may be reduced by substantial weed growth in the Canal, or if Waranga Basin storage volume is above 380,000 ML. Reduced Stuart-Murray Canal capacities due to Waranga Basin levels are shown in Table 6.

Changes in regulated inflows to the Stuart-Murray Canal are restricted to ±400 ML/d every four hours, to minimise erosion of the canal, with 3 regulations per day, although in an emergency 4 regulations can be made (Steven Hall G-MW, pers.comm.). There is now scope for the restriction on the number of regulations per day to be removed following the automation of regulators in the Stuart-Murray Canal in 2005.

- **Table 6 Stuart-Murray Flow Restrictions – Waranga Basin Volumes**

Waranga Basin Volume (ML)	Maximum Stuart-Murray Flow Entering Basin (ML/d)
400,000 – 405,000 ML	2,000
390,000 – 400,000 ML	2,500
380,000 – 390,000 ML	3,000
370,000 – 380,000 ML	3,500

Stuart-Murray Canal offtake flows can be above those in Table 6 due to irrigation demand reducing the flows entering Waranga Basin.

C.5.7 Cattanach Canal

The Cattanach Canal can divert up to 3,690 ML/d from Goulburn Weir to the Waranga Basin. No diversions to irrigation areas occur along from the Cattanach Canal. In general Stuart-Murray Canal flows are held fairly constant, with the Cattanach Canal operated to pass inflow variations into Goulburn Weir to Waranga Basin.

Changes in regulated inflows to the Cattanach Canal are restricted to ±400 ML/d every four hours to minimise erosion of the canal (Steven Hall G-MW, pers.comm.). There is no restriction on the number of regulations that can be made in a day.

C.6 Waranga Basin

C.6.1 General

Waranga Basin is an off-stream storage that enables unregulated flows into Goulburn Weir to be harvested. It also provides a balancing storage for the operation of the Goulburn System. Waranga Basin holds 412,000 ML when at the full supply level of 121.36 m AHD. The majority of inflows to Waranga Basin come from regulated diversions from Goulburn Weir through the Stuart-Murray and Cattanach Canals. The storage also receives some unregulated inflows from the local catchment.

C.6.2 Outlet Works

The two offtake structures from Waranga Basin are a minor outlet which supplies the Central Goulburn 7 and 8 systems, and the major outlet which supplies that Waranga Western Channel.

- **Table 7 Waranga Basin Outlet Discharge Capacity**

Outlet	Discharge Capacity at FSL (ML/d)
Major	4,210
Minor	1,850

C.6.3 Waranga Basin Operation Guidelines

At the end of an irrigation season Waranga Basin operations become focused on maximising the volume of water harvested from unregulated catchment inflows to Goulburn Weir. In most years there are insufficient unregulated inflows to Goulburn Weir to allow Waranga Basin to fill. Initially a filling target of 300 mm below Full Supply Level (121.36 m AHD) is used, as maintaining the storage at FSL over long periods can result in significant erosion issues. After achieving the initial target, G-MW will generally aim to fill the storage for as short a period of time as possible, by allowing for recession inflows to Goulburn Weir, and demand off Goulburn Weir and the Basin.

In dry years where there is insufficient inflow to Waranga Basin to achieve planned target levels during the irrigation season, additional releases from Eildon may be required to increase volumes held in Waranga. These releases will be minimised and delayed for as long as possible to reduce the risk that subsequent higher Goulburn Weir inflows will result in a net loss of resource.

During the irrigation season Waranga Basin is operated to provide airspace to harvest unregulated inflows into Goulburn Weir, but it must also be maintained at level sufficient to provide adequate discharge capacity. The determination of target levels for Waranga Basin takes into account the actual situation in each season. For seasons with very high allocations Waranga Basin can be required to be operated at higher levels than for seasons with low allocations. In determining target levels G-MW will take into account the allocation, current demands, current levels, any available supplements from the Campaspe and Loddon, and how much water remains to be delivered.

Toward the end of the irrigation season the Waranga Basin is drawn down to provide airspace for winter harvesting, and to minimise Eildon releases. The target drawdown level for the storage is 114.97 m AHD (104,000 ML) by 15 May. The rate of drawdown depends on delivery volumes remaining, the capacities of the outlets under gravity, and available resources at Greens Lake.

C.7 Waranga Western Channel (WWC) Operations

Waranga Western Channel services the Central Goulburn 9 Channel, the Rochester delivery system of the Rochester-Campaspe area, and the Pyramid-Boort irrigation area . Flows released from Waranga Basin can be supplemented if water is available by pumping water from Greens Lake, the Campaspe System or from the Loddon System. The supplements are used to offset capacity constraints along the WWC, and to provide additional resources for supply to the three irrigation areas.

Whilst the major outlet from Waranga Basin to the WWC has a capacity of 4,150 ML/d, WWC capacity reduces to around 3,150 ML/d downstream of the Central Goulburn 9 offtake. Orders for the Pyramid-Boort and Rochester Irrigation Areas are combined to determine the flow requirement downstream of the Central Goulburn 9 offtake.

Table 8 Waranga Western Channel Capacity

Location	Channel Capacity (ML/d)
Major Outlet (Waranga Basin)	4,150
Downstream CG 9 Offtake	3,350
Downstream Campaspe Siphon	3,200
Downstream Tandarra Pondage	900
Upstream Loddon Weir	550
Downstream Loddon Weir	1,100

In every second year the Waranga Western Channel can be operated in the non-irrigation season to supply Grampians Wimmera Mallee Water with volumes provided for in Schedule 3 of the Goulburn Bulk Entitlement. Up to 24,000 ML can be supplied in the May to September period subject to available channel capacity. Up to 2,000 ML can also be supplied to Grampians Wimmera Mallee Water each year in the April to May period.

C.8 Operation of Lower Goulburn River

C.8.1 Irrigation System Outfalls to Lower Goulburn River

The majority of outfalls that enter the Goulburn River from the Central Goulburn Irrigation Area initially discharge into drains. Flows from the drains enter the Goulburn via Wells, Yambuna and

Warrigal Creeks. Table 9 shows the major drains and channels discharging to the lower Goulburn River.

Table 9 – Central Goulburn Irrigation System Outfalls to Lower Goulburn River

Outfall	Drainage Catchment	Channels
Central Goulburn		
Direct to Goulburn		15/6/4, Lower 6/4
Drains via Wells Creek	Ardmona	CG14/4, CG11/4, CG19/6, CG6/19/6
	Undera	CG27/4
	Rodney	CG5/19/6
Drains via Yambuna Creek and Warrigal Creek	Wyuna	CG19/8, CG20/6, CG 16/8, CG 8 (No. 15 outfall), CG 9 (No. 6 outfall), CG 27/6 (No. 12A outfall), CG 41/9, CG 5/27/6 (No. 12 outfall), CG 9 (No. 10 outfall)

Shepparton Irrigation Area outfalls also generally discharge into drains. Table 10 provides details of the outfalls to the Lower Goulburn and the outfalls that enter tributaries of the Goulburn including the Lower Broken River.

Table 10 – Shepparton Irrigation System Outfalls

Outfall	Channels
To Goulburn River	
Direct to Goulburn River	SH2, SH1/22/12
Shepparton Drain 3	SH1/14/10, SH3/11, SH4/11, SH7/11, SH12/12, SH2/12/12, SH3/12/12, SH17/12
Shepparton Drain 4	SH2/15/12, SH15/12, SH18/12, SH20/12, Upper12, SH2/12, SH 15A/4, SH4/14, SH7/14A, SH14A, SH 3/8/14
To Lower Broken River	
Shepparton Drain 2	SH10, SH 20/10, SH15/10, SH MID1/10, SH10/1/10, Lower 1/10
Shepparton Drain 5	SH16/10
Shepparton Drain 6	SH13/10, SH2/13/10, SH1/14/10
Shepparton Drain 8	SH10/10
Shepparton Drain 9	SH8/10
Other Goulburn Tributaries	
To Castle Creek	SH1
To Seven Creeks	SH 8/2, SH6
To Honeysuckle Creek	SH3B, SH4

C.8.2 Flood Operations Overview

The Goulburn River downstream of Shepparton is confined within a leveed floodway but its capacity is inadequate to convey even moderate flood events. To reduce the probability of overtopping the levees water is allowed to pass from the floodway into Bunbartha Creek at Loch Garry, Deep Creek, Wakiti Creek, Hagens Creek and Hancocks Creek. Of these the Loch Garry regulator has by far the highest capacity of 60,000 ML/d.

Loch Garry is a 48 bay regulator located around 16 km downstream of Shepparton. Prior to the construction of the levees, floodwater would have regularly broken out of the Goulburn into Bunbartha Creek. Operation of Loch Garry is based on Shepparton river heights. Removal of bars commences 24 hours after the Shepparton gauge level has exceeded 10.36 m (110.487 mAHD) with all bars being removed 24 hours after the river level at Shepparton has exceeded 10.96 m.

C.8.3 Lower Goulburn Waterway & Floodplain Management Plan (SKM, 1998)

This report states that *"… the capacity of the leveed river floodway downstream of Shepparton is inadequate to convey even moderate floods."*

The capacity of the leveed river floodway downstream of Shepparton is given below.

River Reach	Capacity (ML/d)
Upstream of Loch Garry (Medland Rd)	185,000 ML/d (40 year ARI)
Loch Garry to Deep Creek Outlet	85,000 ML/d (7 year ARI)
Deep Creek Outlet u/s McCoy's Bridge	75,000 ML/d (5 year ARI)
McCoy's Bridge	65,000 ML/d (4 year ARI)
Downstream of McCoy's Bridge to Yambuna Forest	60,000 ML/d (3 year ARI)
Yambuna Choke	37,000 ML/d (2 year ARI)

Flows from the Goulburn River can only pass through three gaps in the Bama Sandhills:

- At the Yambuna Choke
- Through a flood course associated with Madowla Lagoon
- At high river stage, along Yambuna Creek to Warrigal Lagoon and Kanyapella Basin.

The last two of these three gaps are now blocked by levees. Flood flows also find their way through a fourth gap in the sandhills via overflows to Deep Creek and the Murray River. The Murray River is also confined to a narrow gap in the Bama Sandhills (known as the Barmah Choke), which causes the Murray to backup during floods. When the choke capacity of about 10,000 ML/d is exceeded, additional flows are forced north along the Edward River. Maximum flow along the Murray through the Choke is approximately 35,000 ML/d.

The maximum capacities of each of the outlet structures along the lower Goulburn are given below. Note that these figures are estimates of the maximum capacities during major floods, when the outlets are surcharged. Flows through Loch Garry, for example, would be significantly reduced for small to medium sized floods (Water Technology, 2005).

- **Table 11 Lower Goulburn Outlet Structure Capacities**

Outlet	Capacity (ML/d)
Loch Garry regulator	60,000
Deep Creek outlet	3,000
Wakiti Creek outlet	3,100
Hagens Creek outlet	100
Hancocks Creek outlet	3,700

Extract from Water Technology, 2005:

Repeated failure of levees constructed near the riverbank at Loch Garry, particularly in the 1916 floods, and frequent flooding for prolonged durations of landholders downstream of Loch Garry led to the creation of the Loch Garry Minor Flood Protection Scheme.

The proposal required the construction of a levee surrounding the Loch Garry wetlands with an associated regulator structure to control flows into Bunbartha Creek.

The intent of the scheme, which was adopted in 1925, is to protect Bunbartha Creek and the surrounding lands from minor (nuisance) floods (less than or equal to a 2.5-year ARI) overflowing from Loch Garry. For floods greater than 10.36m (34 feet) on the Shepparton gauge (2.5-year ARI flood), the scheme was to release the same proportion of flow out of Loch Garry and into the Deep Creek floodplain as flowed into Loch Garry prior to the establishment of the scheme.

Based on the available information at the time leading up to the schemes adoption in 1925, the flow of 44,000 ML/d (509 m^3/s) was calculated and designed to pass through the Loch Garry regulator onto the Deep Creek floodplain during a repeat of the 1916 flood. This operation, which is still in place today, attempts to restore flow distribution and prevent levee failures along the Goulburn River.

The current operating rules for operation of the regulator require that 24 hours after the Shepparton gauge exceeds 10.36m (110.487m AHD), 23 bars are removed and for every additional 0.031m rise in the river level at the Shepparton gauge 23 more bars are removed. If the river continues to rise, all bars are to be removed 24 hours after the river reaches 10.96m (36 feet) at Shepparton.

C.9 Flow Monitoring in the Goulburn System

C.9.1 Upstream of Lake Eildon

The Big, Jamieson, Delatite and Howqua Rivers form the major tributaries of the Goulburn River upstream of Lake Eildon. Table 12 lists the gauging stations for each of the tributaries and for the Goulburn River upstream of Lake Eildon. Gauged flows are used by Goulburn-Murray Water in assisting in predicting the magnitude of inflows to Lake Eildon. A water balance calculation of inflows is used to determine inflows for operational decisions.

■ **Table 12 - Gauging Stations for Major Streams upstream of Lake Eildon**

Stream	Gauging Stations	
	Station Id	Station Name
Big River	405227	Big River @ Jamieson
Goulburn River	405219	Goulburn River @ Dohertys
Howqua River	405215	Howqua River @ Glen Esk
Delatite River	405214	Delatite River @ Tonga Bridge
Jamieson River	405218	Jamieson River @ Gerrang Bridge

C.9.2 Lake Eildon to Goulburn Weir

Table 15 lists the gauging stations in each reach of the Goulburn River having environmental flow recommendations. Three of the reaches are located between Lake Eildon and Lake Nagambie.

Flows entering the first reach are measured immediately downstream of the Lake Eildon pondage. Gauging stations at Trawool and Seymour measure flows in the river. Flows entering the upstream end of reaches 1 and 3 are measured by the flows downstream of Lake Eildon and at Seymour. The flows entering the Molesworth to Seymour reach are not measured at Molesworth, however the gauging station at Trawool does measure flows within the reach.

The major tributaries of the Goulburn River entering reach 1 are the Rubicon and Acheron Rivers. Both streams have gauging stations, listed in Table 13, with remote access via telephone.

Major tributaries entering reach 2 between Molesworth and Seymour include the Yea River and King Parrot Creek upstream of the Trawool gauging station. A gauging station at Ghin Ghin on the Goulburn between the two tributaries provides access to river levels but does not have a stage –discharge relationship. Downstream of the Trawool gauging station, Sunday Creek is major source of tributary inflows. Other smaller streams including Mollison Creek, Sugarloaf Creek and Whiteheads Creek are also gauged.

Hughes Creek and Major Creek enter the Goulburn River in reach 3, from Seymour to Lake Nagambie.

- **Table 13 - Major Tributary Gauging Stations Eildon to Lake Nagambie**

Reach	Stream	Gauging Stations	
		Station Id	Station Name
1	Rubicon River	405241	Rubicon River @ Rubicon
1	Acheron River	405209	Acheron River @ Taggerty
2	Yea River	405217	Yea River @ Devlin's Bridge
2	King Parrot Creek	405231	King Parrot Creek @ Flowerdale
3	Sunday Creek	405212	Sunday Creek @ Tallarook

C.9.3 Downstream of Goulburn Weir

Between Nagambie and Loch Garry the major tributaries are Sevens Creek, Castle Creek and the Broken River. All of these tributaries enter the Goulburn River above the Shepparton gauging station.

- **Table 14 – Major Tributary Gauging Stations Downstream of Lake Nagambie**

Stream	Gauging Stations	
	Station Id	Station Name
Seven Creeks	405234	Seven Cks @ Downstream of Polly McQuinn Weir
	405237	Seven Cks @ Downstream of Euroa
Castle Creek	405246	Castle Creek @ Arcadia
Broken River	404206	Broken River @ Moorngag
	404216	Broken River @ Goorambat (Caseys Weir)
	404224	Broken River @ Gowangardie
	404222	Broken River @ Orrvale

Table 15 - Goulburn Reaches for Environmental Flow Compliance - Hydrographic Stations

		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Leon Tepper – Thiess Tatura)**
1	*Lake Eildon to Molesworth*	405203	Goulburn River @ Eildon	▪ Low flows < 1,000 ML/d there has are issues with measurement accuracy
2	*Molesworth to Seymour*	405201	Goulburn River @ Trawool	▪ Likely issues with lower flows (<1000 ML/d) ▪ No control ▪ Gaugings occur 2 km upstream
3	*Seymour to Nagambie*	405202	Goulburn River @ Seymour	▪ Good measurement
4	*Nagambie to Loch Garry*	405259	Goulburn River @ Goulburn Weir	▪ Flood measurement only >3.5 m
		405200	Goulburn River @ Murchison	▪ Not a good site ▪ Loop measurement issue ▪ Lower flows OK
		405204	Goulburn River @ Shepparton	▪ changes to the river channel and current earthworks mean that it is not a good site
5	*Loch Garry to the River Murray*	405276	Goulburn River @ Loch Garry	▪ Flood site only
		405232	Goulburn River @ McCoys Bridge	▪ Best measurement site downstream of Goulburn Weir ▪ Floods breakout at high flows causing flow estimation issues
Living Murray contribution	*Conformance assessed at Reach 5*	405232	Goulburn River @ McCoys Bridge	▪ See Above

Appendix D Operation of Broken Creek

D.1 Introduction

The Broken Creek commences on the Broken River at Casey's Weir and ends in the Murray River near Barmah (refer Figure 6 to Figure 8). A number of tributaries, channel outfalls and drains feed into Broken Creek. A number of weirs have been in operation on the Creek for a considerable period of time especially downstream of Katamatite.

A significant number of irrigators divert from Broken Creek along the whole of its length. The diverters downstream of Katamatite are supplied predominantly by water from the Goulburn system via the East Goulburn Main Channel outfall, and also from the Murray System via a number of irrigation channels that outfall to the creek. Diverters in the Broken Creek upstream of Katamatite are supplied by diversions from the Broken River into the Creek at Casey's Weir.

D.2 Losses in the Broken System

D.2.1 Loss Estimates in Resource Planning Models

The GSM model does not incorporate losses along Broken Creek. There are, however, losses along Broken River.

D.2.2 Seasonal Allocation Loss Allowance

Seasonal allocation assessments for the Broken System include loss allowances for:

- Combined river transmission and operational losses in the Broken River and Creek; and
- Evaporation losses from Lake Nillahcootie and Lake Mokoan related to storage level through surface area.

Table 16 gives the daily loss rates used in the seasonal allocation assessment for reaches within the Broken System. Over a full irrigation season the losses amount to around 28,600 ML.

Table 16 - Estimated Upper Bound Broken system losses (G-MW 2006a)

Reach/Storage	Loss (ML/d)
Broken River upstream of Casey's Weir	35
Broken River downstream of Casey's Weir	50
Broken Creek	20
Total resource loss	**105**

D.3 Broken River

D.3.1 Lake Nillahcootie

Lake Nillahcootie situated south of Benalla has a capacity of 40,000 ML at a FSL level of 264.5 m AHD. Completed in 1967 the dam consists of an earth and rockfill embankment 35 metres high and 791 metres long. The main spillway has a gothic arch shape crest and has the ability to pass up to 117,000 ML/d. Outlet works consist of an 1800 mm diameter concrete encased steel pipe with regulation controlled by either a 450 mm or a 1350 mm diameter cone valve. The 450 mm valve with a maximum discharge capacity of 200 ML/d is used for smaller flows. The larger valve has a maximum discharge capacity of around 1,800 ML/d and a minimum discharge capacity of 100 ML/d to avoid seal damage.

Lake Nillahcootie is unmanned with regulations generally occurring on a Monday, Wednesday or Friday when G-MW personnel are on-site.

- Figure 5 Lake Nillahcootie

D.3.2 Casey's Weir

Casey's Weir was constructed in 1885. It has a sill level of 157.27 m AHD and provides a pool for diversions into Broken Creek. The Broken Creek offtake at Casey's Weir can pass up to 210 ML/d into the Creek.

▪ **Figure 6 Casey's Weir**

▪ **Figure 7 Casey's Weir Offtake Gates to Broken Creek**

D.4 Upper Broken Creek

Upstream of Katamatite, diversions from the Broken River at Casey's Weir provide regulated flows in the Broken Creek. Current diversions are to meet demands of regulated diverters upstream of Waggarandall Weir, the Tungamah Stock and Domestic System, and the North East Regional Water Authority (NERWA) Townships of Devenish, Tungamah and St James. The Tungamah system demand will cease once the Tungamah Stock and Domestic pipeline has been completed, as will the NERWA demand once a pipeline from Yarrawonga is completed.

If unregulated inflows are insufficient to meet the diversion requirements, water is regulated on from the Broken storages to satisfy this demand. Once Lake Mokoan has been returned to a wetland, flows will be regulated from Lake Nillahcootie.

In the spring of 2005 an additional diversion to the Broken Creek was undertaken with the intention of passing it to the lower Broken Creek to assist in meeting environmental objectives. Flows diverted from the Broken River for this purpose were surplus to in-valley requirements.

- **Figure 8 Broken Creek downstream of Casey's Weir to flow monitoring station**

D.5 Lower Broken Creek

D.5.1 Inflow Sources

Regulated flow into the lower Broken Creek is sourced primarily from outfalls from the Murray Valley or Shepparton irrigation systems, and from the Creek's natural catchment. A total of eleven channel outfalls from the Murray Valley Area deliver water to the Broken Creek, of which, M.V. Channel 7/3 outfall has the greatest capacity. The 7/3 outfall has a capacity of 80 ML/d and can provide regulated flows into Broken Creek in around four days if channels are empty and there is no irrigation demand (David Derby, G-MW, pers comm.). The three outfalls of the number 6 channel can also be used to outfall up to 55 ML/d.

Inflows regulated from the Shepparton Irrigation Area come mainly from the East Goulburn Main Channel outfall although they can be regulated through other channels such as the EG No.12 Channel. Table 17 lists the channel outfalls to the Lower Broken Creek. The time required to regulate water at the EGM outfall can vary from 4 hours to 5 days (Peter Norden, G-MW, pers comm.). The timing of a change to regulated outfalls will depend on demands and channel levels at that time.

Regulated or unregulated flows from the upper Broken Creek will also provide flows to the lower Broken Creek. Regulated inflows from the upper Broken Creek are restricted to 30-40 ML/d due to limited channel capacity downstream, of Waggarandall Weir.

- **Table 17 Murray Valley and Shepparton Outfalls to Broken Creek**

Outfall Description	Water Source	Capacity (ML/d)
M.V. No. 7/3 Katy Creek	Murray Valley	80
M.V. 5/3	Murray Valley	10
M.V. No. 3	Murray Valley	10
4 Main	Murray Valley	10
M.V 6/6	Murray Valley	15
M.V. 4/8/6	Murray Valley	10
M.V. 8/6	Murray Valley	10
M.V. 15/6	Murray Valley	20
M.V. No. 6 Outfall 1. (Jewells Outfall)	Murray Valley	20
M.V. No. 6 Outfall 2. (Flanners Outfall)	Murray Valley	20
M.V. No. 6 Outfall 3. (End 6 Main)	Murray Valley	15
SP.E.G.NO. 12 Outfall 2. (Hollands Outfall)	Shepparton	10
E.G. No. 12 Outfall 1. (Hicks Outfall)	Shepparton	10
E.G. 34 (sum of 34 and 34 end)1	Shepparton	10
E.G. 38/12 Outfall	Shepparton	10
EGM Outfall	Shepparton	250+

Note: **1** - E.G. 34 Outfall flows enter the Broken Creek system through Shepparton Drain 13A

D.5.2 Broken Creek Weirs

A number of weirs on the lower Broken Creek downstream of Nathalia have been replaced/upgraded in the last ten years to provide fish passage and SCADA controlled overshot gates. The regulating gates on the automated weirs can pass up to 1,000 ML/d (David Derby, G-MW, pers.comm.). Earlier issues with regulating low flows have been reduced by only using 1 of the 2 automated gates for flows less than 200 ML/d. Operation of the fish passages is also automated.

Travel time from the East-Goulburn Main Channel offtake to Rice's Weir used in a 2003 SKM study to develop a daily flow model for the Broken Creek was approximately 10 days (SKM 2003). Advice from G-MW (David Derby, G-MW, pers.comm.) obtained for the current study indicates around 11 days. The 11 day estimate is based on operations prior to the upgrading of the weir structures. The installation of regulating gates may reduce travel times as the passing flow does not require the weir pool levels to build up. The travel time from Katamatite to Rice's Weir is around a day longer than the travel time from the East-Goulburn Main Channel to Rice's Weir.

- **Table 18 Lower Broken Creek Weirs**

Structure	Stage (m AHD)	Discharge (ML/day)
Chinaman's Weir	100.06	100.0
	100.061	1600.0
	100.24	2000.0
Balls Weir	99.11	100.0
	99.111	1200.0
	99.36	1600.0
	99.59	2000.0
Luckes Weir	98.19	100.0
	98.20	800.0
	98.23	1200.0
	98.73	2000.0
Hardings Weir	96.90	100.0
	96.91	400.0
	97.05	800.0
	97.38	1200.0
	97.66	1600.0
	97.89	2000.0
Schiers Weir	96.60	100.0
	96.61	400.0
	96.62	800.0
	96.75	1200.0
	97.02	1600.0
	97.24	2000.0
Kennedys Weir	96.10	100.0

Structure	Stage (m AHD)	Discharge (ML/day)
	96.11	400.0
	96.12	800.0
	96.22	1200.0
	96.47	1600.0
	96.69	2000.0
Rice's Weir	95.00	100.0
	95.01	400.0
	95.02	800.0
	95.03	1200.0
	95.24	1600.0
	95.43	2000

D.5.3 Lower Broken Creek Operating Guidelines

In 2003, G-MW developed a new set of operating guidelines (refer Goulburn-Murray Water 2003) in consultation with the Department of Primary Industries (DPI), the Department of Sustainability and Environment (DSE), the Goulburn Broken Catchment Management Authority (GBCMA), and the local community.

D.5.4 In Season Operation (15 August to 15 May)

During the irrigation season G-MW aims to operate the Broken Creek system to:

- provide a consistent pool level that allows entitlement holders to operate their pump installations
- maintain passing flows through the system for environmental requirements

To achieve these two objectives requires G-MW to operate to strategies that incorporate the management of diverters, operating the weirs in harmony, tracking of available supplements to the Broken Creek, and the monitoring of the system to identify and prevent environmental emergencies (G-MW 2003).

– **Table 19 - Key weir level information**

Weir	Crest Height (m AHD)	Fishway Minimum Operating Level (m AHD)	Minimum Pump Height (m AHD)	Minimum Operating Level (m AHD)	Maximum Operating Level* (m AHD)
Nathalia	100.77	100.48	100.49	100.50	**100.75**
Chinamans	100.06	100.04	99.88	100.06	100.06
Balls	99.11	99.09	97.93	99.11	99.11
Luckes	98.19	98.07	97.91	98.19	98.19

Hardings	96.90	96.88	96.89	96.90	**97.14**
Schiers	96.60	96.58	96.59	96.60	**96.76**
Kennedys	96.10	96.08	95.90	96.10	96.10
Rices	95.00	94.98	94.80	95.00	95.00

* **Maximum operating levels highlighted in BOLD for harvesting weirs, with harvesting storage volumes as follows:**
Nathalia Weir: 270 ML; Hardings Weir: 140 ML; Schiers Weir: 70 ML.

The ability of Nathalia, Hardings and Schiers Weirs to harvest water above their normal operating levels allows for the harvesting and re-regulation of flows in excess of downstream requirements in these pools.

D.5.5 Out of Season Operation (15 May to 15 August)

Out of the irrigation season the weirs are set to automatically operate at a target level which is generally lower than that required during the irrigation season. Toward the beginning of the irrigation season weir pool levels are generally gradually increased to in-season operating levels.

D.5.6 Fishway Operation

Nathalia Weir and the downstream weirs have fishways that pass 35 ML/d when levels exceed the minimum operating levels (refer Table 19). The Broken Creek operating rules aim to keep the fishways open whilst flows in the Creek exceed 35 ML/d, and to close them when flows fall below this and weir pools may commence to fall. Both the spillway gates and the fish ladders have automatic control and therefore can be immediately operated if flows and levels fall below target.

D.5.7 Flood Operation

Flooding in the Lower Broken River is not an uncommon occurrence and G-MW's Lower Broken Operational Guidelines (G-MW 2003) include discussion on the operation of the Lower Broken Creek during flood events. At and downstream of Nathalia the SCADA operated weirs will open until the gate capacity has been exceeded. Until gate capacities are exceeded there will only be minor increases in pool levels. Once gate discharge capacities are exceeded, increasing flows will be the dependent on the level that the pool is above the spillway crest. At Numurkah, Station Street and Melville Street weirs stop logs can be removed for larger floods according to the Numurkah flood management plan. Minor floods can pass these weirs without the need to remove the stop logs.

D.6 Flow Monitoring in Broken Creek

There is only 1 hydrographic gauging station (Table 15) in the Lower Broken Creek that would be available to monitor compliance with environmental flow recommendations. However Goulburn-Murray Water has operational measurement of flows at the automated weirs within the Broken Creek.

Hydrographic stations are available to measure the regulated flows to the Broken Creek from the East Goulburn Main (Station 405732) and flows entering from the upper Broken Creek via a gauging station at Katamatite (Station 404214). Flow measurement upstream of Katamatite exists on the Boosey Creek at Tungamah (Station 404204) and at the Broken Creek offtake at Caseys Weir (Station 404217). Goulburn-Murray Water has also established a gauging station at Waggarandall Weir on the Broken Creek to assist in determining system losses.

- **Table 20 - Goulburn Reaches for Environmental Flow Compliance - Hydrographic Stations**

		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Rohan Oliver – Thiess Kerang)**
1	Broken Creek	404210	Broken Creek @ Rices Weir	▪ Good site ▪ Ultrasonic flow meter

Figure 9 Broken Creek System

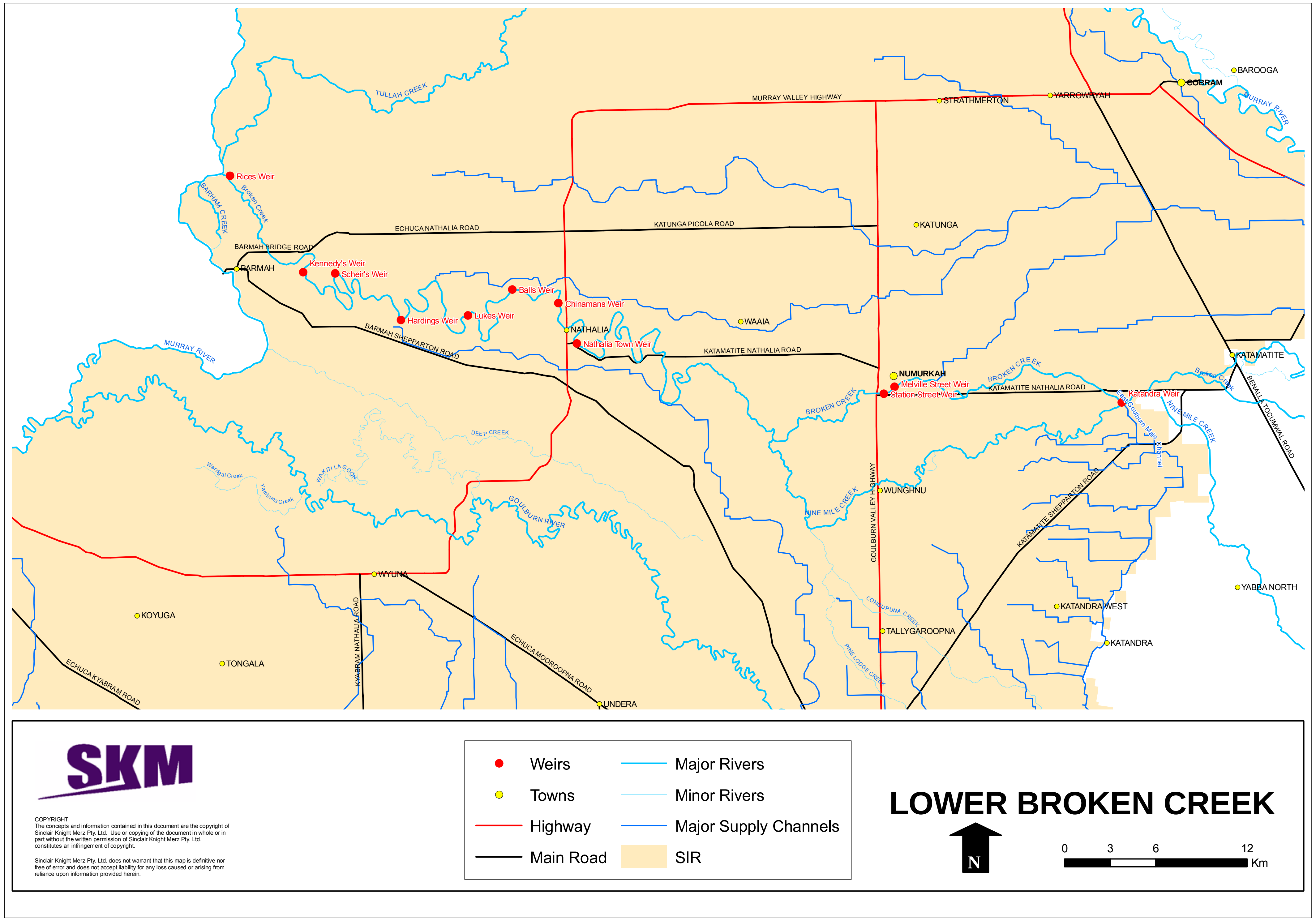
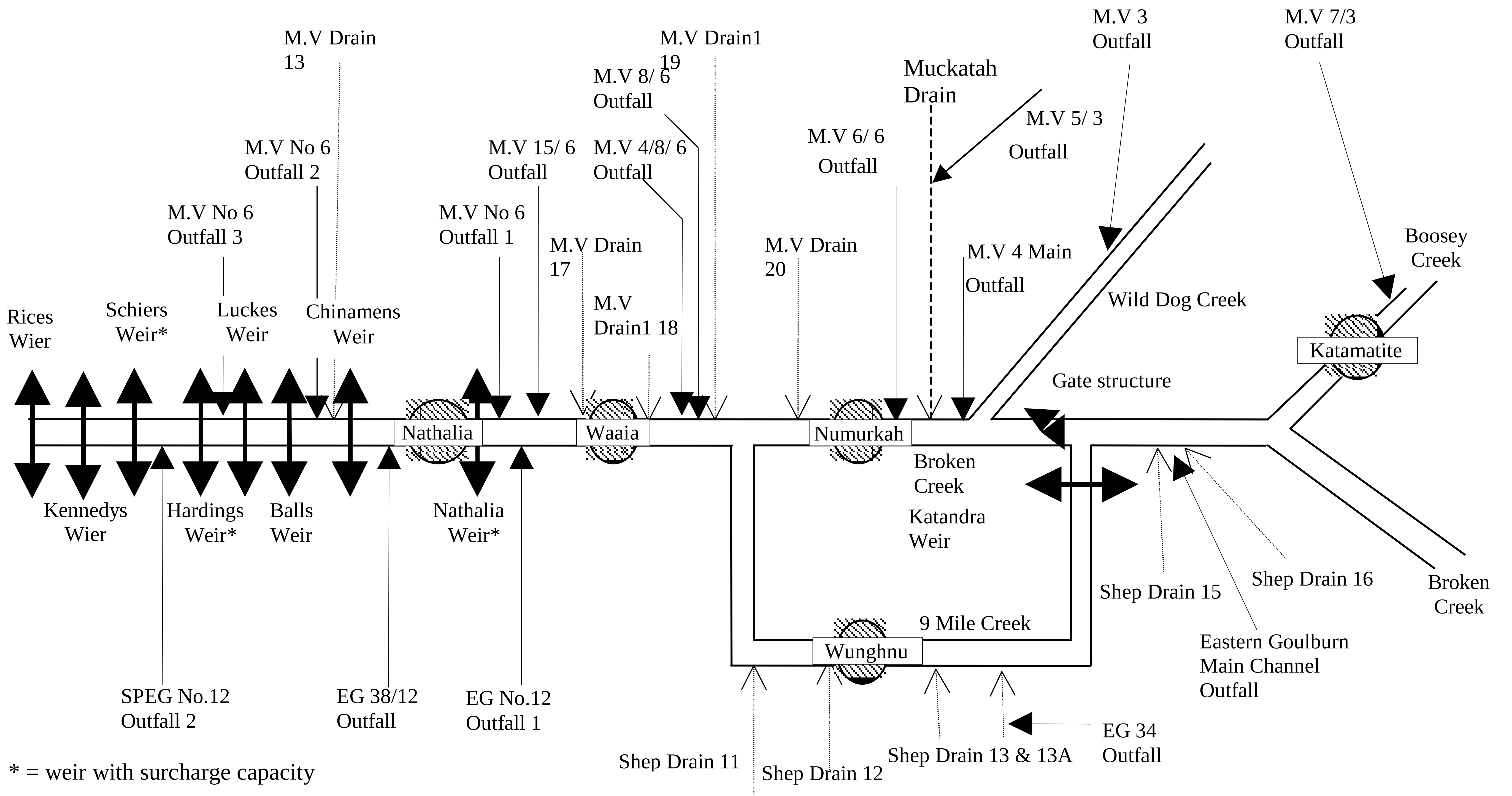


Figure 10 Broken Creek Schematic



* = weir with surcharge capacity

Appendix E Operation of Campaspe System

E.1 Campaspe Basin Overview

The Campaspe catchment covers an area of 517,150 ha (5,172 km^2). The Campaspe River has its headwaters in the Great Dividing Range and Wombat forest up to an altitude of 800 metres. It flows in a northerly direction for 160 km joining the River Murray at Echuca. The major tributary of the Campaspe River is the Coliban River, with McIvor and Wild Duck Creek being other significant tributaries flowing into Lake Eppalock. Downstream of Lake Eppalock the major tributaries of the Campaspe River are Axe and Mount Pleasant Creeks (G-MW 2005a).

The Campaspe Basin has two separate supply systems within it, the Coliban and Campaspe systems. The Coliban System based on the Coliban River supplies both urban and irrigation requirements and is operated by the Coliban Water Authority. The Campaspe System with resource impounded in Lake Eppalock is operated by Goulburn-Murray Water and supplies irrigation demands downstream of Lake Eppalock and part of the urban requirements of Bendigo. Resource in Lake Eppalock is shared between Goulburn-Murray Water and Coliban Water.

E.2 Campaspe Entitlements and Usage

Overall entitlements in the Campaspe System are defined in the Bulk Entitlement Conversion Orders held by Goulburn-Murray Water and Coliban Water. The entitlements at the time the Bulk Entitlements came into force are given in Table 21.

- **Table 21 Entitlement Volumes – Bulk Entitlement Conversion Orders**

Supply	Regulated Annual Water Licences: Water Right/ Licence Volume (ML)	Regulated Annual Water Licences: D&S (ML)	Other Entitlements (ML)
Goulburn-Murray Water			
Campaspe Irrigation District	19,564	1,155	
Eppalock to Campaspe Siphon	16,551		
Campaspe Siphon to River Murray	1,857[1]		
Coliban Water			
From Eppalock and Coliban Storages			50,260[2]
Goornong, Axedale			1578
Rochester			143

1. Defined as Partially Regulated in the Bulk Entitlement
2. Annual average over a 3 year period includes urban and rural customers, 17,440 of total can be taken from Eppalock

Trade since the bulk entitlement commenced has seen the total entitlement in the Campaspe Irrigation District fall from 20,719 ML to 20,280 ML at the start of the 2005/2006 irrigation season. Licence volume between Eppalock and the Campaspe Siphon has fallen from 16,551 to 16,330 ML in the same period.

G-MW's Campaspe Bulk Entitlement allows a supplement from the Campaspe System to the Goulburn System. Up to 4,000 ML of unregulated supplement and 24,700 ML of regulated supplement may be transferred to the Goulburn annually. The volume of regulated supplement available is related to the Campaspe system allocation as per Table 22. Supplements can be made by outfalling water from the Campaspe East and West channels to the Waranga Western Channel or via the Campaspe Pumps at Campaspe Siphon.

- **Table 22 - Regulated Supplement – Schedule 2 G-MW Campaspe BE**

Campaspe Irrigation District Allocation (% Water Right)	Supplement (ML/Annum)
<110	0
110-119	6,200
120-129	12,300
130-149	18,500
≥150	24,700

Usage from 2001/2002 to 2004/2005 is shown in Table 23. Low storage volumes since 2002/2003 have seen restrictions placed on water availability and subsequent low usage.

- **Table 23 Campaspe Usage 2001/2002 to 2004/2005**

Supply	2001/2002	2002/2003	2003/2004	2004/2005
Goulburn-Murray Water (IPM Database outputs)				
Campaspe Irrigation District	36,160	20,620	22,730	9,910
Eppalock to Campaspe Weir	14,270	9,170	8,910	4,020
Campaspe Weir to Campaspe Siphon	710	490	440	270
Campaspe Siphon to River Murray	1,680	1,110	850	160
Coliban Water (Annual Reports)				
From Eppalock and Coliban Storages	40,994	33,962	28,744	25,721
Goornong, Axedale	195	183	130	117
Rochester	443	230	240	135

E.3 Campaspe System Losses

E.3.1 Loss Estimates in Resource Planning Models

The Goulburn Simulation Model is used as the basis for long term modelling of the Goulburn System, including Campaspe River. The model incorporates transmission losses (due to evaporation and percolation to groundwater as examples) from Lake Eppalock to Campaspe Weir as approximately 4% of Eppalock releases. The model also incorporates operational losses at Campaspe Weir as 10% of the water supplied to irrigators and the WWC downstream of Campaspe Weir.

E.3.2 Seasonal Allocation Assessments

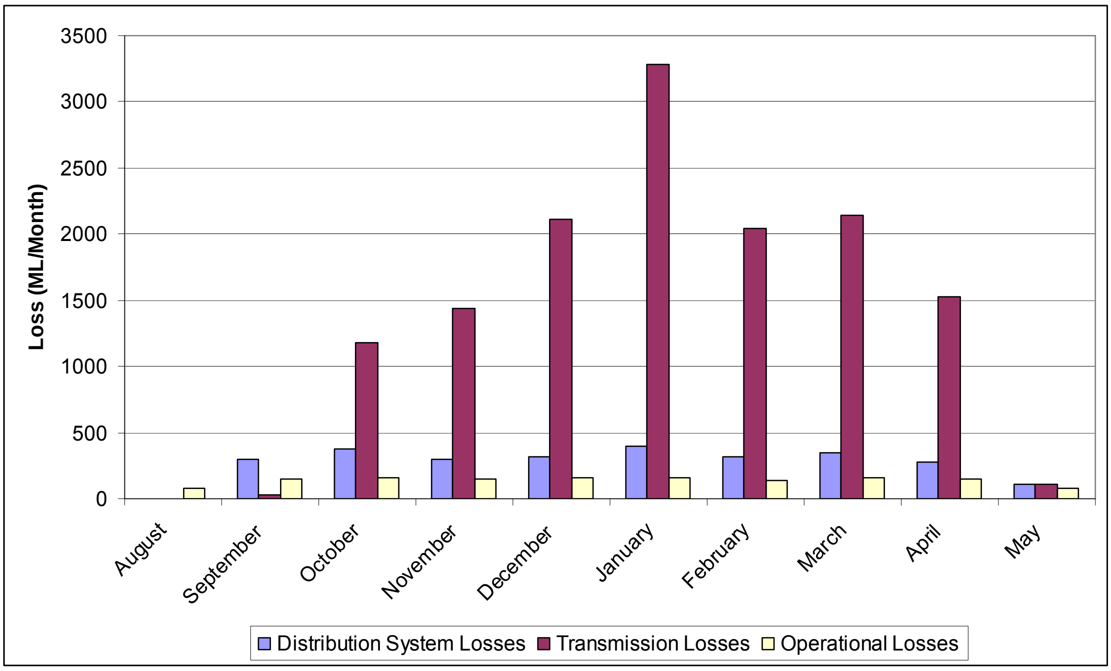
Seasonal allocation assessments for the Campaspe System included allowances for:

- River transmission losses in the Campaspe River
- The operational losses for the Campaspe River which are equal to the expected volume that is passed through the system in excess of delivery requirements. This is commonly needed to provide sufficient depth in the river to allow irrigators access to pump water.
- Distribution system losses within the Campaspe Irrigation District
- Evaporation losses from Lake Eppalock and Campaspe Weir related to storage level through surface area.

As with the other systems the losses used in the season allocation assessments are the expected worst case losses.

Figure 18 shows the monthly loss allowances for transmission, operational and distribution system losses. Transmission losses make up the majority of losses with an allowance of around 13,900 ML over the irrigation season. Transmission losses peak in January at around 3,300 ML/Month. Operational loss allowances remain at 5 ML/d over the season giving a total of around 1,400 ML over the season and around 150 ML/month. Expected maximum distribution system losses total around 2,800 ML for the season with a peak monthly loss of 400 ML in January.

▪ **Figure 11 – Campaspe System Seasonal Allocation Loss Allowances (G-MW 2006b)**



E.3.3 Loss Estimates in Operational Planning

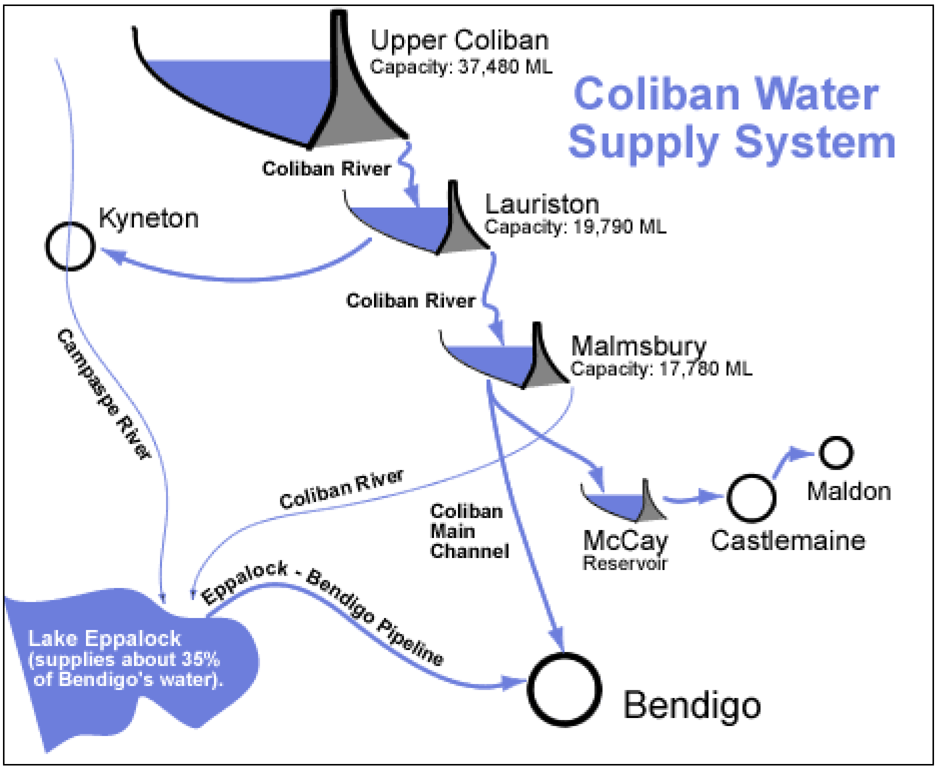
Daily loss estimation required for the determination of required releases from Lake Eppalock and Campaspe Weir are undertaken by Goulburn-Murray Water area staff, with the Regulated Systems Unit providing an overview of system performance. Losses used for daily planning are based largely on staff experience and current catchment conditions.

E.4 Coliban System

The Upper Coliban, Lauriston and Malmsbury storages store resource for the operation of the Coliban System. Resource in the three storages is used to supply:

- Bendigo via the Coliban Main Channel from Malmsbury Reservoir
- 14,700 ML of rural entitlement also from the Coliban Main and ancillary channels
- Castlemaine and Maldon from Malmsbury Reservoir via the McCay reservoir
- Kyneton on the Campaspe River from Lauriston Reservoir

Rural entitlement allocations are determined in spring along with any requirement to restrict urban demands. Rural usage accounts for around 40% of Coliban Water's available water for the Bendigo area (DSE 2006)



- **Figure 12 Coliban System of Waterworks (http://www.coliban.com.au/reservoirs/set_reservoirs.html)**

E.4.1 Upper Coliban

Furthest upstream is the Upper Coliban storage, the largest of the three storages with a full supply capacity of some 37,480 ML. There are no environmental minimum flow requirements downstream of this storage. Upper Coliban has a free overfall fixed crest spillway and two low level outlets, each capable of releasing from 20 ML/d to 190 Ml/d.

E.4.2 Lauriston

The Upper Coliban storage effectively discharges into the tailwater of Lauriston Reservoir. Lauriston has a capacity of 19,800 ML, with a gated spillway comprising ten 2.7 metre high gates and two 650 mm diameter low levels outlets. Each outlet has a capacity that ranges from approximately 50 ML/d to 450 ML/d.

E.4.3 Malmsbury

Around 3 km downstream of Lauriston is Malmsbury Reservoir with a capacity of 17,780 ML. Coliban Water's Bulk Entitlement Conversion Order for the Campaspe system provides for a minimum flow downstream of Malmsbury of 8 ML/d or natural.

Malmsbury has a gated spillway comprising nine gates extending 1.5 m to 2.1 m below the Full Supply Level. Gate 2, which extends 2.1 m below FSL releases the first 3,085 ML/d. Above 3,085 ML/d, other gates are progressively opened until the maximum discharge of 33,120 ML/d at FSL is achieved. The spillway gates can be used to release low flows for limited periods. Extended low flow releases can result in damage to the gate seals.

Discharges to the Coliban Main Channel are via a 750 mm diameter cone valve or a 200 mm conduit supplied from the main 1,200 mm outlet conduit. The 200 mm conduit, which has an estimated discharge capacity of around 10-15 ML/d, was installed to meet the environmental flow minimum releases. Discharges from the main valve can range from 45 ML/d to 260 ML/d.

Discharges to the River from the Coliban Main Channel are achieved via a 300 mm outlet from the Channel around 200 metres downstream of the valves. It is estimated that up to 30 ML/d could be released to the River via this outlet. It is estimated a further 100 ML/d could be released to the River via a scour outlet downstream of the Malmsbury township. Works on the scour outlet structure to reduce occupational health and safety risks, in particular the risk of a slips, trips and falls and manual operation, would be required before it could safely be used.

- **Figure 13 Malmsbury Outlet to Coliban Main Channel**

E.5 Lake Eppalock

E.5.1 General Information

Lake Eppalock is situated on the Campaspe River, impounding 312,000 ML at its Full Supply Level of 193.910 m AHD. The dam, constructed in the 1960's, is formed by a 700 metre long earth and rock fill embankment with a fixed crest, free overfall, concrete main spillway of 141,900 ML/d capacity. A secondary spillway with a crest level of 195.74 m AHD and 161,500 ML/d capacity, and a tertiary spillway with a crest level of 197.57 m AHD and 46,500 ML/d capacity, pass flows in larger flood events.

The resource in Lake Eppalock is shared between Goulburn-Murray Water and Coliban Water. G-MW has access to 82% of the capacity of the storage with Coliban Water accessing the remaining 18%. Inflows into the storage are shared in the same ratio as the storage capacity. The available resource for each authority is continuously accounted for by G-MW as the appointed storage operator.

- **Figure 14 Lake Eppalock**

E.5.2 Outlet Works

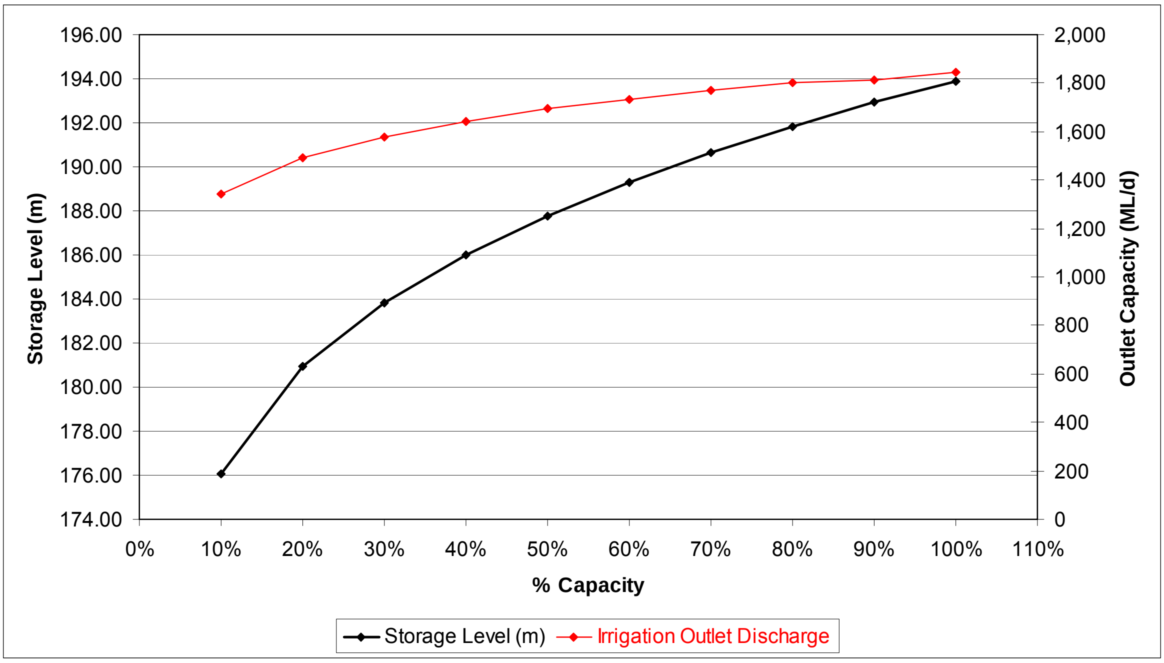
Regulated discharges to the Campaspe River can be made by an 1150 mm cone dispersion valve or through the Coliban pump station. At full supply the valve can discharge around 1,850 ML/d to the river.

The pump station is comprised of three turbines that can utilise releases to pump water to Bendigo via a pipeline. A minimum flow of 120 ML/d is required to operate one turbine with a maximum flow through all turbines of 750 ML/d. Around 90 ML/d can be pumped to Bendigo when the maximum flow is being passed through the turbines. When the turbine pumps are unavailable, an electric powered pump of 30 ML/d capacity is utilised to supply Bendigo. The lowest level that a turbine has been operated to is 179 m AHD (46,730 ML, 15% Capacity)

- **Table 24 Maximum Discharge to River Through Pump Station Turbines**

Number of Turbines	1	2	3
Discharge Capacity (ML/d)	250	520	750

- **Figure 15 Lake Eppalock – 1150 mm Irrigation Outlet Discharge Capacity**



Source: G-MW Plan 102170

E.5.3 Eppalock Releases to River

The volume of regulated release required at Lake Eppalock is based on the collation of ordered water for the Campaspe Irrigation District, diversion licence holders on the Campaspe River, supplementary supplies to the Waranga Western Channel and any passing flow requirement.

Once downstream demands are determined the actual release will also take into account expected losses and any unregulated inflows downstream of the storage. Travel time from Lake Eppalock to Campaspe Weir is in the order of 2 days (G-MW 2005a)

E.6 Campaspe Weir

Campaspe Weir provides a pool to supply the Campaspe East and Campaspe West channels. Releases downstream of the Weir supply private diverters between the Weir and the Murray River, and required minimum flows at Campaspe Siphon. The weir pool has a capacity of approximately 2,626 ML at a Full Supply Level of 120.42 m AHD.

The G-MW Campaspe Bulk Entitlement allows up to 270 ML/d to be diverted to the Campaspe West area through the Campaspe No. 1 offtake and 105 ML/d to the Campaspe East area through the Campaspe No. 2 offtake.

In years of high allocation the pool has generally been operated to a maximum of 100 mm below the Full Supply Level. In years of low allocation the weir pool has been able to be operated between 200-300 mm below Full Supply Level. Being able to operate the weir pool below FSL allows re-regulation of inflows to the weir reducing losses from the regulated system.

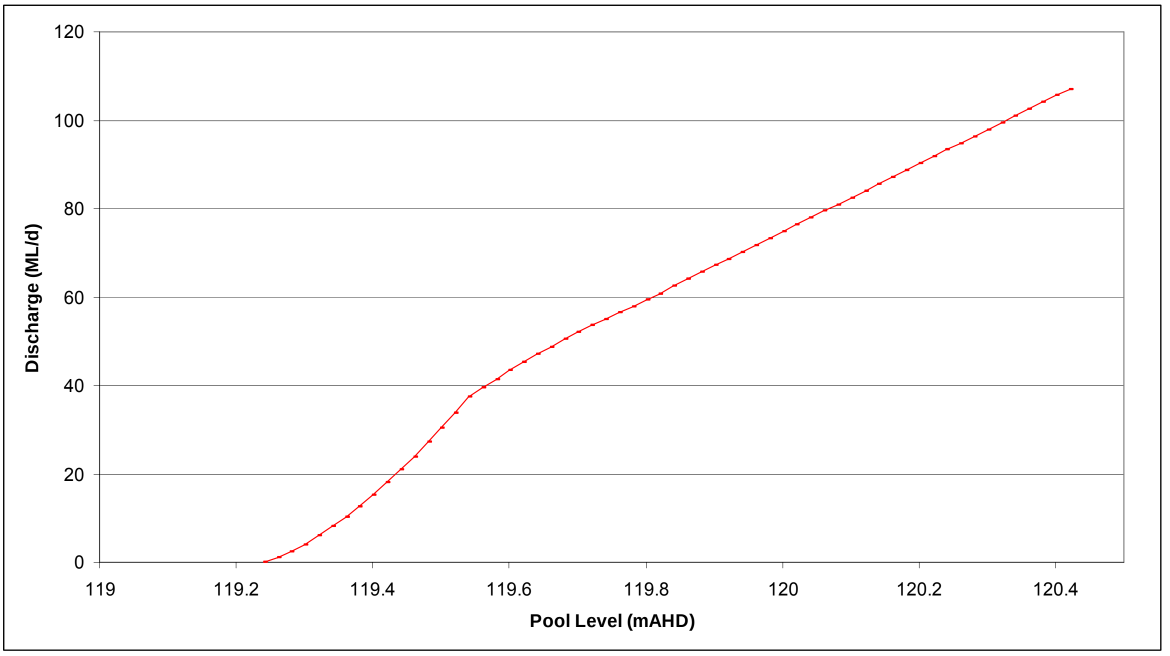
The discharge capacity of the Campaspe No 2 offtake is more sensitive to pool level fluctuations at Campaspe Weir, and defines how far below FSL the weir pool can be operated. Table 25 provides details of the offtake sill levels and supply levels at the first downstream regulator for each offtake. In the 2003/2004 season the weir pool was operated down to 119.95 m AHD, however offtake diversions were only 8 ML/d at the No 1 offtake and 15 ML/d at the No 2 offtake.

- **Table 25 Campaspe 1 and 2 Offtakes**

Heading	Campaspe 1 (West)	Campaspe 2 (East)
Sill Level (m AHD)	117.76	119.08
Weir Volume at Sill Level (ML)	737	1,486
Supply level at 1st regulator (m AHD)	119.54	119.69
Allowable BE Diversion Rates (ML/d)	270	105

A regulating structure at Campaspe Weir allows flows to be passed downstream flows when the weir is not spilling. The sill of the regulating structure is 119.06 m AHD with a corresponding weir pool volume of 1,472 ML. At FSL a maximum discharge of 107 ML/d can be made through the gate; Figure 16 shows the maximum discharge through the gate over its operating range.

■ **Figure 16 Campaspe Weir Regulating Structure – Gate Rating**



Source: G-MW Document Reference 1391167 v2

Supplements from the Campaspe to the Goulburn can be diverted from Campaspe Weir, through the Campaspe Irrigation District and outfalled to the Waranga Western Channel. With no in-system capacity constraints, up to 50 ML/d could be discharged via the Campaspe 1 (West) the Campaspe 2 (East) channels.

E.7 Campaspe Siphon

Diversions from the Campaspe River to supplement flows in the WWC are achieved by a pump station that can divert up to 500 ML/d. These flows will be called on if there is resource available from the Campaspe System, and WWC downstream demands exceed what can be supplied by upstream sources.

Campaspe River flows downstream of the siphon could be supplement by outfalling water from the WWC. The WWC outfall structure comprises 5 regulating gates that have been traditionally used to outfall water due to rainfall rejections, or to pass inflows from Wanalta and Cornella Creeks. It is estimated that under free flow conditions up to 2,300 ML/d could be outfalled from WWC to the Campaspe River, although previous operation manuals defined a maximum release of 1,470 ML/d. In recent years small outfalls have been passed to provide flow in the Campaspe River downstream of the Siphon, to be passed to the River Murray.

Irrigation requirements downstream of the Campaspe Siphon are defined as partially regulated. Prior to the introduction of minimum flows passing the Campaspe Siphon, a targeted flow of 15 ML/d was passed downstream to provide access to water by private diverters.

E.8 Flow Monitoring in the Campaspe System

E.8.1 Coliban River

Flows downstream of Malmsbury Reservoir were measured by a hydrographic station until 2000. Gauging station 406215 (Coliban River @ Lyal) measures the discharge from Malmsbury Reservoir, and Sandy and Myrtle Creeks, which are the major tributaries of the Coliban River in this reach.

E.8.2 Campaspe River

Upstream of Eppalock

Gauging station 406213 on the Campaspe River at Redesdale measures the majority of flows entering Lake Eppalock. The gauged flows from the Coliban system provide the majority of the remainder.

Lake Eppalock to Campaspe Weir

Flows entering the upstream end of reach 2 are measured by a gauging station close to the Lake Eppalock outlet works. Axe, Mt Pleasant and Forest Creeks are the three major tributaries entering the Campaspe River between Lake Eppalock and Campaspe Weir. Axe Creek and Mt Pleasant Creek both have gauging stations as listed in Table 12. Mt Pleasant and Forest Creeks are ephemeral streams and as such the major impact on Campaspe River hydrology is from Axe Creek (SKM 2006).

Flows downstream of the Axe and Forest Creeks confluences are measured at gauging station 406201 at Barnadown.

▪ **Table 26 – Tributary Gauging Stations Downstream of Eppalock**

Stream	Gauging Stations	
	Station Id	Station Name
Axe Creek	406214	Axe Creek @ Longlea
Mt Pleasant Creek	406224	Mount Pleasant Creek @ Runnymede

Campaspe River downstream of Campaspe Weir

Flows entering reach 3 are measured at Campaspe Weir. There are no intermediate flow measurement sites in reach 3, nor any significant tributary inflows.

▪ Table 27 - Campaspe System - Gauging Stations in Reaches With Environmental Flow Recommendations

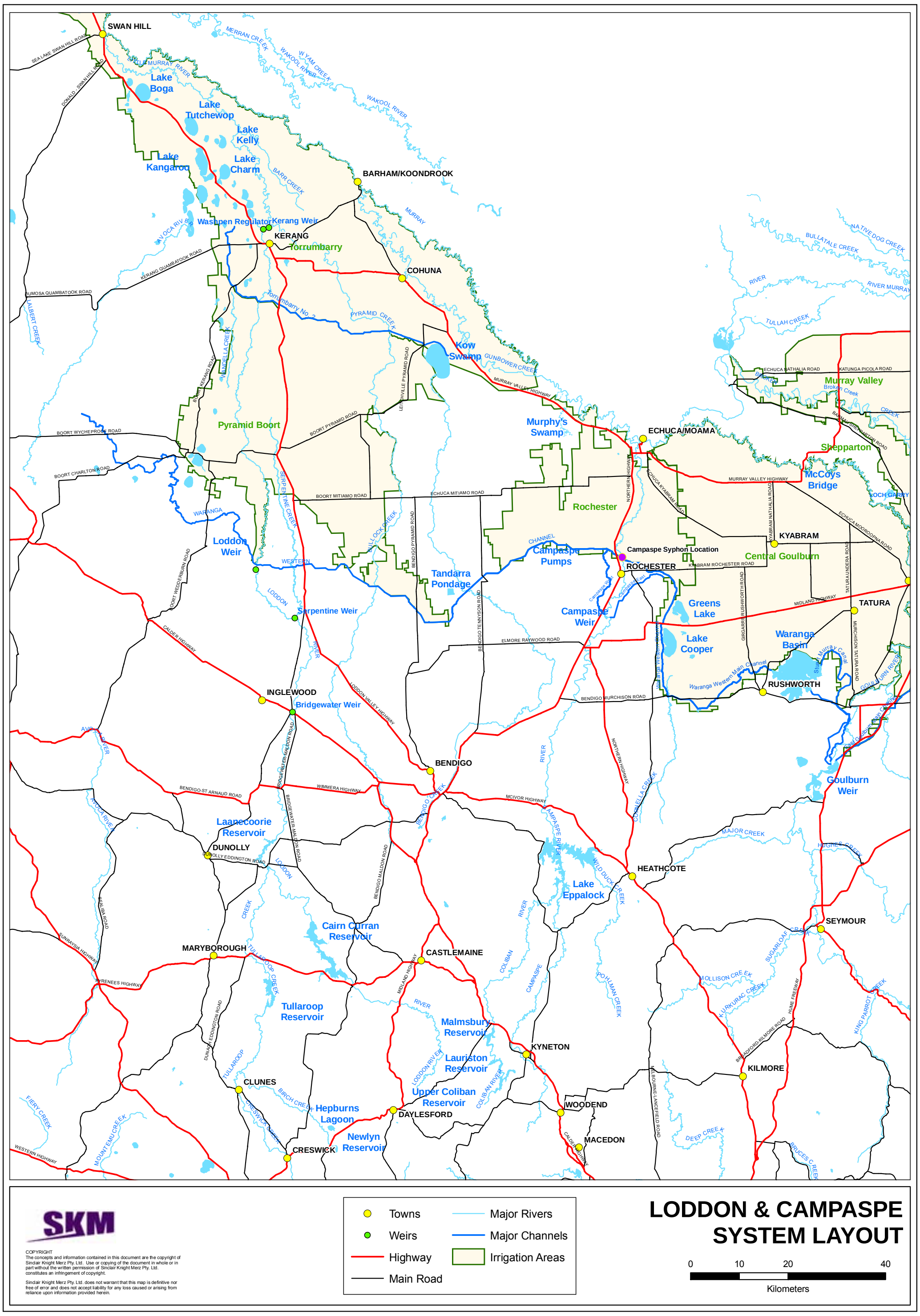
		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Leon Tepper – Thiess Tatura)**
Reach 1	*Coliban River: Malmsbury Reservoir to Lake Eppalock* *A – Lyal Road (main conformance point)* *B – Phillips Road (checking point U/S of A)*	406215	Coliban River @ Lyal	▪ Good site
Reach 2	*Campaspe River: Lake Eppalock to Campaspe Weir* *A – Doakes Reserve (main conformance point)* *B – English's Bridge (checking point D/S of At)*	406225	Campaspe River @ Lake Eppalock (Outlet Measuring Weir)	▪ Measuring weir allows good measurement of regulated releases from outlet works
		406219	Campaspe River @ Lake Eppalock (Head gauge)	▪ Storage level allows for calculation of spillway discharge
		406207	Campaspe River @ Eppalock	▪ Adequate measurement for higher flows when Lake Eppalock is spilling
		406201	Campaspe River @ Barnadown	▪ measurement OK when flows are within channel capacity ▪ poor access limits flow measurement for overbank flows ▪ some issues of public interference with site
Reach 3	*Campaspe River: Campaspe Weir to Campaspe Siphon*	406203	Campaspe River @ Campaspe Weir	▪ Thiess records height but no measurement of flow
Reach 4	*Campaspe River: Campaspe Siphon to the River Murray*	406202	Campaspe River @ Rochester (Campaspe Siphon)	▪ Measurement currently OK. ▪ Proposed installation of a fish ladder may lead to measurement issues
Living Murray contribution	*Conformance assessed at Reach 4*	406265	Campaspe River @ Echuca	▪ Good measurement when River Murray at normal summer levels. ▪ If River Murray levels high causes backup

E.9 Irrigation Outfalls - Campaspe River

Table 28 lists outfalls from the Rochester Irrigation District listed in Appendix N as having their final destination as the Loddon River. In addition there is one spur channel in the Campaspe Irrigation District that also outfalls into the Campaspe River. The majority of outfalls from the Campaspe Irrigation District enter the Waranga Western Channel.

Table 28 – Rochester Irrigation System Outfalls

Outfall	Channels
Direct to Campaspe River	RO12, RO1/14, RO2/1/3/14
To Drain 4	RO2/11
To Rochester Main Drain	RO3/14
Drain 1A/2	RO1/3/14



■ **Figure 17 Loddon Campaspe System**

Appendix F Operation of Loddon System

F.1 Loddon Overview

The Loddon River has a total catchment of 15,320 km^2 with the three main streams being the Loddon River, Tullaroop Creek and Bet Bet Creek. Cairn Curran, Tullaroop and Laanecoorie are the major water storages on the Loddon River. Resource from the Loddon is used to supply regulated diversion entitlements upstream of Loddon Weir, and to provide supplements to the Boort Irrigation District if sufficient water is in store.

The Birches (Bullarook) Creek System is located upstream of Tullaroop Reservoir. It comprises two storages (Newlyn Reservoir and Hepburn Lagoon) which supply regulated irrigation entitlements directly from the storage and down to Lawrence Weir on Birches Creek. Spills from the two storages will result in inflows to Tullaroop Reservoir.

Downstream of Laanecoorie a number of weirs are in place to allow water to be diverted from the river. Loddon Weir, Serpentine Weir and Bridgewater Weir are directly used to divert water from the upstream storages. Kerang Weir below Loddon Weir interacts with the Torrumbarry Irrigation Area.

On average, inflows to Cairn Curran are twice that to Tullaroop. As the storage volumes are a similar ratio the storage volumes are operated in harmony to equalise the chance of filling. Therefore on average Cairn Curran releases are twice that of Tullaroop.

F.2 Loddon Entitlements and Allocations

The Birches (Bullarook) Creek system supplies 909 ML of regulated entitlement. The total entitlement includes 100 ML reserved for the urban centres of Springhill and Clunes. The needs of the townships are generally fulfilled by groundwater, and there is seldom a need to access the 100 ML reserve. Bulk entitlements for this system are being developed.

Entitlements to water in the Loddon System are defined by the Loddon Bulk Entitlement Conversion Orders gazetted in November 2005. Table 29 gives the volumes of entitlement defined in the Loddon System Bulk Entitlement Conversion orders which may be restricted by seasonal allocations.

- **Table 29 Entitlement Volumes – Potential Restriction through Allocation Process**

	Regulated Annual Water Licences		Other Entitlements (ML)
Supply	Licence (ML)	D&S (ML)	
Cairn Curran Dam to	1468.0	154.0	

Supply	Regulated Annual Water Licences Licence (ML)	D&S (ML)	Other Entitlements (ML)
Laanecoorie Reservoir			
Tullaroop Dam to Laanecoorie Reservoir	3028.5	28.0	
Laanecoorie Reservoir to Bridgewater	6642.4	170.0	
Bridgewater to Loddon Weir (incl Serpentine Ck)	10044.5	160.0	
East Loddon Water Works District		1,600[1]	
Coliban Water			820
Central Highlands			1,200
Wetland Entitlement			2,000

1. Annual average over a 3 year period

Seasonal allocations for licensed entitlement holders in the Loddon System are linked to the Goulburn System under some circumstances. If the Goulburn System allocation is less than 100% of entitlement, then the Loddon allocation cannot exceed the Goulburn allocation. Sales allocations in the Loddon commence when the Goulburn allocation reaches 110% and remain 10% less than the Goulburn allocation. Table 30 gives the maximum Loddon allocation for different Goulburn allocations.

- **Table 30 Loddon Bulk Entitlement Allocation Relationships**

Goulburn Allocation (%Water Right)	0	50	100	110	150	170	200
Loddon Allocation for Irrigation Licensees (% Licence Volume)	0	50	100	100	140	160	190

Different restrictions apply to other entitlements in the Loddon System:

- The Wetland Entitlement is restricted by the seasonal allocation if allocations are less than or equal to 100% but restricted to 100% of entitlement if seasonal allocations are greater than 100%.
- Coliban and Central Highlands water usage and Stock and Domestic, and the East Loddon Waterworks District, are restricted to:
  1) 50% of their entitlement if the seasonal allocation is less than 50%
  2) To the same ratio as the seasonal allocation from 50% to 100%
  3) A maximum of 100% if the seasonal allocation is greater than 100%

The Bulk Entitlement Conversions Orders also define entitlements, where access is not governed by seasonal allocations. These entitlements are:

- An account in Cairn Curran and Tullaroop Reservoirs to provide water for river freshening flows
- The deficit-reimbursement account in Cairn Curran. The account accrues water when Cairn Curran and Tullaroop's total volume is less than 60,000 ML, when minimum flows are reduced and allows reimbursement of this water once the total storage volume exceeds 80,000 ML.
- A carryover volume of urban entitlement in Tullaroop
- Carryover of unused wetland entitlement

Water can be made available to the Boort Irrigation Area if there is sufficient reserve in store to meet high reliability rights in the current and following irrigation seasons. Volumes of reserve shown in Table 31 are defined in the Loddon BE and once exceeded, diversion to the Boort Irrigation Area can be made. The releases can assist in alleviate channel capacity constraints in the Waranga Western Channel or to assist in maximising resource in the Goulburn system.

- **Table 31 Reserves in Loddon Storages to Allow Goulburn Supplement**

Month	Reserve (ML)
January	73,000
February	66,000
March	56,000
April	56,000
May	56,000
June	89,000
July	89,000
August	89,000
September	88,000
October	86,000
November	82,000
December	78,000

Allocations in the Loddon System in 2002/2003 and 2003/04 were less than 100% of licensed volume. The bulk of usage has occurred downstream of Laanecoorie Weir as shown in Table 32.

- **Table 32 Usage in the Loddon System**

Supply	2001/2002	2002/2003	2003/2004	2004/2005
Bullarook/Birches Creek	1148	954	755	846
Cairn Curran Dam to Laanecoorie Reservoir	1261	818	821	1026
Tullaroop Dam to Laanecoorie Reservoir	650	239	273	284
Laanecoorie Reservoir to Bridgewater	4304	2708	3192	3381
Bridgewater to Loddon Weir (incl Serpentine Ck)	7860	4683	6280	7453
Coliban Water[1]	N/A	509	460	516
Central Highlands[2]	N/A	N/A	863	1,000

1. From Coliban Water Annual Report. No figure for 2001/2002.

2. From State Water Account. No figures for 2001/2002 and 2002/2003

F.3 Loddon System Losses

F.3.1 Birches/Bullarook

F.3.2 Loss Estimates in Resource Planning Models

In the Birches Creek REALM model, losses are included into Reach 4, downstream of Lawrence Weir reach (upstream of Tullaroop Reservoir). The losses here are calculated as a percentage of the flow upstream, depending on the scale of the flow, such that:

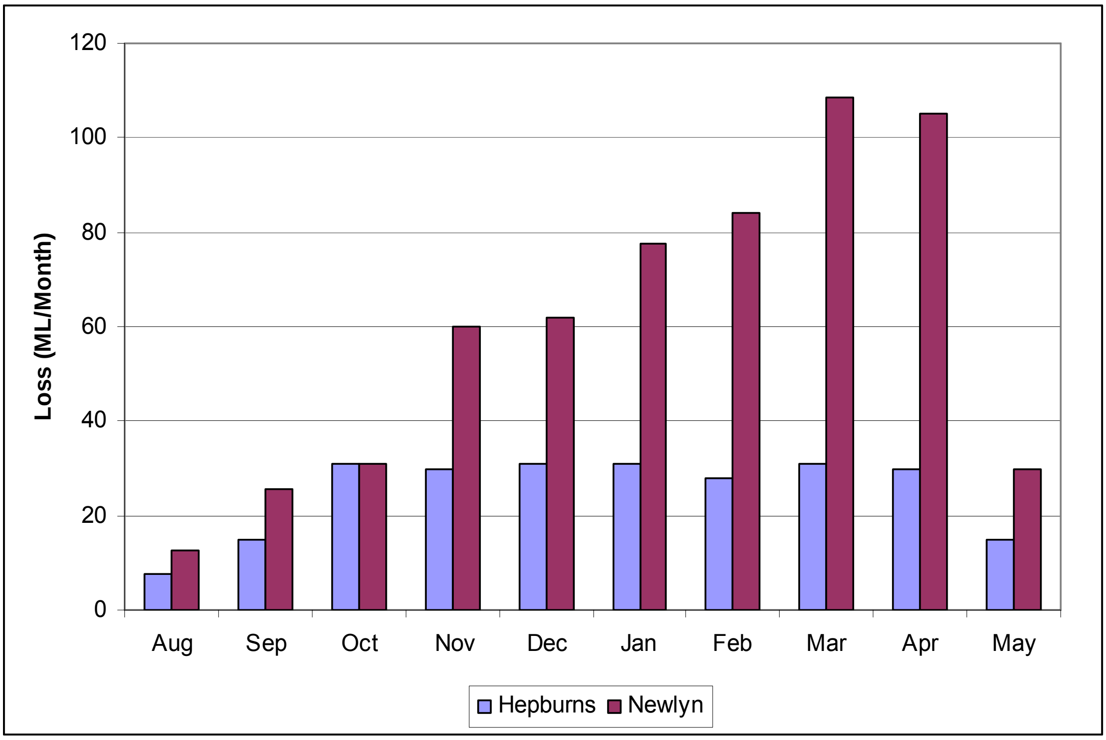
- If the flow upstream is greater than 100 (ML/month), loss = 5% of the upstream flow
- If the flow upstream is less than 100 (ML/month), loss = 25% of the upstream flow

F.3.3 Seasonal Allocation Loss Allowance

Seasonal allocation assessments for the Bullarook System include loss allowances for:

- River transmission losses met from Newlyn water
- Operational losses allowances from Hepburn Lagoon and Newlyn Reservoirs
- Evaporation losses from storages related to storage level through surface area

Figure 18 shows the monthly allowances for losses to be met from each of the storages. Losses from Hepburn Lagoon are assumed to be a constant 1 ML/d. Losses from Newlyn peak in March at around 110 ML for the month.



F.3.4 Loddon System

F.3.5 Loss Estimates in Resource Planning Models

The Goulburn Simulation Model is used as the basis for long term modelling of the Goulburn System, including the Loddon River. The model incorporates river losses at:

- Tullaroop Creek, from Tullaroop Reservoir to Laanecoorie Weir, as 2 % of flow
- Loddon River from Cairn Curran to Laanecoorie as 2% of flow.

The model also incorporates operational losses downstream of Loddon Weir as flows supplied to the WWC from Loddon River. This has a maximum capacity of 260 ML/month.

No mechanisms have been included in the GSM model to calculate and incorporate losses at Kerang and Serpentine Weirs.

F.3.6 Bulk Entitlement

The Loddon Environmental Reserve Bulk Entitlement (DSE 2005) includes loss allowances in the calculation of natural inflows. Natural flow calculations use upstream gauged flows to estimate flows under a natural regime.

For flows passing Laanecoorie weir the percentage of upstream inflows lost are given by:

$Loss_{U/SLaan} = 13.25*((1.1*Q_{nat\ CC} + 1.2*(1.1*Q_{nat\ Tul} + Q_{407213}) + 1.1*Q_{407211})*30.4)^{-0.61541}$ expressed as a percentage

Where:
$Loss_{U/SLaan}$ = Loss factor upstream of Laanecoorie
Q_{natcc} = Natural flow at Cairn Curran
Q_{natTul} = Natural flow at Tullaroop
Q_{407213} = Flow measured at hydrographic station 407213, McCallums Creek at Carisbrook
Q_{407211} = Flow measured at hydrographic gauging station 407211, Bet Bet Creek at Bet Bet

The loss between Laanecoorie Weir and Serpentine Weir

$loss_{\%u/sSerp}$ = the lower of [{0.75525 - 0.065666*ln($Q_{nat\ Laan}$*30.4)} expressed as a percentage or 40%].

Where:
$loss_{\%u/sSerp}$ = loss between Laanecoorie Weir and Serpentine Weir
$Q_{natLaan}$ = calculated natural flow passing Laanecoorie Weir

Loss calculation between Loddon Weir and Kerang Weir

$loss_{lod\text{-}ker\ weir}$= the lower of [{0.75525 - 0.065666*ln($Q_{Lod\ Weir}$ *30.4)} expressed as a percentage or 40%].

Where:

$Loss_{lod\text{-}kerweir}$ = loss between Loddon Weir and Kerang Weir

F.3.7 Seasonal Allocation Loss Allowance

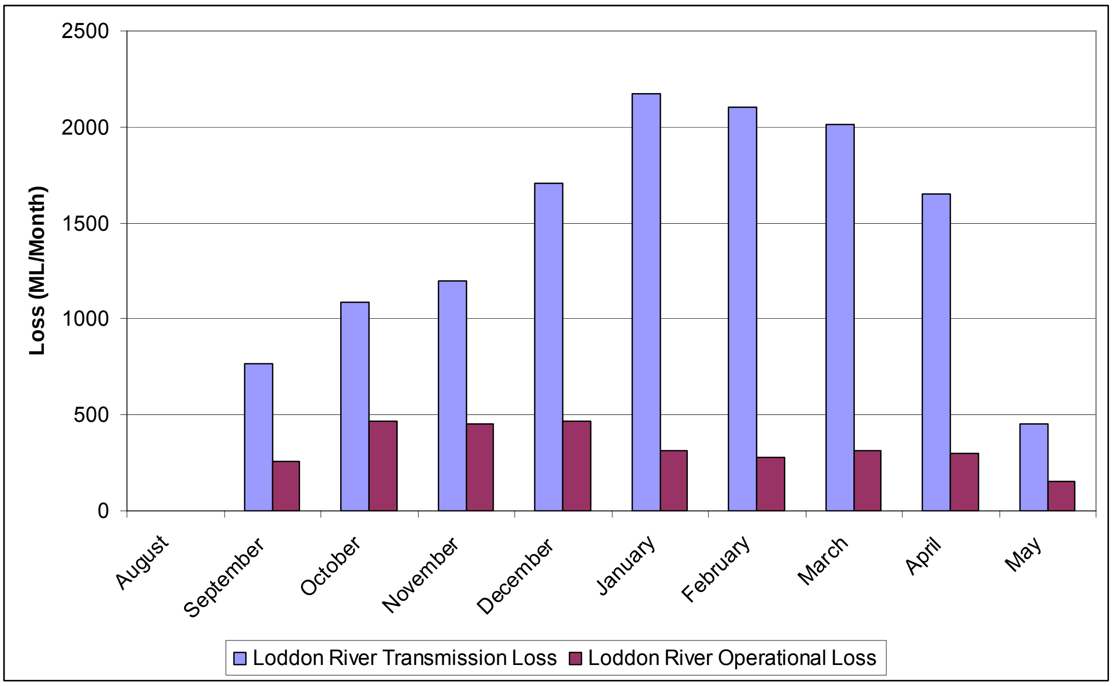
Seasonal allocation assessments for the Loddon System included allowances for:

- River transmission losses in the Loddon River and Tullaroop Creek
- Operational losses for the Loddon River

- Evaporation losses from Cairn Curran, Tullaroop and Laanecoorie Weir related to storage level through surface area

Figure 18 shows the monthly allowances for transmission and operational losses. Transmission losses make up the majority of losses with an allowance of around 14,400 ML over the irrigation season. Transmission losses peak in January at around 2,200 ML/Month. Operational loss allowances total around 3,400 ML over the season, peaking at 470 ML/month during October.

- **Figure 18 – Loddon System Seasonal Allocation Loss Allowances (G-MW 2006c)**



F.3.8 Loss Estimates in Operational Planning

Loss estimation in operational planning is carried out by Goulburn-Murray Water Area and Diversion staff. The Regulated Systems Unit within the Catchment and Planning Group provides an overview of the system performance.

F.4 Newlyn Reservoir

Located north-east of Ballarat, Newlyn Reservoir is formed by an earth fill embankment and a concrete ogee crest spillway. At its nominal Full Supply Level of 532.09 m AHD Newlyn Reservoir holds 3,300 ML. However this level was only obtained by the installation of flash boards on its spillway. As the flash boards are no longer operated the operating full supply is 531.79 m AHD (2,970 ML), the level of the spillway crest.

At the Full Supply Level a discharge of 35 ML/d can be made through the outlet works. Goulburn-Murray Water's operational planning expects the peak average daily use to occur in January with an average of 11 ML/d being released (G-MW 2005c). In recent years the storage has been drawn downs to around 16% (500 ML) of capacity. At these low levels G-MW has been able to discharge 5 ML/d to meet downstream irrigation demands.

F.5 Hepburn Lagoon

Hepburn Lagoon situated 33 km north of Ballarat, impounds 2,500 ML at its Full Supply Level of 516.04 m AHD. The main embankment is on Langdons Creek with the pool backing up over a saddle to merge with a pool formed by a dam at the head of the Old Mill Race Creek (SKM 2002). A concrete, free overfall spillway is located on the larger embankment.

Until recently the Full Supply Level of the storage was 516.54 m AHD (3,000 ML). A recent dam safety review ascertained that the spillway capacity was insufficient, with subsequent works reducing the crest level of the spillway by 0.5 m.

The practical minimum operating level for Hepburn Lagoon outlet is around 10% storage capacity. At minimum operating level around 1 ML/d can be released through the outlet compared to 25 ML/d at FSL. It should be noted that the storage has been drawn down below the 10% capacity in the recent years by excavating a link channel between the two pools and the outlet works.

Peak average daily release from Hepburn from G-MW operational planning is around 4.2 ML/d during January (G-MW 2005).

F.6 Cairn Curran Reservoir

F.6.1 General Overview

Cairn Curran Reservoir on the Loddon River near Maldon was completed in 1956. At its full supply level of 208.46 mAHD it has a capacity of 148,760 ML and has a water surface area of 1,900 hectares. The main embankment is an earth and rock fill structure having a total length of 656 metres and a maximum height of 34.9 metres (G-MW 2006).

The primary spillway at Cairn Curran has a sill level of 200.23 m AHD (42,660 ML) and three radial gates for flood release. At FSL a flow through the primary spillway of around 140,000 ML/d can be achieved with all gates open. Flows over a secondary spillway formed by a natural saddle two kilometres from the main embankment commence once the storage level rises above 209.80 m AHD. At the crest level of the emergency spillway around 172,000 ML/d will be passing through the primary spillway with all gates open (G-MW 2006). At the crest level of the main embankment (211.36 m AHD) the emergency spillway will be passing around 70,000 ML/d and the main spillway 212,000 ML/d (G-MW 2006).

- Figure 19 Cairn Curran Reservoir Spillway Gates

F.6.2 Outlet Works

Discharges from the storage can be achieved via:

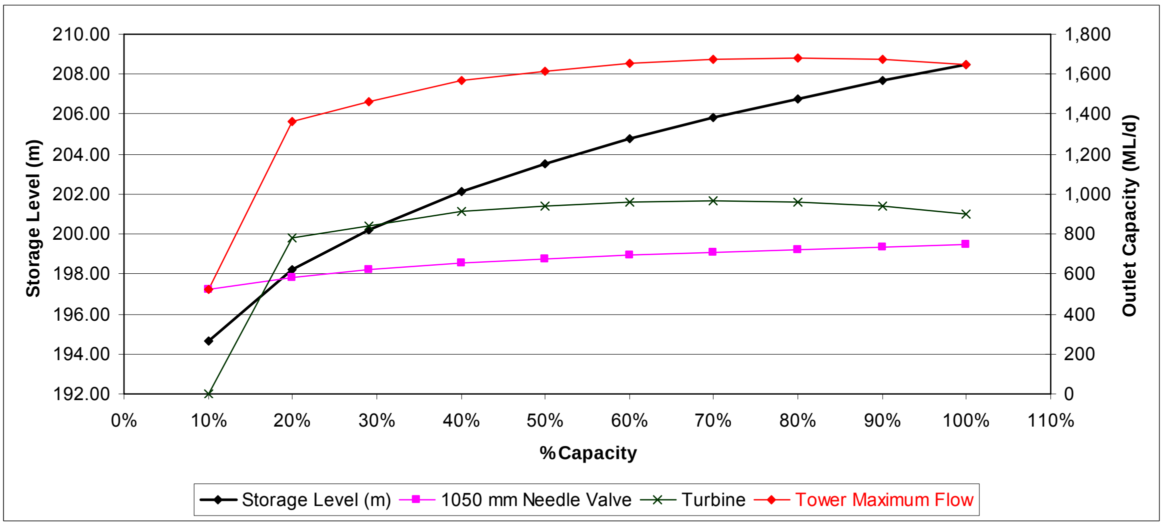
- An 1,050 conduit via a needle valve irrigation outlet to the river for irrigation releases
- An 1,800 mm conduit to a 2 MW power station
- The spillway gates.

Releases of less than 220 ML/d need to be passed through the irrigation outlet valve. Once releases reach 220 ML/d the minimum discharge capacity for the hydro station is exceeded and, AGL Hydro is given the option of passing the releases through its turbines. Once required discharges exceed the hydro station capacity, around 810 ML/d at FSL, releases are again made through the irrigation outlet. Operation of the turbines has shown that the discharge capacity of 810 ML/d at FSL is lower than shown on the plan used to calculate the figures shown in Figure 20.

Once flows exceed the combined hydro station and irrigation outlet capacity, the irrigation outlet can be closed and releases made through the spillway gates. The minimum opening for the spillway gates is 100 mm for short term releases; for continuous releases a gate opening of 200 mm is recommended. At FSL a gate opening of 200 mm corresponds to a flow of 720 ML/d through 1 gate (G-MW 2006)

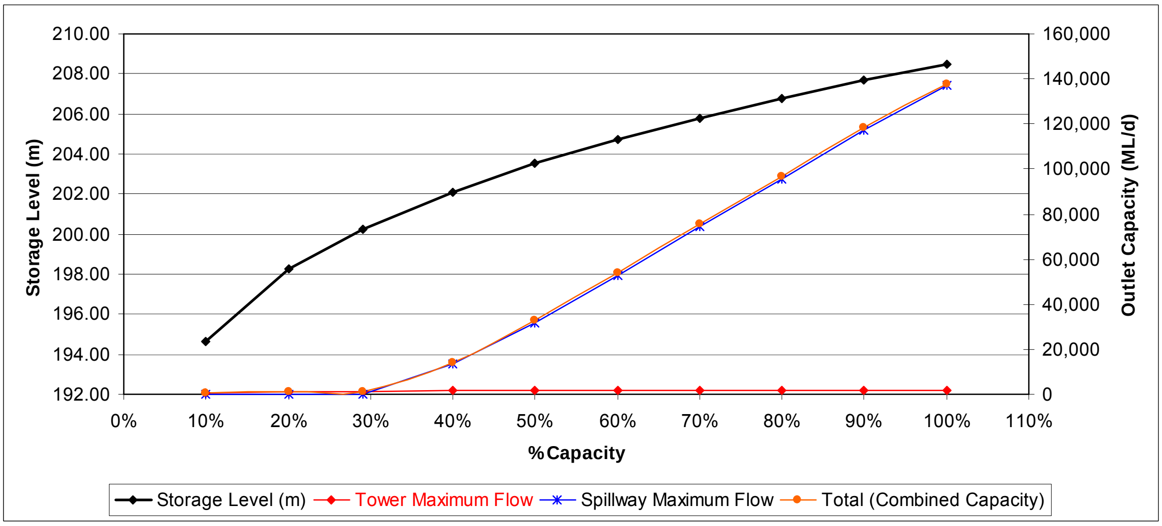
The location of Laanecoorie downstream of Cairn Curran provides some flexibility in operation of the power station. High short term releases can be re-regulated at the downstream storage. During the low resource period in recent years, small periods of high releases have occurred to assist in maintaining the turbines.

- **Figure 20 Cairn Curran Outlet Tower Release Capacity**



Source: G-MW Plan 102172 – 1,050mm valve, Plan 98249 Turbine

- **Figure 21 Total Cairn Curran Release Capacity**



Source: Spillway G-MW Cairn Curran Flood Operations Manual

F.6.3 Release Requirements

Releases from Cairn Curran are made up of allowances for:

- Private diverter irrigation demand between Cairn Curran and Laanecoorie
- Any release available under the provisions of the Loddon Environmental Bulk Entitlement. These will be called out by the Environmental Manager, currently the North Central Catchment Management Authority.
- Release to be passed to Laanecoorie Weir
- Allowance for losses between Cairn Curran and Laanecoorie
- Allowances for unregulated inflows between Cairn Curran and Laanecoorie.

The balance of releases to Laanecoorie from Cairn Curran and Tullaroop is based on equalising their chances of spilling. These releases will also be influenced by Laanecoorie target storage volumes.

F.6.4 Cairn Curran Flood Operations

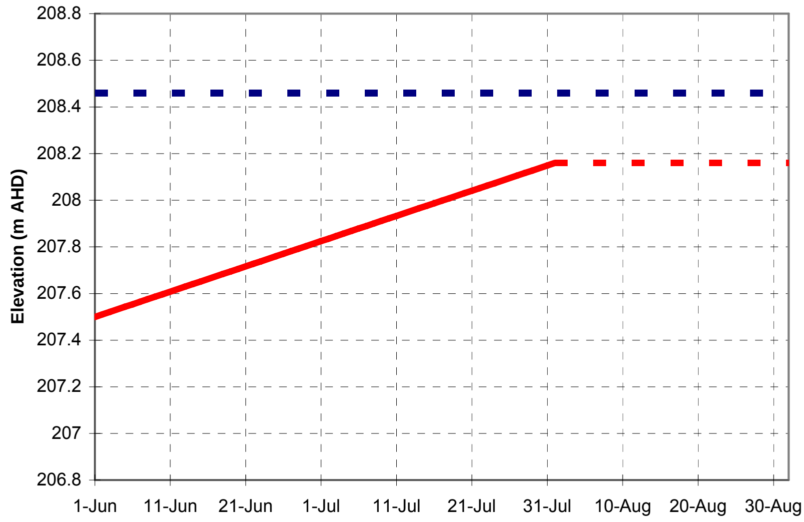
Flood operations at Cairn Curran are primarily based around dam safety, with a secondary goal of mitigating floods. Once it is determined that an inflow event is sufficient for Cairn Curran to increase to target levels or FSL, flood operation procedures come into force.

Targeted maximum rate of rise for flood releases is 1,500 ML/d/hr up to the bank full capacity of 8,000 ML/d; minor flooding occurs at 2.0 m (6,000 ML/d). However for significant events this rate may be exceeded for dam safety reasons. Generally releases should be below inflows unless the flood peak has passed, or the storage has reached FSL (G-MW 2006).

There no defined rate of fall following a flood peak. To reduce the chance of slumping, rates of fall at the same rate or slower than the natural hydrograph recession should be targeted once flows fall below bank capacity.

Target filling curve for Cairn Curran Reservoir between 1 June and 30 August is shown on Figure 22. The storage is maintained close to the target filling curve to provide airspace for flood mitigation. When levels in the storage exceed the target filling curve during June and July, pre-releases are made to provide this airspace. From 1 August storage filling is governed by seasonal conditions including irrigation demand. G-MW operates the reservoir with an aim to have it at FSL just prior to the commencement of the irrigation season or an irrigation demand emerging depending on seasonal conditions.

▪ **Figure 22 Cairn Curran Reservoir Target Filling Curve**



(Source: G-MW Flood operating guidelines)

F.7 Tullaroop Reservoir

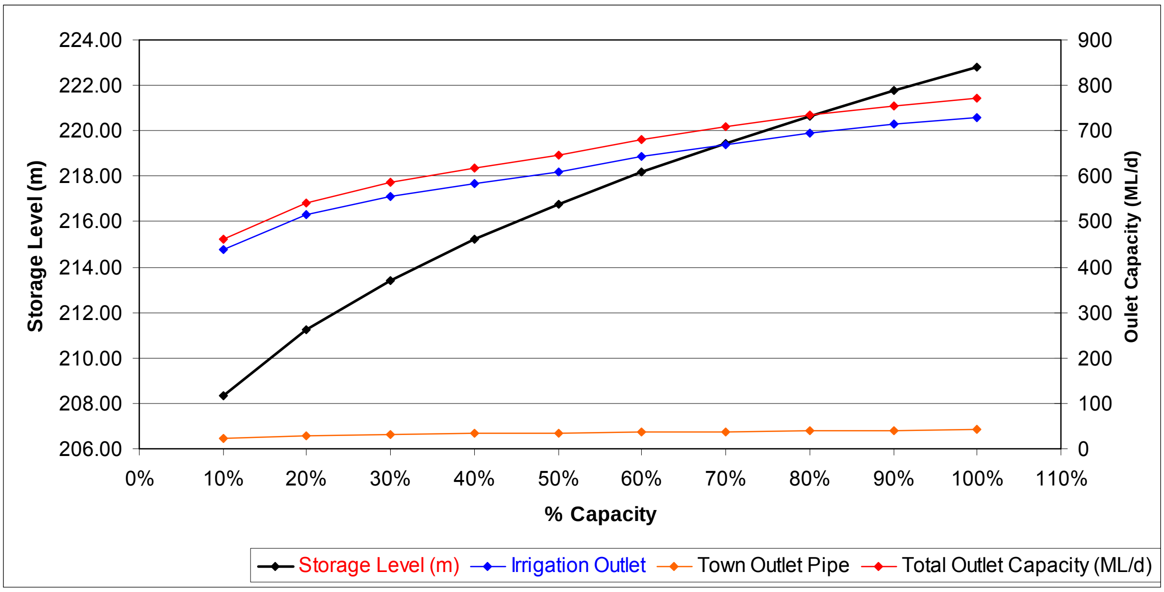
F.7.1 General Overview

Tullaroop Reservoir was completed in 1959 and has a capacity of 73,690 ML at 222.80 m AHD. The dam consists of an earthen and rock fill main embankment and a concrete free overfall main spillway with a discharge capacity of 70,950 ML/d. Regulated releases can be made via a 1,050 mm irrigation conduit or a 375 mm conduit for urban supply. The urban conduit also supplies a pump from which water is pumped Maryborough and is generally not available to make downstream releases.

F.7.2 Outlet Works

According to the stage-discharge relationship plan the irrigation outlet works can pass 730 ML/d when the storage is at FSL, while the urban outlet can pass 42 ML/d. An actual release of 730 to 740 ML/d has been achieved through the outlet valves though currently the maximum discharge is restricted to 450 ML/d due to vibration in the outlet works. The lowest intake on the outlet tower for the irrigation valve has a centreline of 206.2 m AHD (5% capacity) with the lowest urban intake having a centreline of 205.7 m AHD (4% capacity).

■ **Figure 23 Tullaroop – Outlet Discharge Capacity**



F.7.3 Release Requirements

Required releases from Tullaroop are made up of:

- Demand from entitlement holders between Tullaroop and Laanecoorie
- Any call on water available to the environment by the Loddon Environmental BE. Requests for release will be made by the nominated Environmental Manager who, in the Loddon system, is the North Central Catchment Management Authority.
- Releases to be passed to Laanecoorie Weir
- Allowance for losses between Tullaroop and Laanecoorie
- Allowances for unregulated inflows between Tullaroop and Laanecoorie.

As noted above, the balance of releases to Laanecoorie from Cairn Curran and Tullaroop is based on equalising their chances of spilling. These releases will also be influenced by Laanecoorie target storage volumes.

F.8 Laanecoorie Weir

F.8.1 Overview and Outlet Works

Laanecoorie Weir was completed in 1891, and was enlarged to the current dimensions in 1935. Full supply level of the storage is at 160.20 m AHD. Capacity at FSL is 7,930 ML. The concrete spillway is topped by 234 tilting gates that allow water to flow both over and under them once FSL is exceeded. Four irrigation valves in the spillway structure enable around 1,300 ML/d of regulated discharge downstream of the storage.

- Figure 24 Laanecoorie Weir

F.8.2 Determination of Downstream Releases

Required releases from Laanecoorie are made up of:

- Loddon entitlement holder demands downstream of Laanecoorie
- Any call on water available to the environment by the Loddon Environmental BE. Requests for release will be made by the nominated Environmental Manager who, in the Loddon system, as noted previously, is the North Central Catchment Management Authority.
- Any Boort Irrigation Area supplement requirement at Loddon Weir
- Allowance for losses downstream of Laanecoorie

F.8.3 Determination of Regulated Inflow Requirement

Laanecoorie provides the ability to re-regulate releases from Cairn Curran and Tullaroop and also provides opportunities to harvest additional resource. During recent irrigation seasons a minimum operating target at Laanecoorie of 4,000 ML has been used. Previously, with more resource in the system, it was operated down to 5,000 ML during the irrigation season. If inflows result in Laanecoorie exceeding the target level the additional resource in Laanecoorie is used to meet downstream flow requirements. Toward the end of the irrigation season Laanecoorie is usually drawn down to sill level (158.65 m AHD, 2,940 ML). In recent years with low resources in the upper storages Laanecoorie has been drawn down lower than the sill level. The timing of the drawdown is dependent on providing irrigators on the weir pool with access via their pumps while demands remain.

F.9 Loddon (Fernihurst) Weir

The Waranga Western Channel, supplied by Goulburn resource from Waranga Basin and supplemented by the Campaspe System, uses the Loddon Weir pool to pass resource across the Loddon River. The capacity of the WWC upstream of Loddon Weir is only 550 ML/d where it outfalls into Loddon Weir, but it has the capacity to divert 1,100 ML/d into the Boort Irrigation Area. The utilisation of the increased capacity to the west of Loddon Weir requires supplement from the Loddon System.

Diversion Licence holders between Loddon Weir and Kerang Weir are defined as unregulated with no releases from Loddon Weir being made to meet any irrigation requirements. Regulated releases from Loddon Weir are made to meet environmental flow requirements defined in the Environmental Bulk Entitlement Conversion Order.

A proposed 2006 project to refurbish a number of gates includes the installation of an overshot gate that improves Goulburn-Murray Water's ability to regulate flows of up to 70 ML/d downstream of Loddon Weir. This gate will overcome the existing constraints in meeting the environmental flow requirements of the Loddon Environmental Bulk Entitlement, below 70 ML/d.

Before the BE minimum flow rules came into force the minimum flow passing Loddon Weir was controlled by an orifice cut into one gate that passed 7 ML/d when the weir was at FSL. Flows would be less than 7 ML/d when the weir was operated below FSL or when debris was caught in the orifice. Accurate regulation of flows above 7 ML/d was difficult to achieve using the undershot gates.

In the process of installation of the one overshot gate mentioned above, all remaining 27 undershot gates are to be automated. The gates at Loddon Weir have been designed to be able to pass a flow of 3,500 ML/d, with the overshot gate having a capacity to pass up to 1,000 ML/d in a flood event. However as tail water levels increase the capacity of the gates falls to around 350 ML/d (Bill Viney, G-MW, pers.comm.).

▪ **Figure 25 Loddon Weir – Looking at upstream side of structure**

F.10 Other Weirs

F.10.1 Serpentine Weir

Serpentine Weir is a concrete structure with a design crest level of 113.42 m AHD (accuracy of this level currently under review). Under natural conditions a moderate flow down the Loddon River would see flows entering Serpentine Creek. Serpentine Weir allows diversions to be made to Serpentine Creek under lower regulated flow conditions. Regulated diversions to Serpentine Creek are used to meet Loddon diverter requirements and can be used to supplement supply to the Pyramid Hill Irrigation Area.

Regulated flows of up to 150 ML/d have been made to Serpentine Creek during years with high allocations and demand. Maximum regulated diversions generally occur in March and April.

Goulburn-Murray Water is planning to install a regulating door at an opening in the weir. This side opening door will have an opening of 600 mm which will allow around 36 ML/d to be regulated downstream if the pool level is below crest level.

- **Figure 26 Serpentine Weir**

F.10.2 Bridgewater Weir

Bridgewater Weir is a fixed crest weir approximately 180 metres in length, located near the Calder Highway crossing of the Loddon River northwest of Bendigo. It provides a pool from which water is diverted to the East Loddon Waterworks District. A race provides water to an historical flour mill for fire fighting purposes, at a rate of 8 to 10 ML/d. This water returns to the Loddon River downstream of Bridgewater Weir (Dale McGraw, G-MW, pers.comm.).

- **Figure 27 Bridgewater Weir – Looking East toward Centre of Weir**

F.10.3 Kerang Weir

Kerang Weir is a fixed crest weir (Ian Hetherington, G-MW, pers.comm.) with a minimum discharge level of 75.15 m AHD (SRWSC 1983). The structure comprises 14 no. 1.82 metre wide bays.

Inflows to Kerang Weir are via the Torrumbarry System from Pyramid Creek, the Torrumbarry No. 2 channel and the upper Loddon River. Regulated flows to supply demands from or below Kerang Weir are sourced from the Torrumbarry System.

Kerang Weir creates a pool that allows up to 850 ML/d to be regulated to the Kerang Lake system through the Washpen regulator. Around 100 ML/d is passed downstream of Kerang Weir to supply private diverters downstream (SRWSC 1983).

Regulated flows of up to 1,000 ML/d can be passed to Pyramid Creek from Kow Swamp via Box Creek. Up to 1,170 ML/d can be released from Kow Swamp to supply the Torrumbarry No 2 channel with 500 ML/d able to be outfalled from the channel to the Loddon River via an automated regulating gate.

F.11 Loddon Catchment Flooding

F.11.1 Upstream of Loddon Weir

High flows into Laanecoorie will be a result of flows in Bet Bet Creek, unregulated spills at Tullaroop and flood operations at Cairn Curran. If below FSL, Laanecoorie Weir may provide some mitigation of flood peaks. At Serpentine Weir, high flows see water spilling from the Loddon River into Serpentine Creek. Serpentine Creek flows will flow back into the Loddon River at Kerang Weir after flowing down the Nine-Mile Creek and then Pyramid Creek.

F.11.2 Downstream of Loddon Weir

Downstream of Loddon Weir flood operations are aimed at passing flood flows north to the Murray River and mitigating flood peaks by regulating water into the Kerang Lakes System (SRWSC 1983). Flood waters spill from the main Loddon River into anabranches and distributaries channel downstream of Loddon Weir. The proportion of spill varies with flow but commence when flows downstream of Loddon Weir exceed 1,600 ML/d (SRWSC 1983).

A proportion of the flood flows to Kerang Weir can be diverted to the Kerang Lakes via the Washpen regulator. However regulated flows need to consider the volumes already in the Lakes, and any other inflows to the Lakes including flows from Wandella Creek, Sheepwash Creek, the Avoca River, and the available capacity of the No 7 outfall to the Little Murray River. Flows to Sheepwash Creek commence once the level at Kerang Weir exceeds 75.59 m AHD (SRWSC 1983).

F.12 Flow Monitoring in the Loddon System

F.12.1 Birches Creek

In the Birches/Bullarook Creek system hydrographic stations are located in reach 2 and reach 4. There is no hydrographic station in reach 1 but Goulburn-Murray Water has access via SCADA to Newlyn Reservoir releases.

F.12.2 Upstream of Cairn Curran and Tullaroop

The Environmental Reserve Bulk Entitlement Conversion Order uses a number of gauges upstream of Cairn Curran and Tullaroop Reservoirs for natural flow estimation. Upstream of Cairn Curran the gauges used for natural flow calculations are:

- Station 407215 – Loddon River at Newstead
- Station 407230 – Joyces Creek at Strathlea
- Station 407239 – Middle Creek at Rodborough

Other gauging stations upstream of Cairn Curran include stations 407217 - Loddon River at Vaughan, 407221 - Jim Crow Creek @ Yandoit and 407300 Muckleford Ck @ Muckleford.

Stations 407215, 407230 are connected to Goulburn-Murray Water's SCADA system. Stations 407221, 407217 and 407300 have access via telemetry.

Upstream of Tullaroop the flows measured at station 407222, Tullaroop Ck at Clunes are used in equations for natural flow estimation.

F.12.3 From Cairn Curran and Tullaroop to Laanecoorie

Discharges from Cairn Curran are measured by a gauging station downstream of the storage. Regulated discharges from Tullaroop are measured by a gauging station downstream of the outlet works and spills are determined by measurement of the storage level and applying a discharge relationship for the spillway.

Natural flow calculations at Laanecoorie include the estimated natural flow at Cairn Curran and Tullaroop plus an allowance for unregulated tributary inflows. Tributary inflows are based on the gauged flows on Bet Bet Creek at Bet Bet (Station 407211) and McCallums Ck at Carisbrook (station 407213).

F.12.4 From Laanecoorie to Loddon Weir

For environmental flow recommendation purposes, the Loddon River from Laanecoorie to Loddon Weir has been subdivided into reaches 3a and 3b. Flows are gauged downstream of Laanecoorie (station 407203) at the upstream end of reach 3a, and at Serpentine Weir (station 407229) at the upstream end of reach 3b.

F.12.5 Downstream of Loddon Weir

Environmental flow recommendations have been developed for two reaches below Loddon Weir. Reach 4 extends from Loddon Weir to Kerang Weir, with reach 5 continuing down to the River Murray confluence.

Flows into reach 4 are measured at site 407224, the Loddon River downstream of Loddon Weir. A gauging station at Appin South (station 407205) provides an intermediate measure of Loddon River flows.

A gauging station at Kerang Weir (station 407202) measures the flow passing into reach 5. There are no further active gauging stations downstream to measure flows into the River Murray.

▪ Table 33 Gauging Stations in Birches Creek

		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Rohan Oliver – Thiess Kerang)**
1	Birches Creek: Newlyn Reservoir to Hepburn Race			
2	Birches Creek: Hepburn Race to Lawrence weir	407227	Birch Creek @ Smeaton	▪ Good site for flow measurement ▪ Broad Crested Control
3	Birches Creek: Lawrence weir to Creswick Creek confluence			
4	Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir	407222	Tullaroop Creek @ Clunes	▪ Good site and has telemetry) ▪ flows impacted on by treated wastewater

▪ Table 34- Gauging Stations in Loddon System

		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Rohan Oliver – Thiess Kerang)**
1	Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir	407210	Loddon River @ Cairn Curran Reservoir	▪ a good site in general ~500 m downstream of outlets ▪ issue occurs when G-MW needs to undertake work on their outlet. Drain water through pipes in the control structure. Requires re-rating once works complete
2	Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir	407244 407248	Tullaroop Creek @ Tullaroop Reservoir (Head Gauge) Tullaroop Creek @ Tullaroop Res. (Outlet Meas. Weir)	▪ Spillway discharge calculated from level ▪ Out of water at low levels ▪ good – broad crested – knife edge ▪ G-MW SCADA
3a	Loddon River: Laanecoorie	407203	Loddon River @ Laanecoorie	▪ Problem site due to the gauge being immediately downstream weir and the control 2

		Relevant Hydrographic Stations		
Reach Number	**Reach Description**	**Site ID**	**Site Name**	**Adequacy of Gauge (pers comm. Rohan Oliver – Thiess Kerang)**
	Reservoir to Serpentine Weir			km downstream ▪ Hard to gain an effective measure of flow due to time to reflect flow change and diversions between Laanecoorie and the control
3b	Loddon River: Serpentine Weir to Loddon Weir	407229	Loddon River @ Serpentine Weir	▪ The door in the structure has leaked causing issues with the rating. ▪ Installation of a slide door will require door openings to be monitored
4	Loddon River: Loddon Weir to Kerang Weir	407224	Loddon River @ Loddon Weir	▪ Good as a new control (knife edge) has been installed and will increase sensitivity ▪ Issue: Telemark reads to nearest 1 cm
		407205	Loddon River @ Appin South	▪ Good at very low flows (5 ML/d) ▪ Even at flows of 10-15 ML/d control drowns out due to downstream Cumbungi growth and logs in the river bed.
5	Loddon River: Kerang Weir to the River Murray	407202	Loddon River @ Kerang	▪ Good site
Living Murray contribution				

F.13 Irrigation Outfalls - Loddon River

Table 35 and Table 36 lists outfalls in the Torrumbarry and Pyramid Hill- Boort Irrigation areas listed in Appendix N as having their final destination as the Loddon River.

- **Table 35 – Torrumbarry Irrigation System Outfalls to Loddon River**

Outfall	Channels
Direct to Loddon River	TO4, TO6 (McKnight), TO6 (Heffers), TO1/7
To Barr Creek	TO1 (McKnight)

- **Table 36 – Pyramid-Boort Irrigation System Outfalls to Loddon River**

Outfall	Channels
Direct to Loddon River	PH1/12, PH2, PH9/2, PH3/2/8/2, PH1/9/2, PH8/2, PH2/8/2

In addition to the outfalls listed in Table 36, outfalls from the Number 12 channel outfall to the Pennyroyal Creek, which may also reach the Loddon River (pers comm. K Orr – G-MW).

Appendix G Goulburn System Options

G.1 Introduction

In this chapter, options are developed for improving the delivery of the recommended environmental flow regimes. The options are generally based on a need to overcome the current constraints to environmental flow delivery identified in Chapter **4**. Options have been grouped by reach and flow component. Each option is described, and comment is then provided on the likely effectiveness of each option in meeting the recommended environmental flow component that it was intended to address within that reach.

Indicative cost estimates have been presented for some options. All costs provided are capital costs only and do not include any allowances for on-going costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that would allow detailed cost estimates to be developed

G.2 Goulburn River: Eildon to Goulburn Weir – Summer Low Flows

The Goulburn River is used for delivering irrigation water to Shepparton, Central Goulburn, Rochester and Pyramid-Boort Irrigation Areas. It conveys a maximum flow of about 10,000 ML/d during the summer months to supply irrigation demands, which is well in excess of the maximum environmental flow threshold for this section of the river. The summer environmental low flow threshold for this section is generally of the order of 2,000 ML/d.

Eleven options were considered to overcome this constraint:

- G1S1 - Pipeline from Eildon to Goulburn Weir
- G1S2a - Pulse Flows from Eildon – Large Amplitude
- G1S2b - Pulse Flows from Eildon – Small Amplitude
- G1S3 - Modified Operation of Waranga Basin
- G1S4 - Divert Flows from Broken River into EGM
- G1S5 - On-stream storage at Camp Hill
- G1S6 - Enlarge Waranga Basin
- G1S7 - On-farm and regional winter-fill storages
- G1S8 - Use of Lake Cooper
- G1S9 - New storage along East Goulburn Main Channel
- G1S10 - Inter-connector channel from Yarrawonga to EGM

G.2.1 Option G1S1 - Pipeline from Eildon to Goulburn Weir

Description

This option involves construction of a pipeline from Eildon to Goulburn Weir to carry the irrigation flows in excess of the environmental flow threshold. The full supply level (FSL) of Eildon pondage is 217.60 mAHD which is about 93 m above the Goulburn Weir FSL of 124.24 mAHD. Hence, a gravity pipeline has been assumed for this option. Table 46 below provides a summary of the option and cost.

- **Table 37 Pipeline/Gravity Option Summary**

	Pipeline Option
Length (km)	190
Size	17 No. 2400 mm dia steel pipelines
Capital Cost ($billion) – incl. 50% contingency	23

Effectiveness

This option would allow the river to be run as per the environmental flow recommendations and is highly effective in delivering the environmental flows for this reach during summer months.

G.2.2 Option G1S2a - Pulse Flows from Eildon – Large Amplitude

Description

One possible option to partly meet the environmental flow requirement is to “pulse” the flow rate in the river during the summer months. The variation in the flow is expected to provide some environmental benefits by allowing periodic inundation of “benches”. The Goulburn Weir has a storage capacity of 25,000 ML and has an active storage of about 3,300 ML (i.e. about 0.3 m below FSL) under current operation.

This option considered pulsing large amplitude flows ranging between 2,000 ML/d and 18,000 ML/d. Pulsing of flows with large amplitude would cause significant variation in storage levels of Goulburn Weir and require additional storage volume or pumping into channels. Additional storage volumes of around 100,000 ML would be required either at Goulburn Weir or at Waranga Basin. Storing this water at Waranga Basin would require enlarging Waranga Basin and increasing the capacity of the Stuart Murray Canal and Cattanach Canal. However this option was considered to be ineffective as the higher flows would be detrimental to the environment in summer, and the low flow periods would only be short due to the rise and fall requirements and to maintain an average irrigation flow of about 10,000 ML/d.

This option was not costed.

Effectiveness
This option was considered to be ineffective as the high flows would negate the benefits of low flows. The low flow needs to be sustained to effectively meet ecological objectives.

G.2.3 Option G1S2b - Pulse Flows from Eildon – Small Amplitude

Description
This option is identical to Option G1S2a except that the pulses are designed to utilise the available active storage at the Goulburn Weir, which is about 3,300 ML (i.e. about 0.3 m below FSL) under current operation. Pulsing of smaller amplitude flows between 7,000 ML/d and 13,000 ML/d was considered. This option was shown to be effective on the Mitta Mitta River (Sutherland et al., 2002) and would probably be more effective than the larger amplitude option and could be achieved using existing infrastructure.

No capital works are required for this option.

Effectiveness
Smaller pulses do not get below the minimum flow threshold and therefore are not effective in meeting the environmental flow recommendation. However, the smaller pulsing could have other benefits as proved in the Mitta Mitta River. Studies on the Mitta Mitta River (Sutherland et al 2002) indicate that small pulsed flows deliver some environmental benefit. A similar outcome may occur in the Goulburn.

G.2.4 Option G1S3 - Modified Operation of Waranga Basin

Description
The current operation of Waranga Basin is governed by a number of factors including water availability, unregulated flows downstream of Eildon, minimising damage to the embankment and bulk entitlement requirements. G-MW operates the basin to maximise water harvesting within the bulk entitlement limits, minimise losses and maximise reliability of supply by following a number of considerations. The primary considerations are:

- Fill Waranga Basin from unregulated inflows downstream of Eildon during winter/spring before the commencement of the irrigation season
- Maximise capturing of AGL Hydro Power (AHP) releases during winter/spring
- Allow Waranga Basin to be drawn down rapidly during the early part of the irrigation season to provide airspace to harvest additional inflows should they occur
- If Waranga Basin is likely to fill well before the commencement of irrigation season, limit filling to minimise embankment erosion. This is conditional on future unregulated inflows being sufficient to fill the storage to capacity before being drawn down by irrigation demand

- As Waranga Basin approaches FSL, water can be transferred to Greens Lake to provide additional airspace in Waranga Basin.
- Once spring unregulated inflows have receded and irrigation demand is emerging, develop a draw down plan for the irrigation season depending on the seasonal allocation and the target end of season storage level. The objective of the plan is to tailor Eildon releases to minimise the risk of spill at Goulburn Weir whilst ensuring that Waranga Basin does not fall below a level required to command major and minor offtakes.
- Modify the draw down plan for Waranga Basin as necessary as the irrigation season progresses. This will be influenced by any rain events during the balance of the season as well as AHP entitlement releases.
- The target end storage volume will be governed very much by allocation levels. In recent years with low end of season demand Waranga Basin has been drawn down to 100 GL. In years with higher end of season demand, maintaining outlet capacity will constrain the minimum level that can be achieved.
- Water held in Greens Lake toward the end of the irrigation season can be used to assist in the drawdown of Waranga Basin. Water pumped from Greens Lake can assist in meeting downstream demands when the Major Outlet capacity becomes constrained due to low levels in Waranga Basin.
- Utilise available airspace in the Goulburn Weir pool to maximise harvesting potential

A modified operation would involve filling the basin from Eildon releases during winter/spring and making use of natural Goulburn flows to fill the basin during the summer months. Under current arrangements, this would be likely to impact on system reliability.

Effectiveness

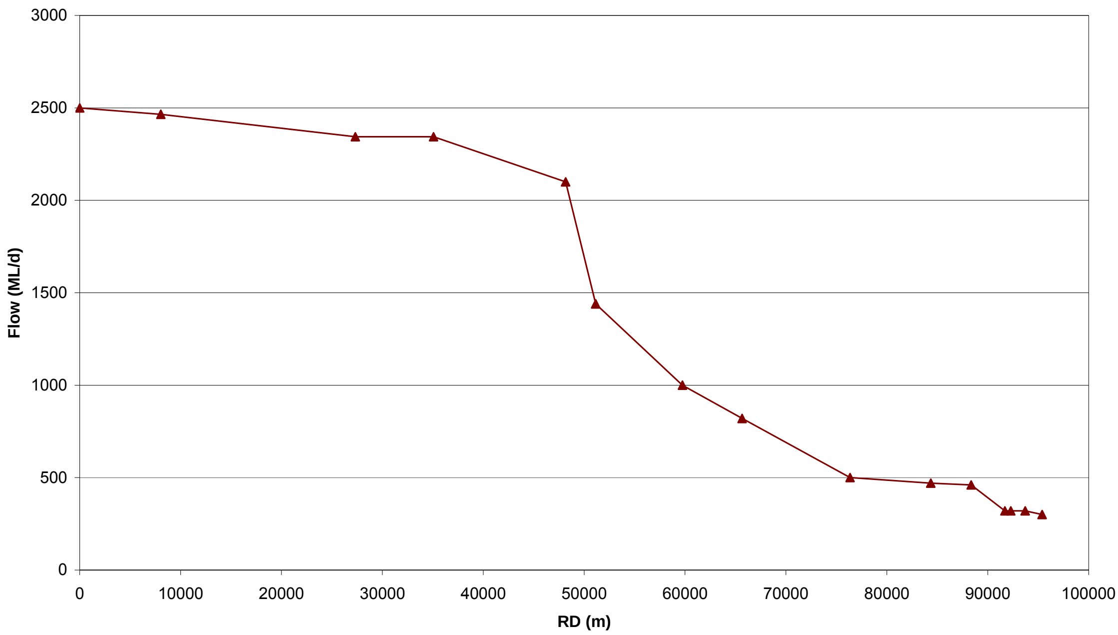
This option would be largely ineffective as it would provide only marginal reduction in delivery of summer flows.

G.2.5 Option G1S4 - Divert Flows from Broken River into EGM

Description

Figure 28 below shows the East Goulburn Main Channel (EGM) peak demands along the entire length of the channel. The Broken River crosses the EGM at 48,000 m and the peak demand at this point is 2,100 ML/d. This option would require pumping of flows from the Broken River to the EGM at a rate of about 2,100 ML/d during the summer months and would enable the Goulburn River summer flows upstream of Goulburn Weir to be reduced by 2,100 ML/d.

▪ **Figure 28 EGM Demands**



Effectiveness

Whilst this option would provide some improvement in summer low flows, these would still be around 7,000 to 8,000 ML/d, and this option would thus be largely ineffective.

G.2.6 Option G1S5 - On-stream storage at Camp Hill

Description

An on-stream storage at Camp Hill on the Goulburn River near Seymour would enable transfer of water in winter from Eildon to the new storage and enable reduced flows in the section of the river from Eildon to Camp Hill. This option was considered by the then Rural Water Commission (RWC 1986) and a cost estimate was prepared for a 300 GL storage at this site, which would allow summer peak flows to be reduced by about 3,000 ML/d.

The capital cost of this option is expected to be around $100 million based on the investigations undertaken in 1986.

Effectiveness

This option would be largely ineffective in the reach from Eildon to Camp Hill in that it would only reduce the summer flows to around 7,000 to 8000 ML/d, and completely ineffective from Camp

Hill to Goulburn Weir as no change in summer flows would be expected between Camp Hill and Goulburn Weir.

G.2.7 Option G1S6 - Enlarge Waranga Basin

Description

Enlarging the existing Waranga Basin by 300 GL would provide similar benefit to the on-stream storage at Camp Hill but with the additional benefit of enabling peak summer flows to be reduced by 3,000 ML/d in the entire reach from Eildon to Goulburn Weir.

Three possible options were considered for increasing the storage volume. These options are raising the existing embankment, constructing a new embankment on the northern side, and enlarging the storage by additional excavation on the eastern side along the Cattanach Canal.

Raising Embankment – Two options of raising the embankment by 1 m and 2 m were considered and would provide an additional 70 GL and 130 GL respectively. The additional storage volumes were calculated by extending the stage-storage relationship for the current storage. Raising storage levels above current FSL will reduce the capacity of the Cattanach Canal when the storage is above current FSL by approximately 1,000 ML/d and 2,000 ML/d for 1 m and 2 m raising respectively. These additional storage volumes are considered insufficient to lower the river flows below the minimum summer threshold flows and therefore the raising option was considered ineffective.

***Extending Storage to North* -** The land on the northern side of the existing embankment is lower than the existing bed of the storage basin and thus extending the storage would create additional dead storage and would require water to be pumped into the channels. The cost of this option is expected be around $5 billion.

***Extending Storage to the East* -** The land on the eastern side is higher than the Waranga Basin FSL and hence an excavated storage is required. Disposal of material from the excavated storage would be an issue. The cost of this option is expected be around $5 billion.

Effectiveness

This option would be largely ineffective as it would only reduce the summer flows to around 7,000 to 8000 ML/d.

G.2.8 Option G1S7 - On-farm and regional winter-fill storages

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages that would be filled in winter. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

On average, 1,300 GL is delivered by the Goulburn System every year to meet irrigation demands. The Waranga Basin has an active storage of about 300 GL and another 300 GL can be delivered to Goulburn Weir from Eildon within the constraints of the recommended flow during the irrigation season. Therefore, a total storage requirement of 800 GL including loss allowances has been assumed for this option. This can be provided entirely by larger G-MW owned regional storages or landowner owned on-farm storages, or a combination of both. For the purpose of this study, it has been assumed that the storages would comprise:

- 40 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and
- 3,000 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

These storages would provide a total storage volume of 800,000 ML. The capital cost of providing these storages are expected to be around $3 billion.

Effectiveness

This option would be highly effective as it would provide storage for the majority of the required water use. This option would also free up channel capacities (eg EGM) and would aid in meeting environmental flow requirements in other systems (eg Broken Creek).

G.2.9 Option G1S8 - Use of Lake Cooper

Description

Lake Cooper, which is located on the eastern side of the Waranga Western Channel to the west of Waranga Basin has a surface area of about 1,100 ha and a targeted storage volume of 27,000 ML. Lake Cooper can store water to a level of around 105.65 mAHD (35,400 ML) before water spills to Greens Lake. The targeted level is aimed at reducing flooding in the vicinity of the lake.

A channel linking Lake Cooper and Greens Lake is used to transfer water if Lake Cooper is above target volumes and Greens Lake is below target levels (102.23 mAHD). The sill of the outlet to the link channel has a level of 103.2 mAHD (pers comm. Sarah Drowley, G-MW) with an associated volume of around 6,500 ML.

The salinity of Lake Cooper has typically been between 4,000 and 5,000 EC (HydroTechnology 1993). Inclusion of Lake Cooper in the supply system will need to consider the impacts on Waranga Western Channel salinity.

Effectiveness

This option would be ineffective in meeting the flow requirements as the limited storage volume would only provide very slight improvement in the delivery of summer low flows.

G.2.10 Option G1S9 - New storage along East Goulburn Main Channel

Description

The objective of an off-line storage along the EGM would be to store adequate water to meet irrigation demands during the season. The EGM currently delivers an entitlement of around 260 GL and it is estimated that a 300 GL storage would be required to meet this entitlement. The storage would be filled by gravity and pumped out during the irrigation season.

The capital cost of this storage is expected to be around $4 to 5 billion.

Effectiveness

Whilst this option would provide some improvement in summer low flows, these would still be around 7,000 to 8,000 ML/d, and this option would thus be largely ineffective.

G.2.11 Option G1S10 – Inter-connector channel from Yarrawonga to EGM

Description

The concept of an inter-connector channel between the Murray and Goulburn systems was initially suggested in a 1989 Rural Water Commission report (RWC 1989) into the development of new water supply sources in northern Victoria and raised again in a 1992 Department of Water Resources Report (DWR 1992). The inter-connector channel option was investigated again in 2005 and two capacity options (2,000 ML/d and 4,000 ML/d) were investigated (SKM, 2005).

An inter-connector channel with a capacity of around 1,500 ML/d from the Murray to the EGM would enable a reduction in summer flows in this reach, provided that offsetting flows to the River Murray are not required in summer.

The estimated capital cost of this option is $200 million.

Effectiveness

Whilst this option would provide some improvement in summer low flows, these would still be around 7,000 to 8,000 ML/d, and this option would thus be largely ineffective.

G.3 Goulburn River: Downstream of Goulburn Weir – Summer Low Flows

Goulburn River flows downstream of Goulburn Weir are currently based on meeting Goulburn Bulk Entitlement requirements. The BE requirement immediately downstream of Goulburn Weir is a weekly average flow of 250 ML/d and a minimum daily rate of 200 ML/d. The recommended minimum summer environmental flow in this reach is 610 ML/d and compliance with this volume is relatively low.

There are no infrastructure or operational constraints to delivering flows of this magnitude from Goulburn Weir.

G.4 Goulburn River: Downstream of Goulburn Weir – Summer Freshes

Under current conditions, summer freshes typically occur in response to rain rejections. Although the Scientific Panel did not set any summer fresh flow recommendations, it felt that the current frequency and duration of summer freshes in this reach approximate the natural pattern (refer Section 3.3). It is likely that improved channel management (e.g. through automation) would result in a reduction of these summer freshes. However, provision of these freshes should be built into any of these improved management options.

There are no infrastructure constraints at present to deliver these freshes and hence no cost has been allowed.

G.5 Goulburn River: Winter/Spring Flood Flows

Winter/spring flood flows need to be released from Eildon to provide recommended winter/spring overbank flood flows. There are no infrastructure constraints to releasing these flows from Eildon. When Eildon is not spilling, the dam can pass 28,000 ML/d at the sill level of the spillway flood gates. The release capacity is greater than 20,000 ML/d for storages levels as low as 10% therefore the opportunity to release 20,000 ML/d always exists. The capacity to release large flows reduces with reduced storage levels in Eildon. Outputs from the Goulburn River REALM model indicate that the reservoir does not exceed the spillway gate level for 12 years out of the 27 year simulation period, therefore the potential for large flow releases are limited to around every second year on average. Larger releases from Eildon will be constrained by the potential for exacerbation of downstream flood impacts (refer Section 3.3). Diversions to Waranga Basin can influence flood volumes downstream of Goulburn Weir.

Currently there is no mechanism to predict when a release from Eildon Dam or Goulburn Weir should be timed to coincide with the largest natural winter/spring event for a particular year.

Current operation of the Eildon reservoir does not include environmental releases for spring overbank flooding. In fact the reservoir is currently used to reduce the magnitude/frequency of flooding by absorbing flood flows such that the reservoir level exceeds that of the target filling curve (or if full, the FSL).

Options for achieving the environmental flow recommendations must result in altering the magnitude/frequency of flood events. Alternatively, the environmental objectives may be achieved by altering the degree of inundation that occurs for particular flood flows, thereby changing the magnitude and frequency of wetland inundation, without necessarily changing the magnitude/frequency of the flow regime.

Existing points of operational control within the system that allow manipulation of flow peaks are the Eildon Dam, Goulburn Weir and Loch Garry.

The following options are considered:

- G1Sp1a - Modified Eildon Operation (Target release)
- G1Sp1b - Modified Eildon Operation (modify target filling curve to optimise provision of environmental floods)
- G1Sp2 - Pump into Key Wetlands
- G1Sp3 - Construct Weirs to Direct Flows into Key Wetlands
- G1Sp4 - Minimise Harvesting of Floods into Waranga Basin (only applies to the section of the River downstream of Goulburn Weir)

G.5.1 Option G1Sp1a - Modified Eildon Operation (Target release)

Description

Eildon is currently operated for flood mitigation during wet weather events and also for water harvesting (refer Chapter 3.3 for details). The reservoir is filled according to 'target filling curves' that identify the preferred reservoir level at a particular time of year. If a flood event occurs such that the volume of flow into the reservoir is greater than that required to achieve the desired reservoir level, the operators have the option of releasing flows, or harvesting water above the volume of the target filling curve. When the reservoir is at Full Supply Level (FSL), and a flood event occurs, it is possible to temporarily surcharge the reservoir above FSL, thereby temporarily storing part of the flood volume to help attenuate the flood peak.

Although the environmental flow recommendations imply that a modification to extreme events is required in all reaches, there is a point above which the environmental benefits will be marginal, and the non-beneficial impacts of flooding become severe. Additionally the options to practically manage larger (less frequent) events become limited as the infrastructure is overwhelmed by the scale of the event.

There are two possible components to modifying the operation:

- Target Release - aim to release one 20,000 ML/day event per year to coincide with the largest winter/spring event of that year
- Manage Surcharge - managing Eildon in such a way that it does not exceed the target filling curves. Additionally, when FSL is reached, operate the spillway gates to match outflows with inflows. If the releases are likely to exacerbate flooding, the spillway could be used to attenuate the flood peak by holding water back temporarily in the storage.

The following analysis was undertaken to test the impact of changed Eildon operation on the frequency and magnitude of flood events in downstream reaches.

(i) For each of the annual maxima events at gauge 405201 (just downstream of the King Parrot Creek confluence), obtain the peak discharge at gauge 405203 (immediately downstream of Eildon Dam).

(ii) Increase the peak discharge of each of the annual maxima events at gauge 405201 by 20,000 ML/d less the peak at gauge 405203.

(iii) Derive the flood frequency relationship for the gauged annual maxima event at 405201 and the adjusted annual maxima series at 405201.

The difference between the two curves is an indication of the impact of releasing 20,000 ML/day from Eildon during the largest winter/spring event of each year. This analysis is shown below in Figure 29.

▪ **Figure 29 Impact of Target Eildon Releases**

This analysis does not take into account the attenuation of flows released from Eildon prior to reaching the gauge site 405201. Therefore this is an over-estimate of the impact on the flood frequency relationship. Further work would be required to improve this estimate. The further downstream of Eildon the less impact such releases would have on peak flows. It is also worth noting that peaks become larger with distance downstream due to tributary inflows.

Flood damages in the Eildon to Goulburn Weir reach of the Goulburn River are incurred typically for floods with a magnitude greater than that of the 10 year ARI event. This translates to an event with a peak flow in the order of 30,000 ML/d to 40,000 ML/d. This option increases the frequency of these events from 1 in 10 years to approximately 1 in 2 years. This change in frequency increases the expected average annual damages resulting from floods. To further explore this impact the damage verses frequency results as given in the report Economic Evaluation of Flood Damages (Read Sturgess and Associates 2001) were adjusted for Molesworth, Thornton and Seymour (shown in Figures Figure 30 to Figure 32).

Assuming a 4% discount rate, and evaluating the damages over a 30 year period the analysis indicates that the net present value of the damages would increase by $1.29 Million in Molesworth, $11.16 Million in Thornton and $10.71 Million in Seymour (total $23 Million).

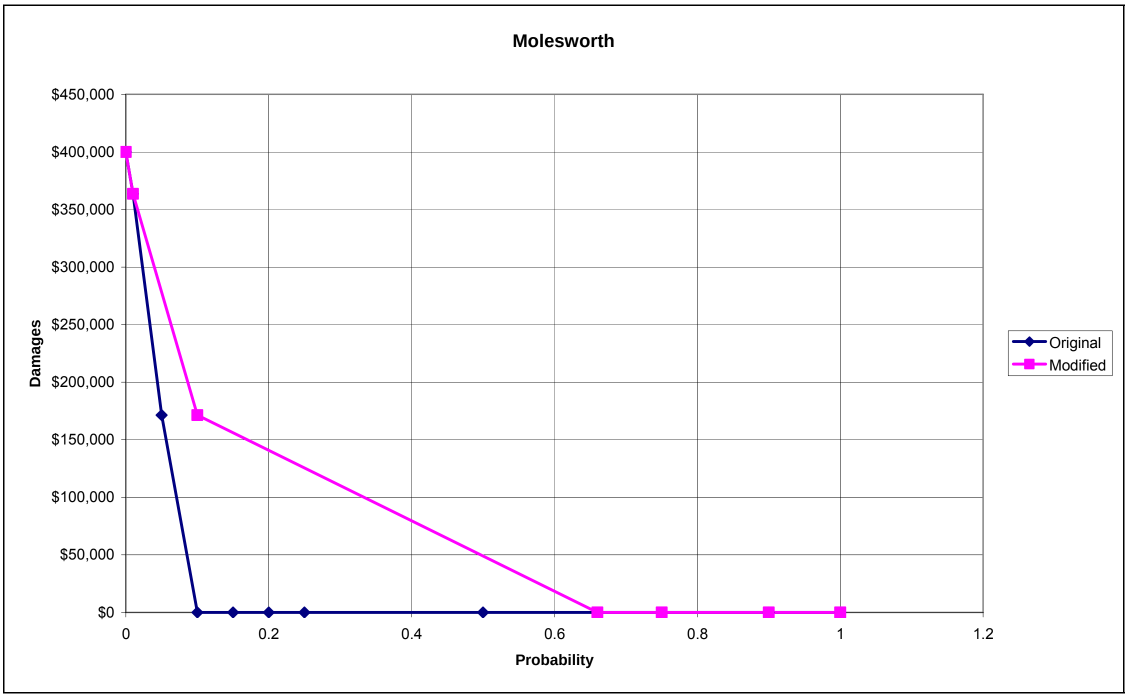
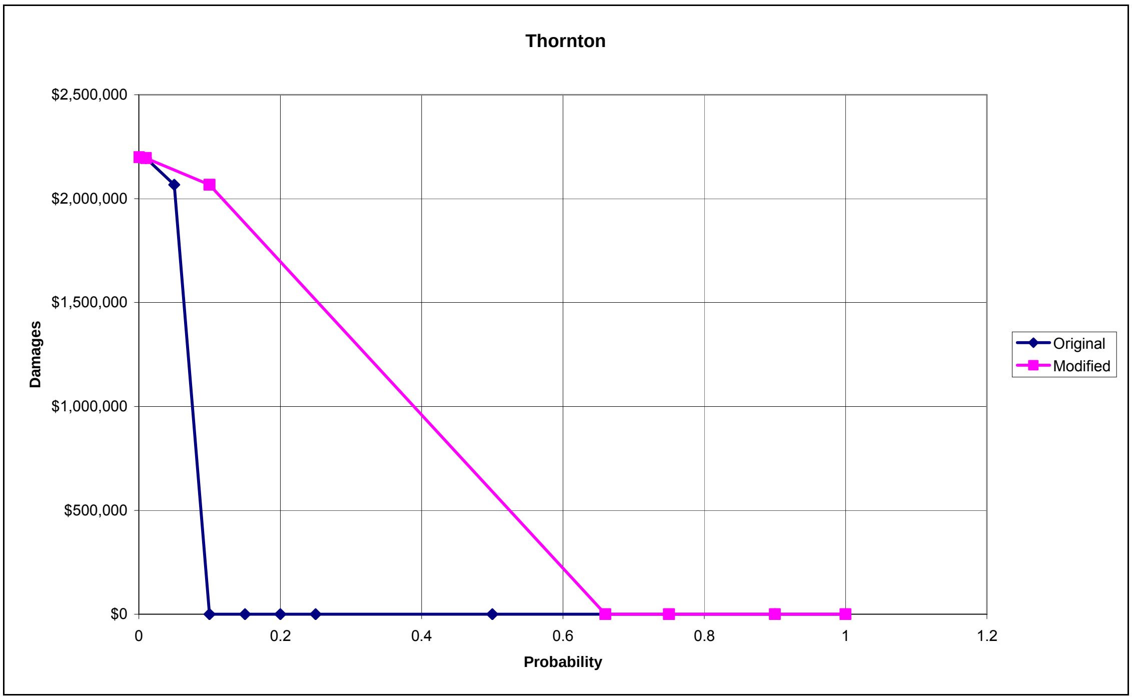
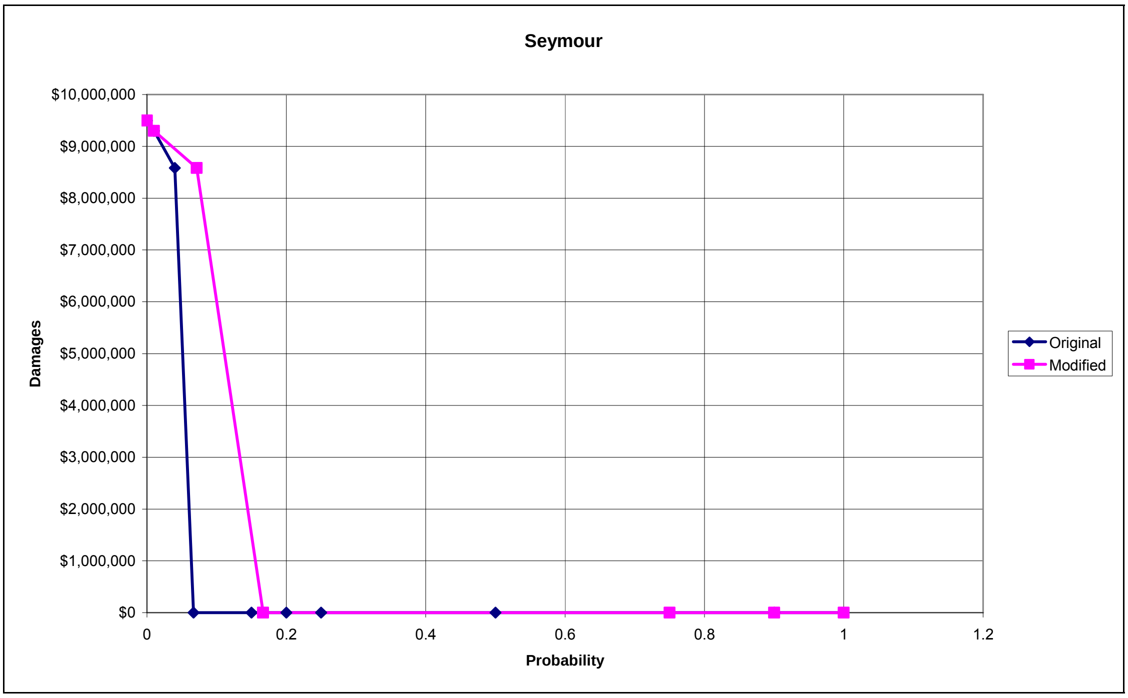


Figure 30 Flood damage curves for Molesworth. The modified curve is the consequence of moving the current ARI curve to the recommended ARI curve. The net present value of the difference between the damages over 30 years is $1.29 million.



▪ Figure 31 Flood damage curves for Thornton. The net present value of the difference between the damages over 30 years is $11.16 million.



▪ Figure 32: Flood Damage Curves for Seymour. The net present value of the difference between the damages over 30 years is $10.71 million.

Effectiveness

This option would be highly effective.

G.5.2 Option G1Sp1b - Modified Eildon Operation (modify target filling curve to optimise provision of environmental floods)

Description

This option is similar to Option G1Sp1a above except that releases would be made based on a modified target filling curve to optimise provision of environmental floods. Further investigation is required to modify target filling curves to achieve this option.

Effectiveness

This option would be highly effective.

G.5.3 Option G1Sp2 - Pump into Key Wetlands

Description

Pump water into wetlands would eliminate the need for over-bank flooding events. It is likely that pumping to wetlands would require significant capital and operating expenditure. There are approximately 400 wetlands with a total area of about 5,000 ha below Eildon. Details of individual wetlands are not available.

The viability of this option would require investigations into the hydraulic connection between the river and the wetlands and the volume of the wetlands. However, for the purpose of the current study, it is assumed that pumps will be provided for six key wetlands. It was further assumed that these wetlands have an area of 100 ha each and will require about 1,000 ML of water delivered over five days at a flow rate of 200 ML/d.

Capital cost of providing pumps to all six wetlands is expected to be in the order of $2.5 million. It is assumed that these sites would not have permanent pump installations but would have necessary facilities to mount portable pumps when required. The cost estimate allows for three 100 ML/d portable pumps.

Effectiveness

This would be expected to be moderately effective in target wetlands but the overall benefit to the reach would be minor.

G.5.4 Option G1Sp3 - Construct Weirs to Direct Flows into Key Wetlands

Description

Key locations for weirs on the Goulburn River would be reaches where there is a natural depression between the river and the wetland. Weirs would increase water levels upstream if located downstream of the depressions, thereby causing more frequent inundation of wetlands. Of course, installing weirs along the Goulburn River would not be a good option environmentally as weir operation would impact on low flows and would require fish passage to be provided. It may not be feasible to install weirs for all wetlands due to hydraulic issues. Investigations into the hydraulic connection between the river and the wetlands and the volume of the wetlands would be required to determine the feasibility. Furthermore, these weirs will also have significant adverse impacts on river health.

Effectiveness

This option is expected to result in detrimental environmental impacts associated with the construction of the weirs for a relatively minor benefit. Hence, this option is considered ineffective overall.

G.5.5 Option G1Sp4 - Minimise Harvesting of Floods into Waranga Basin

Description

This option would not require any infrastructure works, but would require Waranga Basin to be operated differently to minimise harvesting of flood flows.

Adding 7,290 ML/d to smaller flood peaks in Reach 4 would affect flood frequency, so that the "current" flood frequency curve would match the "recommended" flood frequency curve (refer Appendix M).

Effectiveness

This option is moderately to highly effective depending upon volumes, particularly in the lower reaches. Reduced harvesting into Waranga Basin has the potential to substantially improve (increase) flood flows in the lower reaches.

G.6 Goulburn River: Living Murray Contribution - Summer Low Flow

The specified Living Murray Initiative flow requirements are between an additional 1,000 ML/d and 20,000 ML/d depending on the season (refer Chapter 3.3 for details). There are no infrastructure or operational constraints to meeting these requirements.

G.7 Goulburn River: Living Murray Contribution - Spring Low Flow

From July to December each year, a flow of 10,250 ML/d for 6 months comprising of current bulk entitlement of greater than 250 ML/d plus 10,000 ML/d for Living Murray is required.

The following options are considered to meet these requirements:

- Option GMSp1 - Release from Eildon, plus flood management measures (December)

- Option GMSp2 - Minimise harvesting of flows into Waranga Basin (July to November)

G.7.1 Option GMSp1 - Release from Eildon, plus flood management measures (December)

Description

This option requires that releases from Eildon result in a 10,250 ML/d flow reaching the Murray River during the period July to December. This overlaps with the irrigation season which typically begins during August. During the irrigation season the irrigation supply flows in the Goulburn River between Eildon and the Goulburn Weir are typically in the order of 10,000 ML/d. Therefore supplying the flow requirement will result in flows in the order of 20,000 ML/d downstream of Eildon. The infrastructure of Eildon Dam allows such releases to occur. Downstream of the Goulburn Weir flows of this magnitude do not pose a flood threat. Between Eildon and the Goulburn Weir a 20,000 ML/d event is significantly less than a 10 year ARI flood event. According to the report titled Economic Evaluation of Flood Damages for the GBCMA (Read Sturgess and Associates 2001), the townships of Thornton and Molesworth do not incur damages for floods of magnitude less than the 10 year ARI event (therefore would not incur damages during a 20,000 ML/d event). However the BOM flood warning information suggests that minor flooding occurs in Molesworth for flows as low as 14,500 ML/d. The assessment of damages is based on flood events, not sustained periods of high flow, and concentrates on the townships and not the entire reach length. It is likely that some agricultural damages may be incurred as a result of sustained flows of 20,000 ML/d between Eildon and the Goulburn Weir. Information to support this conclusion or quantify the impacts has not been identified.

This option includes flood management. Flood management of this situation could take several forms depending on the degree of potential flood damages. These forms are listed below and could be applied individually or in combination.

- Buy back affected land
- Compensate losses
- Flood protection

Given that the extent of damages that would be incurred is not known at this stage it is not possible to cost this option.

Effectiveness

This option would be highly effective.

G.7.2 Option GMSp2 - Minimise Harvesting of Floods into Waranga Basin (July-November)

Description

This option would not require any infrastructure works, but would require Waranga Basin to be operated differently to minimise harvesting of flood flows.

Adding 7,290 ML/d to smaller flood peaks in Reach 4 would affect flood frequency so that the “current” flood frequency curve would match the “recommended” flood frequency curve (refer Appendix M).

Effectiveness

This option would be moderately to highly effective depending upon volumes, particularly in the lower reaches. Reduced harvesting into Waranga Basin has the potential to substantially improve (increase) flood flows in the lower reaches.

G.8 Goulburn River: Living Murray Contribution - Spring Fresh Flow

In August to November each year, a flow of 20,250 ML/d comprising of current bulk entitlement of greater than 250 ML/d plus 20,000 ML/d Living Murray for 1 to 2 months is required.

The following options are considered to meet these requirements:

- Option GMSp3 - Release from Eildon plus flood management measures (higher standard than GMSp1)
- Option GMSp2 - Minimise Harvesting of Floods into Waranga Basin (as above)

G.8.1 Option GMSp3 - Release from Eildon plus flood management measures (higher standard than GMSp1)

Description

Option is essentially same as GMSP1, except would lead to 30,000 ML/d flows between Eildon and the Goulburn Weir. As the flow is larger it is expected that the potential flood damages would be increased. Modified harvesting of flows into Waranga Basin could be used to manage tributary inflows and associated flooding risks.

Effectiveness

This option would be highly effective.

Appendix H Broken Creek Options

In this chapter, options are developed for improving the delivery of the recommended environmental flow regimes. The options are generally based on a need to overcome the current constraints to environmental flow delivery identified in Chapter 4. Options have been grouped by reach and flow component. Each option is described, and comment is then provided on the likely effectiveness of each option in meeting the recommended environmental flow component that it was intended to address within that reach.

Indicative cost estimates have been presented for some options. All costs provided are capital costs only and do not include any allowances for on-going costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that would allow detailed cost estimates to be developed

H.1 Broken Creek - Low flow

The recommended low flow for the Broken creek during the irrigation season is a minimum flow of 80-140 ML/d to keep the Azolla moving for dissolved oxygen management and to keep the fish ladder functioning.

H.1.1 Constraint – Lack of Channel Outfall Capacity

The major source of flow in Broken Creek is provided by outfall flows from irrigation channels to meet Broken Creek irrigation demands, to support fishway operation and provide some flow to the River Murray. There are 16 channels outfalling into the Broken Creek with total outfall capacity exceeding 500 ML/d. However during peak irrigation demand, the maximum available outfall capacity is reduced to around 250 ML/d (200 ML/d from EGM and 50 ML/d from Murray Valley Channels). Most of this reduced outfall capacity is used to supply irrigation demands on Broken Creek.

There is a recommended minimum flow of around 80-140 ML/d to keep the Azolla moving during summer months and to allow the fish ladder to operate. Conformance for this recommendation is low. A number of options were investigated to deliver this requirement:

- BI1 – Inter-connector from Yarrawonga to Broken Creek (100 ML/d)
- BI2a - Increased capacity from Murray Valley – Enlarge Channels
- BI2b - Increased capacity from Murray Valley – Purchase Channel Capacity
- BI3a - Increased capacity from Shepparton – Augment EGM
- BI3b - Increased capacity from Shepparton – Purchase EGM Channel Capacity
- BI4 - Additional Capacity from Upper Broken Creek

The existing weirs have 3 metre wide gates which makes control of low flows along Broken Creek difficult. One possible option to address this issue would be to modify the weir structures to provide narrower gates. This has been allowed in the cost estimate for all of the above options.

H.1.1.1 Option BI1 - Interconnector from Yarrawonga to Broken Creek (100 ML/d)

This option is similar to Option G1S10 above but requires a smaller inter-connector channel with a capacity of 100 ML/d from Yarrawonga to Broken Creek at Katamatite.

The required length of channel is around 20 km and it is anticipated that this option would cost around $15 million based on similar G-MW assets in AssetLife.

Effectiveness

This option would be highly effective and would completely deliver the recommended flow regime.

H.1.1.2 Option BI2a - Increased capacity from Murray Valley – Enlarge Channels

This option would involve

- Increasing the capacity of the Yarrawonga Main Channel, and Murray Valley Channel No 3, by 140 ML/d; and
- Constructing a link channel with a capacity of 140 ML/d, from Murray Valley Channel No 3, to Boosey Creek near Katamatite.

The estimated capital cost of this option is expected to be around $12 million.

Effectiveness

Enlarging Murray Valley Channels would be highly effective and is expected to completely deliver the recommended flow regime.

H.1.1.3 Option BI2b - Increased capacity from Murray Valley – Purchase Channel Capacity

Total channel outfall capacity available from the MV channels is about 200 ML/d and part of it currently delivers flows to Broken Creek users. Hence, it is assumed that only half of it would be available for purchase. This would only provide part of the requirement and the cost of purchasing additional 100 ML/d capacity share is expected to be around $9 million (pers com G Coburn, G-MW).

This option can't be implemented on its own and would require to be implemented in combination with other options such as enlarging channels or purchasing capacity shares on EGM etc.

Effectiveness

Purchasing capacity share only meets partial requirement and hence was considered moderately effective.

H.1.1.4 Option BI3a - Increased capacity from Shepparton – Augment EGM

This would involve increasing the capacity of the East Goulburn Main Channel and the outfall structure by 140 ML/d.

The estimated capital cost of this option is expected to be around $10 million.

Effectiveness

Enlarging East Goulburn Main Channel could deliver the required flow and is therefore considered highly effective.

H.1.1.5 Option BI3b - Increased capacity from Shepparton – Purchase EGM Channel Capacity

Current EGM outfall capacity is around 300 ML/d and part of it currently delivers flows to Broken Creek users. Hence, it is assumed that only 100 ML/d is available for purchase. This would only provide part of the requirement.

The cost of purchasing 100 ML/d capacity share is expected to be around $9 million (pers com G Coburn, G-MW).

Effectiveness

Purchasing capacity share only partially meets the requirement, and hence would be only moderately effective.

H.1.1.6 Option BI4 - Additional Capacity from Upper Broken Creek

This option would involve releasing water from Nillahcootie, harvesting unregulated Broken River flows, and diverting these to lower Broken Creek via upper Broken Creek to meet the required flow. This option could only meet part of the flow requirement. Without additional works, only around 30 to 40 ML/d could be provided from upper Broken Creek and Boosey Creek due to their limited capacity.

Effectiveness

This is option would be less effective as it can only provide a fraction of the flow requirement due to the capacity of the Broken Creek between Waggarandall and Katamatite being limited to 30-40 ML/d.

H.2 Broken Creek - Spring Flows

There is a recommended requirement to deliver 500 ML/d for seven days at short notice, at the time of a rapid azolla bloom. Even if all outfall channel capacity was available (refer Section H.1.1 above), this requirement couldn't currently be met. A number of options were investigated to deliver this requirement:

- BSp1 - Inter-connector from Yarrawonga to Broken Creek (500 ML/d)
- BSp2 - Offline Storage near upstream end of Azolla affected reach
- BSp3a - Increased capacity from Murray Valley - Enlarge Channels
- BSp3b - Increased capacity from Murray Valley - Purchase Channel Capacity
- BSp4a - Increased capacity from Shepparton - Augment EGM
- BSp4b - Increased capacity from Shepparton - Purchase EGM Channel Capacity
- BSp5 - Additional Capacity from Upper Broken Creek

H.2.1.1 Option BSp1 - Inter-connector from Yarrawonga to Broken Creek (500 ML/d)

This option is similar to Option BI1 above but requires an inter-connector channel with a capacity of 500 ML/d from Yarrawonga to Broken Creek at Katamatite.

The required length of channel is around 20 km and it is anticipated that this option would cost around $20 million based on similar G-MW assets in AssetLife.

Effectiveness

This option would be highly effective and would completely deliver the recommended flow regime.

H.2.1.2 Option BSp2 - Offline Storage near upstream end of Azolla affected reach

Flushing flows of 500 ML/d can be effective in providing flows at short notice. An off-line storage at the upstream end of the Azolla affected reach, with a required capacity of around 4,000 ML to provide the volume of water required to pass 500 ML/d over a seven day period plus storage losses.

The estimated capital cost of this option is around $30 million, based on SKM's recent work on the Broken System Loss Study (SKM, 2006).

Effectiveness

This option would be highly effective and would completely deliver the recommended flow regime.

H.2.1.3 Option BSp3a - Increased capacity from Murray Valley - Enlarge Channels

This option would involve:

- Increasing the capacity of the Yarrawonga Main Channel, and Murray Valley Channel No 3, by 500 ML/d; and
- Constructing a link channel with a capacity of 500 ML/d, from Murray Valley Channel No 3, to Boosey Creek near Katamatite.

The estimated capital cost of this option is expected to be around $12 million.

Effectiveness

Enlarging Murray Valley Channels would be highly effective and is expected to completely deliver the recommended flow regime.

H.2.1.4 Option BSp3b - Increased capacity from Murray Valley - Purchase Channel Capacity

Total channel outfall capacity available from the MV channels is about 200 ML/d and half of it currently delivers flows to Broken Creek users. Hence, it is assumed that only the share that delivers water to Broken Creek would be available for purchase. This would only provide part of the requirement and the cost of purchasing additional 100 ML/d capacity share is expected to be around $9 million (pers com G Coburn, G-MW).

This option can't be implemented on its own and would require to be implemented in combination with other options such as enlarging channels or purchasing capacity shares on EGM etc.

Effectiveness

Purchasing capacity share only meets partial requirement and hence was considered ineffective.

H.2.1.5 Option BSp4a - Increased capacity from Shepparton - Augment EGM

Two sub-options were investigated to deliver additional flow to Broken Creek:

(a) Enlarging EGM Channel

This would involve increasing the capacity of the East Goulburn Main Channel and the outfall structure by 500 ML/d.

The estimated capital cost of this option is expected to be around $30 million.

(b) Purchasing capacity shares

Current EGM outfall capacity is around 300 ML/d and part of it currently delivers flows to Broken Creek users. Hence, it is assumed that only 100 ML/d is available for purchase. This would only provide part of the requirement.

The cost of purchasing 100 ML/d and 300 ML/d capacity shares is expected to be around $9 million and $27 million respectively (pers com G Coburn, G-MW).

Effectiveness

Enlarging East Goulburn Main Channel could deliver the required flow and is therefore considered highly effective.

H.2.1.6 Option BSp4b - Increased capacity from Shepparton - Purchase EGM Channel Capacity

Current EGM outfall capacity is around 300 ML/d and most of the outfall capacity is currently used to deliver irrigation flows to Broken Creek users. It is assumed that all of this outfall capacity could be purchased from the existing Broken Creek users. The cost of purchasing 300 ML/d capacity share is expected to be around $27 million (pers com G Coburn, G-MW).

Effectiveness

Purchasing capacity share only meets partial requirement and hence was considered ineffective on its own unless this could be combined with other options.

H.2.1.7 Option BSp5 - Additional Capacity from Upper Broken Creek

This option would involve releasing water from Nillahcootie, harvesting unregulated Broken River flows, and diverting these to lower Broken Creek via upper Broken Creek to meet the required 500 ML/d flow over seven days. This option was not considered feasible for the following reasons and hence was not investigated further:

- It could only meet part of the flow requirement. Without additional works, only around 30 to 40 ML/d could be provided from upper Broken Creek and Boosey Creek due to their limited capacity.
- Flow would be required at a short notice, however releases from Nillahcootie would take too long to reach lower Broken Creek.

Effectiveness

This is option would be ineffective as Broken Creek capacity between Waggarandall and Katamatite is limited to 30-40 ML/d and the travel time from Nillahcootie is too long to enable effective delivery in response to azolla blooms.

Appendix I Campaspe System Options

In this chapter, options are developed for improving the delivery of the recommended environmental flow regimes. The options are generally based on a need to overcome the current constraints to environmental flow delivery identified in Chapter 5. Options have been grouped by reach and flow component. Each option is described, and comment is then provided on the likely effectiveness of each option in meeting the recommended environmental flow component that it was intended to address within that reach.

Indicative cost estimates have been presented for some options. All costs provided are capital costs only and do not include any allowances for on-going costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that would allow detailed cost estimates to be developed

I.1 Coliban River: Malmsbury to Eppalock – Summer Low Flows

The main control/regulating point for this section of the Coliban River is the Malmsbury Reservoir at Malmsbury. The Malmsbury Reservoir has the following release capability:

- A 1200 mm diameter outlet pipe capable of delivering flows from 45 ML/d to 260 ML/d to the Coliban Main Channel.
- A 200 mm dia PVC outlet from the 1200 mm dia pipe outlet that is capable of delivering flows less than 10-15 ML/d to the Coliban Main Channel. Note that flows between 10-15 ML/d and 45 ML/d could not be released with the current outlet configuration.
- Two channel outfalls capable of delivering a total of 130 ML/d to the river. The first outfall is located approximately 20 m downstream of the cone valve and is capable of delivering a maximum of 30 ML/d to the river. The second outlet is located about 2 km downstream of the reservoir and is capable of delivering a further 100 ML/d to the river.

The environmental flow recommendation for summer low flows for this reach is about 5 ML/d for 6 months of the year. There is no current requirement to comply with environmental flow recommendations in the Campaspe River and the current conformance is only about 56%. The low conformance is partly due to losses in the system, which are not included in the environmental flow recommendation. These losses have not been quantified but are believed to be at least 10-15 ML/d, thus increasing the minimum release requirement including losses to about 15-20 ML/d. This flow can't be delivered with the existing outlet configuration. An option is to modify the outlet to improve its release capability between 10-15 ML/d and 45 ML/d.

I.1.1 Option C1S1 - Modify Malmsbury Reservoir outlet to allow releases between 10-15 ML/d and 45 ML/d

Description

Currently, the reservoir outlet is not capable of delivering flows between 10-15 ML/d and 45 ML/d and this option involves modification of the outlet to overcome this constraint. Under this option, a 300 mm PVC pipe offtake with a butterfly valve would be installed on the main outlet conduit to bypass the main outlet valve. The new outlet would enable releases of up to around 30 ML/d, thus making up the shortfall for low flow release requirements. The summer low flow requirement is only 15-20 ML/d and the channel outfall immediately downstream has sufficient capacity to pass this flow.

The estimated capital cost of this modification is $10,000.

Effectiveness

This option would be highly effective in delivering the required summer environmental low flow regime.

I.2 Coliban River: Malmsbury to Eppalock - Summer Fresh Flows

The existing outlet configuration does not allow the recommended summer freshes to be released from Malmsbury Reservoir to the Coliban River. The maximum environmental flow requirement for summer freshes is 200 ML/d, which is well in excess of the release capacity (approximately 130 ML/d) to the river.

The following option was considered to overcome this constraint:

- C1S2 Increase outfall capacity to 200 ML/d

I.2.1 Option C1S2 - Increase Coliban Main Channel outfall capacity to Coliban River to 200 ML/d

Description

There are two outfalls from the Coliban Main Channel to the Coliban River. The largest of these has a capacity of around 100 ML/d and is located approximately 2 km downstream of Malmsbury Reservoir. Coliban Water currently uses this outfall to drain the Coliban Channel. Whilst enlarging this structure would be relatively easy and cheap, it would require more operational input to ensure that the required flows are released to the river. Also, using this outfall to deliver environmental flows on a regular basis would not enhance delivery of environmental flows to the first 2 km of the river. Hence, in consultation with Coliban Water, it was decided that this option should involve upgrading the smaller outfall to provide the required environmental releases.

Upgrading of this outfall would require the following works:

- Installation of new regulating structure on the Coliban Main Channel downstream of the outfall
- Removing the existing gates and pipes and replacing with new gates
- Grouting the existing channel upstream of the outfall; and
- Installation of a flow monitoring station comprising a broad crested weir and v-notch weir.

The estimated capital cost of these works is $150,000.

Effectiveness

This option would be highly effective in delivering the required environmental flow regime for the summer freshes.

I.3 Coliban River: Malmsbury to Eppalock - Winter Low and Fresh Flows

The winter low and fresh flow requirements are

- Low flow requirement of 35 ML/d - Releasing flows of this magnitude is constrained by the current infrastructure, which cannot release flows in the range between 10-15ML/d and 45 ML/d.
- Fresh flow of 700 ML/d - Can only be released when the storage level is above the spillway.

As described in Section 3.5, the current Malmsbury Reservoir release capacity limits the capability to deliver both low and high winter flows.

Three options were considered to overcome these constraints consisting of one option (i.e. C1S1) to deliver low flows and two options to deliver fresh flows.

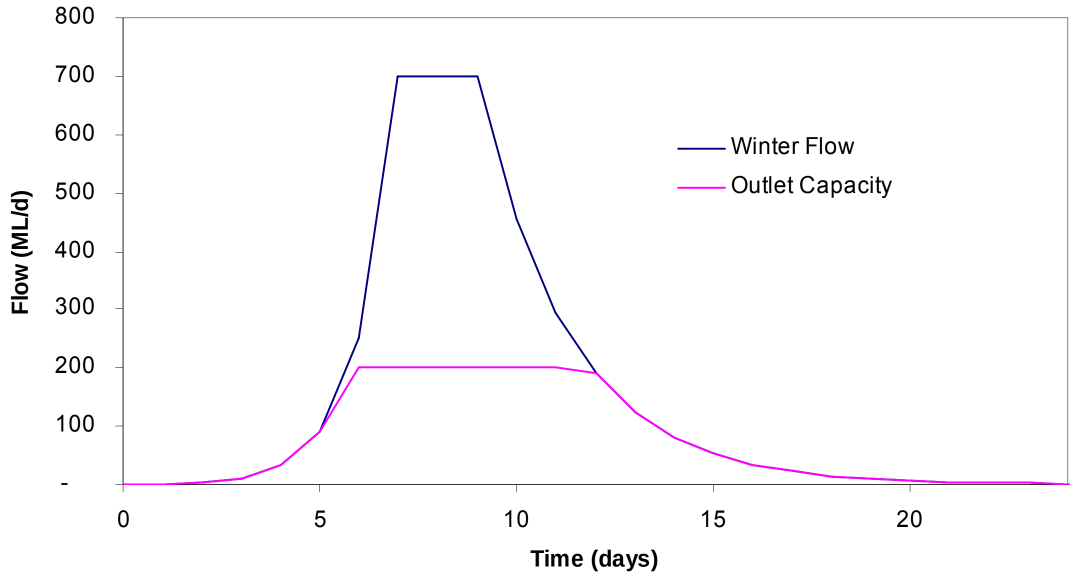
- C1S1 - Modify reservoir outlet to allow releases between 10-15 ML/d and 45 ML/d (refer Section I.1.1 for details)
- C1W1 - Construct a pondage downstream of Malmsbury Reservoir
- C1W2 - Increase capacity of Malmsbury outlet works to 700 ML/d
- C1W3 - Modify Malmsbury operation, including additional releases from upstream storages

I.3.1 Option C1W1 - Construct a pondage downstream of Malmsbury Reservoir

Description

A flow of 700 ML/d is required for 3 days, around four times a year, to provide winter fresh flows. Delivery of this flow is not an issue when storage levels are above spillway sill level. However during low storage levels, a maximum flow of only 200 ML/d (refer Figure 33 below) could be delivered through the outlet conduit, necessitating the need for a pondage to store the water and release it when required. The pondage would be required to store around 2,000 ML, with a maximum release capacity of around 700 ML/d and an allowance for rise and fall in the flood hydrograph.

- **Figure 33 Winter Fresh Flow**



The estimated capital cost of the pondage and associated works is around \$5 to \$7 million, depending on site conditions.

Effectiveness

This option is moderately to highly effective in delivering winter fresh flows depending on the pondage location. If the pondage could be built close to Malmsbury Reservoir then this option would be highly effective.

I.3.2 Option C1W2 - Increase capacity of Malmsbury Reservoir outlet works to 700 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the winter fresh flow requirement of 700 ML/d. The use of existing outlet works was discussed with Coliban Water, and it was concluded that modification of the existing outlet would not be feasible due to lack of space. Hence, a new outlet tower and outlet conduit would be required.

The capital cost of providing a second outlet capable of providing the winter fresh flows is expected to be around \$4 to \$5 million.

Effectiveness

This option would be highly effective in delivering the required winter environmental fresh flow regime.

I.3.3 Option C1W3 - Modify Malmsbury operation, including additional releases from upstream storages

Description

The flow of 700 ML/d can only be released when the storage level is above the spillway. Analysis of storage levels shows that this occurs at least 35% of the time. However this can be increased through the delivery of flows to Malmsbury aimed at maintaining a higher winter storage level to support a release of 700 ML/d as required. This flow is required to occur four times per year for 3 days each, which is a total volume of around 4,000 ML/event. The two storages upstream of Malmsbury are Upper Coliban and Lauriston, both of which are larger than Malmsbury. The maximum outlet capacity from Lauriston (which is below Upper Coliban) is 450 ML/d at FSL. Therefore water can be released at a constant rate into Malmsbury Reservoir and held in store above spillway level for subsequent release at the required rate of 700 ML/s. It is assumed that Malmsbury storage levels can be operated to deliver this flow requirement.

Effectiveness

This option would be highly effective in delivering the required winter environmental fresh flow regime.

I.4 Coliban River: Malmsbury to Eppalock - Winter Bankfull Flows

The bankfull flow recommendation for this reach is 12,000 ML/d occurring once every three years for one day. This flow could be delivered using the spillway gates if the storage level is high. It should be noted that releases above 6,000 ML/d are likely to cause flooding of the Calder Highway and homes at Malmsbury. Current operation of the Malmsbury Reservoir is not aimed at achieving this flow recommendation.

One option has been considered to address this constraint as described below.

- C1W4 - Modify Malmsbury release patterns to produce bankfull flow recommendations

I.4.1 Option C1W4 - Modify Malmsbury release patterns to produce bankfull flow recommendations

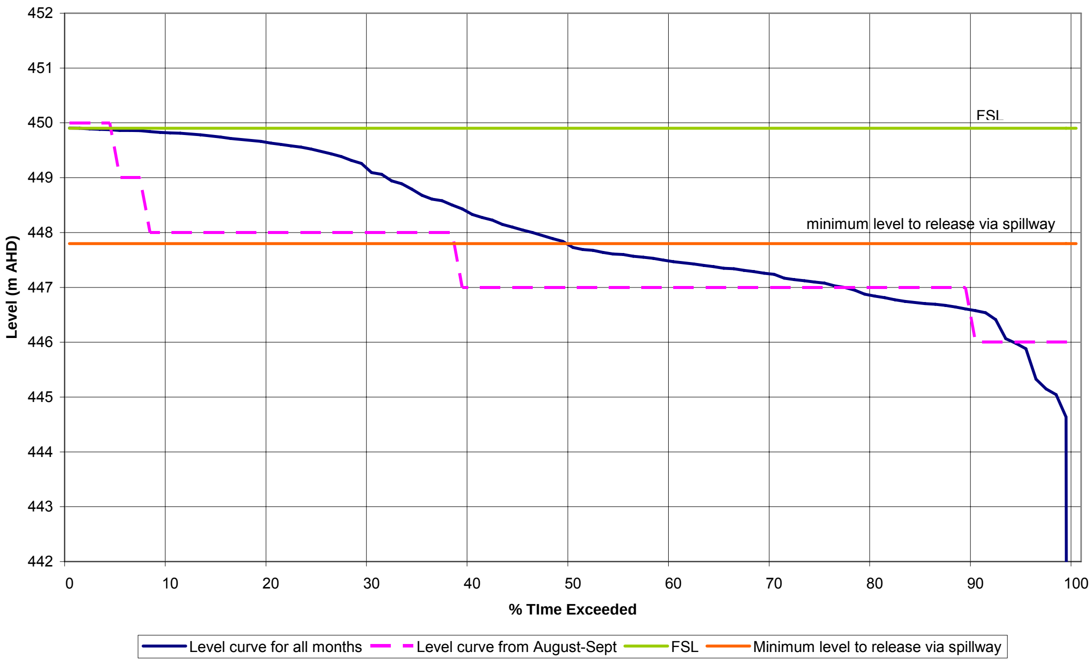
Description

The reservoir has the outlet capacity to release a maximum of 13,000 ML/d by opening all 9 gates of the spillway. Such releases can occur when the reservoir level is within 2.1 m of FSL, which is assumed to be 449.9 mAHD. According to the historic level time series, adequate levels for releasing via the spillway occur 39% of the time during the August to September period (see

Section 4). The flows downstream of the reservoir simulated using the REALM model have been greater than 12,000 ML/d 17 times over a 115 year period during August to September. The bankfull flow recommendation requires that this occur 38 years in every 115 year period. Therefore to fully conform to the flow recommendation an additional 21 events would have been required. The peak event for each August to September period over the 115 years was ranked from highest to lowest and only the 17 highest peaks exceeded 12,000 ML/d. The 38th highest peak was approximately 6,000 ML/d. Therefore the 18th to 38th highest peaks would need to be increased by up to 6,000 ML/d.

This suggests that conforming to the recommended bankfull flow would require an additional flow of up to 6,000 ML/d once every 5 years or so (18% of years).

Anecdotal evidence suggests that nuisance flooding has occurred recently during flows in the order of 6,000 ML/d downstream of the Malmsbury Reservoir at the Calder highway, and in the Malmsbury Township. Therefore flows of up to 12,000 ML/d will cause flood damages that will add to the cost of the option. Further investigations are required to estimate the potential scale of these damages and their associated cost.



- **Figure 34 Level duration curves of Malmsbury Reservoir for all months and for August-September over 21 years**

Effectiveness

The effectiveness of this option is uncertain. Whilst the spillway gates have capacity to release the recommended flows, delivery would also rely on coincident inflows, and would also be limited by the volume of reservoir storage above the level of the spillway gates.

I.5 Campaspe River: Lake Eppalock to Campaspe Weir - Summer Cease to Flow

During the irrigation season this section of the Campaspe River conveys irrigation flows from Lake Eppalock to the Campaspe Irrigation District (CID) via Campaspe Weir. The river conveys a maximum flow of around 600 ML/d during the summer months.

There is no current requirement for summer cease to flow for this reach. However the Scientific Panel recommends a summer cease to flow period of 14 days every year, which would be difficult to achieve given the need to supply irrigation demand during summer.

Six options were considered:

- C2S1 - Pipeline or channel from Lake Eppalock to Campaspe Weir
- C2S2 - On-farm and regional winter-fill storages
- C2S3 - Purchase of CID and all PD entitlement for sale to Bendigo
- C2S4 - Supply CID and PDs downstream of Campaspe Siphon from WWC
- C2S5 - Offline storage near Campaspe Weir, filled in winter
- C2S6 - Use of Green's Lake

I.5.1 Option C2S1 - Pipeline or channel from Lake Eppalock to Campaspe Weir

Description

This option involves construction of a gravity pipeline or channel from Lake Eppalock to Campaspe Weir to carry the irrigation flows in excess of the summer environmental low flow threshold. The storage level of Eppalock at 10% capacity is 176.04 mAHD which is around 56 m above the Campaspe Weir FSL of 120.42 mAHD. Table 38 below provides a summary of the option and associated capital costs.

- **Table 38 Pipeline/Gravity Option Summary**

Item	Pipeline Option	Channel Option
Length (km)	50	50
Capacity (ML/d)[1]	1,200	1,200
Size	3000 mm pipeline	Open Channel
Capital Cost ($million)	450	160

1. Includes an allowance of 340 ML/d for delivering flows to private diverters (PDs) and 500 ML/d for WWC supplement flows.
2. Includes entitlements for Private Diverters between Eppalock and Campaspe Weir

Effectiveness

This option would be highly effective in delivering the recommended summer cease to flow and low flows

I.5.2 Option C2S2 - On-farm and regional winter-fill storages

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages to be filled in winter. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

On average, 39 GL of irrigation water is delivered by the Campaspe System every year. A total storage requirement of 43 GL including loss allowances has been assumed for this option. This can be provided entirely by larger G-MW owned regional storages or landowner owned on-farm storages, or a combination of regional and on-farm storages. For the purpose of this study, it has been assumed that the storages would comprise

- 4 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and
- 115 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

These storages would provide a total storage volume of 43 GL. The capital cost of providing these storages is expected to be around $350 million.

Effectiveness

This option would be highly effective in delivering the recommended summer environmental low flows for this reach.

I.5.3 Option C2S3 - Purchase of CID and all PD entitlement for sale to Bendigo

Description

This option involves purchase of all Campaspe Irrigation District (CID) and private diverter (PD) entitlements to supply Bendigo urban demand. CID and PDs in this reach hold an entitlement of 39,127 ML.

Assuming a purchase price of $1,000 a ML, this option would cost $59 million dollars including 50% contingency.

Effectiveness

This option is highly effective in meeting the cease to flow recommendation.

I.5.4 Option C2S4 - Supply CID and PDs downstream of Campaspe Siphon from WWC

Description

This option involves supplying the CID, all Private Diverters (PDs) downstream of Campaspe Siphon and WWC supplement from the Waranga Western Channel (WWC) and would allow the removal of Campaspe Weir. A flow of 400 ML/d would need to be supplied from WWC under this option.

The WWC is located at the downstream end of the CID and therefore supplying the CID from the WWC would require pumping. In 2003, as part of the Campaspe Weir Feasibility Study (URS, 2003), an option to supply the entire CID from the WWC was investigated.

The works involved with this option are

- Purchasing of 400 ML/d capacity share in WWC at $33 million;
- Supply all PDs between the Campaspe Siphon and the River Murray from the WWC;
- Pumping from the WWC for CID customers and remodelling 12.3 km of Channel No 1 (western side of CID) and 9.5 km of Channel No 2 (eastern side of CID) to reverse their direction of flow. Four relift pumping stations would be required along Channel No 1 to limit the amount of bank raising to a practical height. The remodelling of Channel No 2 would require bank raising only. Other works would include the replacement of road and occupation crossings, siphons, regulators and meter outlets.

The total estimated cost of this option is $65 million including purchasing of capacity share on WWC.

Effectiveness

This option would remove the need to supply PDs between the Campaspe Weir and the River Murray from Lake Eppalock. However there is still a significant irrigation demand from PDs between Lake Eppalock and the weir, and this option is therefore considered moderately effective in delivering the recommended low flows for this reach and ineffective in delivering cease to flow recommendations.

I.5.5 Option C2S5 - Offline storage near Campaspe Weir, filled in winter

Description

This option would involve provision of a winter fill off-line storage adjacent to Campaspe Weir with adequate capacity to meet irrigation demands during the season. The maximum irrigation deliveries to CID and PDs downstream was 40,994 ML in 2001/02 and it was assumed that a volume of 45,000 ML would be required including some allowance for losses. The storage would be filled by gravity and pumped out during the irrigation season.

The capital cost of this storage is expected to be around $750 million.

Effectiveness

This option would remove the need to supply irrigation demands between Campaspe Weir and the River Murray from Lake Eppalock. However there is still a significant irrigation demand for PDs from Lake Eppalock to the Weir, and this option is therefore considered moderately effective in delivering the recommended low flows for this reach and ineffective in delivering cease to flow recommendations.

I.5.6 Option C2S6 - Use of Green's Lake

Description

This option would involve:

- Harvesting Campaspe flows in winter into Greens Lake using WWC. In the past, G-MW has successfully harvested water from Campaspe River to Greens Lake in winter using existing infrastructure. Under this option, volumes of around 25,000 ML would be directed to Greens Lake every winter. It is assumed that the existing infrastructure would be suitable for this option and hence no capital cost has been allowed.
- Use of Lake Cooper to store Goulburn System flows instead of Greens Lake. It is assumed that the existing infrastructure would be suitable.
- Using WWC to supply CID and PDs downstream of the Weir. This is similar to Option C2S4 above.

Total cost of this option is expected to be around $65 million including purchasing of capacity share on WWC.

Effectiveness

This option would remove the need to supply irrigation demands between Campaspe Weir and the River Murray from Lake Eppalock. However there is still a significant irrigation demand for PDs from Lake Eppalock to the Weir, and this option is therefore considered moderately effective in delivering the recommended low flows for this reach and ineffective in delivering cease to flow recommendations.

I.6 Campaspe River: Lake Eppalock to Campaspe Weir - Summer Low and Fresh Flows

The flow recommendations are

- A summer low flow of 10 Ml/d or natural for six months every year
- A summer fresh flow of 100 ML/d for five days three times a year

During the irrigation seasons this section of the Campaspe River conveys irrigation flows from Lake Eppalock to the Campaspe Irrigation District (CID) via Campaspe Weir. The river conveys a maximum flow of around 600 ML/d during the summer months, which is well in excess of the recommended summer environmental low and the fresh flows for this section of the river.

Conformance for both these flows are very poor and seven options were considered to meet this flow recommendation:

- C2S1 - Pipeline or channel from Eppalock to Campaspe Weir (refer Section I.5.1 above for details)
- C2S2 - On-farm and regional winter-fill storages (refer Section I.5.2 above for details)
- C2S3 - Purchase of CID and all PD entitlement for sale to Bendigo (refer Section I.5.3 above for details) – This option does not eliminate the WWC supplement flows and therefore only partially effective to WWC. It will be fully effective for the reach downstream of the WWC (i.e. Campaspe Siphon to Murray River).
- C2S4 - Supply CID and PDs downstream of Campaspe Siphon from WWC (refer Section I.5.4 above)
- C2S5 - Offline storage near Campaspe Weir, filled in winter (refer Section I.5.5 above)
- C2S6 - Use of Green's Lake (refer Section I.5.6 above)
- C2S7 - Pulse discharges from Lake Eppalock

I.6.1 Option C2S7 - Pulse discharges from Lake Eppalock

Description

One possible option to partly meet the environmental flow requirement is to "pulse" the flow rate in the river during the summer months. The variation in the flow is expected to provide some environmental benefits by allowing periodic inundation of "benches". The Campaspe Weir Pool has a storage capacity of 2,600 ML and an active storage of around 200 ML was assumed under current operation.

Two sub-options were considered. The first involved a wider pulse range while the second option was developed to utilise the assumed active storage volume at the weir as shown below:

- Larger pulses - Pulsing flows from 150 ML/d up to 700 ML/
- Smaller pulses - Pulsing between 250 ML/d and 450 ML/d

The larger pulse sub-option would require additional storage of around 1,400 ML at Campaspe Weir. However, this option was considered to be environmentally ineffective as the higher flows would be detrimental to the environment in summer, and the low flow periods would only be short due to the rise and fall requirements in the river and irrigation demand requirements.

The smaller pulse sub-option would require no additional capital works and would use the existing active storage volume. This option was shown to be effective on the Mitta Mitta River (Sutherland et al., 2002) and would likely be more effective than the larger pulse sub-option.

Effectiveness

Both large and small pulse options are ineffective in meeting cease to flow and summer low flow requirements.

I.7 Campaspe River: Eppalock to Campaspe Weir – Winter Low Flows

A flow of 100 ML/d is recommended for six months during winter every year. However, it is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude.

I.8 Campaspe River: Eppalock to Campaspe Weir – Winter Fresh Flows

It is recommended that 1,000 ML/d for 4 days four times a year be provided as winter fresh flows. This recommendation is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude.

I.9 Campaspe River: Eppalock to Campaspe Weir - Winter Bankfull and Over Bank Flows

The winter overbank flow recommendation is 12,000 ML/d occurring once every year for one day during August and the bankfull flow recommendation is 10,000 ML/day for two days every year during the August to September period. Current operation does not produce sufficiently frequent bankfull/overbank flows.

Bankfull and overbank flow requirements of 10,000 ML/d over 2 days and 12,000 ML/d respectively could only be delivered via the spillway if storage levels are high enough, and there are high inflows to the storage. This occurs 12% of the time, which does not meet the flow requirement.

Three options have been investigated:

- C2W1 - Operate Eppalock differently
- C2W2 - Increase capacity of Eppalock outlet works to 12,000 ML/d at lower storage level. This would also meet the Living Murray requirement
- C2W3 - Construct a pondage downstream of Lake Eppalock

These options may require flood mitigation works and consideration of how to piggyback onto downstream high flow events.

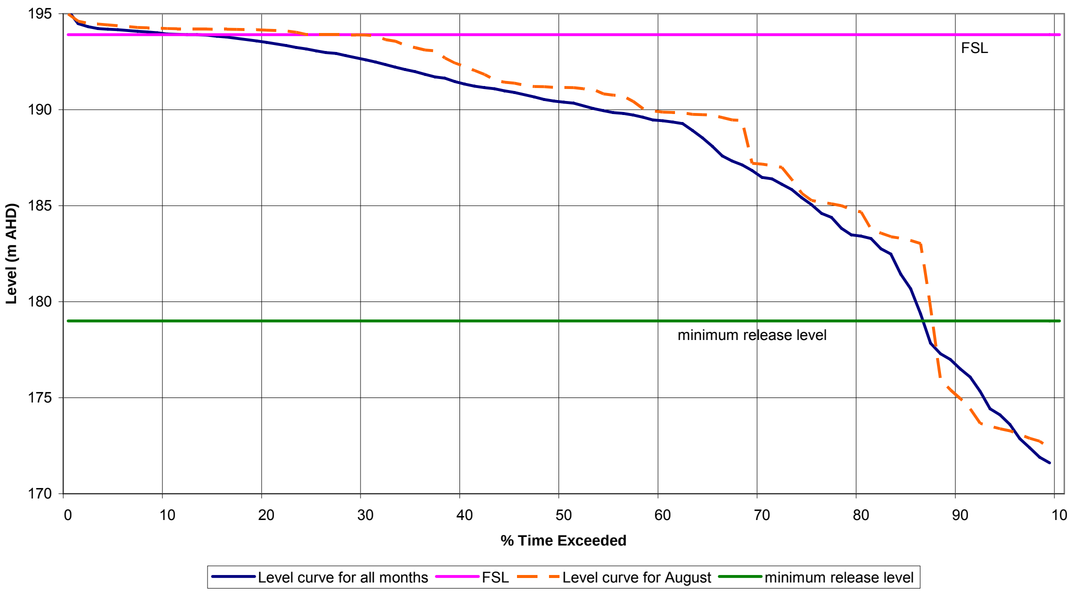
I.9.1 Option C2W1 - Operate Lake Eppalock differently

Description

An analysis of the storage level records for Lake Eppalock was undertaken to assess the option of enhancing high flows in Reach 2 by operating Eppalock differently. This is shown in Figure 35 and Table 39. The Eppalock Dam spillway is a fixed crest arrangement. Apart from overtopping of the spillway, the maximum outlet capacity of the reservoir is 1846 ML/d. As such, the potential for changed operation is limited.

Over the 44 year flow record, flows exceeding 12,000 ML/d at the conformance point downstream of the reservoir have only occurred 8 times. It is assumed that these flows occurred as a result of reservoir spills and inflow to the reservoir is at least 12,000 ML/d.

67% of annual maximum flows are less than 100 ML/d. Therefore releasing 1,846 ML/d during wet weather events will not achieve conformance with the flow recommendation.



- **Figure 35 Level curves of Lake Eppalock for all months and for August over 44 years**

- **Table 39: % of time that storage level is greater than minimum release level (163.15 m AHD), full supply level, and minimum level adequate to meet winter overbank flow recommendations for Lake Eppalock**

Period	% time that storage level > minimum release level	% time that storage. level > FSL	% time that storage level > enviro flow recommendation
All months	87%	12%	0%
August	88%	28%	0%

Effectiveness

This option would be ineffective in delivering required environmental flows.

I.9.2 Option C2W2 - Increase capacity of Lake Eppalock outlet works to 12,000 ML/d at lower storage levels

Description

This option involves construction of new outlet works to increase the release capacity to 12,000 ML/d at low storage levels. The cost of providing additional outlet capacity is expected to be around $25 to $30 million.

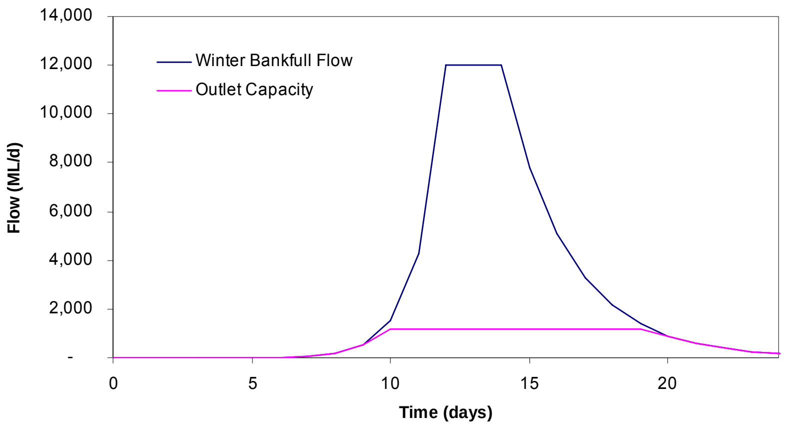
Effectiveness

This option would be highly effective in delivering the recommended winter environmental high flow requirements for this reach.

I.9.3 Option C2W3 - Construct Pondage downstream of Lake Eppalock

Description

Winter bankfull flows of 10,000 ML/d are required once per year for 2 days, or natural. Delivery of flows of this magnitude is possible when the Eppalock storage levels are above spillway level. However, during low storage levels only 1,200 ML/d (refer Figure 35 below) could be delivered through the outlet conduit. This constraint could be overcome by constructing a pondage downstream of the Lake. Water would be released from the Lake into the pondage using the existing outlet conduit, and then in turn released from the pondage when required to meet the specified environmental flow requirements. A storage located below Eppalock with a capacity of around 49,000 ML and a maximum release capacity of 12,000 ML/d would provide the necessary additional flow.



- **Figure 36 Campaspe River – Winter Flows below Lake Eppalock**

The estimated capital cost of the storage and associated works is anticipated to be around $15 to $20 million.

Effectiveness

This option would be moderate to highly effective in delivering the recommended winter environmental high flow requirements for this reach depending on the location of the pondage.

I.10 Campaspe River: Campaspe Weir to Campaspe Siphon - Summer Low and Fresh Flows

Recommended summer flows for this section of the river are:

- A summer low flow of between 10 ML/d and 20 ML/d
- A summer fresh flow of 100 ML/d for six days three times a year.

Conformance for both these recommendations is low due to the need to supply irrigation demand for the Private Diverters and WWC supplement flows.

The section of the Campaspe River from the Campaspe Weir to Campaspe Siphon carries irrigation flows for all Private Diverters during the irrigation season plus WWC supplement flows towards the end of the irrigation season. The normal flow carried by this section of the river in summer is above 20 ML/d for 70% of the time and conformance with the recommended flows is poor.

Three options were investigated to mitigate this constraint and are described below:

- C3S1 - Pipeline or channel from the Campaspe Weir to Campaspe Siphon
- C3S2 - On-farm winter-fill storages
- C3S3 - Purchase of all PD entitlement downstream of Campaspe Weir for sale to Bendigo or upstream irrigators
- C3S4 – Supply PD demand from adjacent channel system

I.10.1 Option C3S1 - Pipeline or channel from the Campaspe Weir to Campaspe Siphon

Description

This option involves construction of a gravity pipeline or channel from the Campaspe Weir to the Campaspe Siphon to carry the irrigation flows in excess of the summer environmental low flow threshold. A fall of 9 m was assumed between the Campaspe Weir and the siphon. Table 40 below provides a summary of the option and associated capital costs.

Table 40 Gravity Pipeline/Channel Option Summary

Item	Pipeline Option	Channel Option
Length (km)	9	9
Flow including WWC supplement (ML/d)	525	525
Size	2,100 mm pipeline	Open Channel
Capital Cost ($million)	$57	$27

Effectiveness

This option would be highly effective in delivering the recommended summer low flows.

I.10.2 Option C3S2 - On-farm winter-fill storages

Description

This option would involve providing on-farm storages for all PDs to be filled in winter. Water would need to be pumped into these storages and pumped out to meet irrigation demands.

It is assumed that sixteen 200 ML capacity landholder owned on-farm storages would be adequate to lower the summer flows to the recommended flow.

The capital cost of providing these storages is expected to be around $7.5 million.

Effectiveness

This option would be highly effective in delivering the recommended summer environmental low flows for this reach.

I.10.3 Option C3S3 - Purchase of all PD entitlement downstream of Campaspe Weir for sale to Bendigo or upstream irrigators

Description

This option involves purchase of all private diverter (PD) entitlements downstream of Campaspe Weir to supply Bendigo urban demand. Total private diverter entitlement downstream of the Campaspe Weir is about 3,000 ML.

Assuming a purchase price of $1,000/ML, this option would cost $4.5 million dollars including 50% contingency.

Effectiveness

This option would be only partially effective in meeting the summer low and fresh flows, as it does not eliminate the supplement flows to Waranga Western Channel in autumn, which are expected to be very high.

I.10.4 Option C3S4 - Supply PD demand from adjacent channel system

Description

Most landholders pump from the Campaspe weir pool. It is assumed that these landowners could be supplied from WWC. Of the four landholders who are not supplied from the pool, one landholder has dual supply and the entire property could be supplied from either an irrigation channel or a river diversion. Some works would be required for the remaining three landholders:

- Two 1.5 km pipelines to supply two properties at a cost of around $3.5 million
- Extend suction line and pump modification for the last landholder at a cost of $0.5 million.

The total cost of supplying these PD demands from adjacent channels is expected to be around $4 million. This cost estimate assumes that the existing channels have sufficient capacity to meet these demands.

Effectiveness

This option would be only partially effective in meeting the summer low and fresh flows, as it does not eliminate the supplement flows to Waranga Western Channel in autumn, which are expected to be very high.

I.11 Campaspe River: Campaspe Weir to Campaspe Siphon - Winter Low Flows

A flow of 200 ML/d is recommended during winter every year. However, it is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude.

I.12 Campaspe River: Campaspe Weir to Campaspe Siphon - Winter High Flows

A flow of 1,500 ML/d for 4 days four times a year is recommended as winter high flows. This recommendation is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude.

I.13 Campaspe River: Campaspe Weir to Campaspe Siphon - Winter Bankfull and Overbank Flows

The recommendation is:

- A winter bank full flow of 8,000 ML/d for two days twice a year
- A winter overbank flow of 12,000 ML/d for one day every year.

These flow recommendations are not currently required to be delivered and conformance is very poor. The outlet capacity at Eppalock reservoir is the main constraint for delivering this recommended flow. The recommended flows could only be delivered via the spillway if storage levels are high enough.

Four options were considered to overcome this constraint:

- C2W1 - Operate Eppalock differently (refer Section I.9.1 above).
- C2W2 - Increase capacity of Eppalock outlet works to 12,000 ML/d at lower storage level (refer Section I.9.2 above).
- C2W3 - Construct a pondage downstream of Lake Eppalock from which to release bankfull and overbank flows (refer Section I.9.3 above).
- C3W1 – Modify Eppalock releases to piggyback on high tributary inflows.

These options may require flood mitigation works, and consideration of how to piggyback onto downstream high flow events.

I.13.1 Option C3W1 - Modify Eppalock releases to piggyback on high tributary inflows

Description

The Eppalock storage can release approximately 1,800 ML/d. This is below the required flows of 8,000 and 12,000 ML/d. Releases from Eppalock during wet weather events only form a part of the total flow in the reaches downstream of the reservoir, the rest coming from local rainfall runoff. Also there are times when the storage spills and releases flows in excess of 1,800 ML/d. This option relates to operating Eppalock such that the full release of 1,800 ML/d occurs to coincide with a wet weather event during winter.

Effectiveness

Annual maximum flows in reach 3 of the Campaspe River were analysed to identify how often flows greater than 12,000 ML/day could be achieved from August to September if the maximum volume of 1,800 ML/day were released from Lake Eppalock. It was assumed that any flow released from Eppalock would continue throughout the downstream reaches. This analysis shows that the opportunity to achieve winter overbank flow in reach 3 occurred 25% of years over the period 1893-2006. This does not comply with the recommended frequency of 12,000 ML/day occurring once per year. Therefore, the current infrastructure of Eppalock can not deliver full conformance with the winter overbank flow recommendation in reach 3.

This option is therefore not effective in delivering the environmental flow requirement.

I.14 Campaspe River: Campaspe Siphon to River Murray - Summer Low and Fresh Flows

The summer low and fresh flow recommendations are:

- low flow of between 10 ML/d and 20 ML/d for six months every year
- fresh flows of 100 ML/d for six days three times a year

The Campaspe River carries irrigation flows for all Private Diverters along this reach during the irrigation season. The typical flows carried by this section of the River in summer are above 20 ML/d for 70% of the time and conformance with the recommended flow regime is poor.

Four options were investigated to mitigate this constraint and are described below:

- C4S1 - Pipeline or channel from Campaspe Siphon to River Murray
- C4S2 - On-farm winter-fill storages

SKM

- C4S3 - Purchase of reach PD entitlement for sale to Bendigo or upstream irrigators
- C4S4 - Supply PD demands from adjacent channel systems

I.14.1 Option C4S1 - Pipeline or channel from Campaspe Siphon to River Murray

Description

This option involves construction of a gravity pipeline or channel from Campaspe Siphon to the River Murray to carry the irrigation flows in excess of the summer environmental low flow threshold. A fall of 12 m was assumed between the Campaspe Weir and the siphon. Table 41 below provides a summary of the option and the associated capital costs.

- **Table 41 Pipeline/Gravity Option Summary**

	Pipeline Option	Channel Option
Length (km)	18	18
Flow (ML/d)	25	25
Size	750 mm pipeline	Open Channel
Capital Cost ($million)	$32	$7

Effectiveness

This option would be highly effective in delivering the recommended summer cease to flow and low flows.

I.14.2 Option C4S2 - On-farm winter-fill storages

Description

There are eleven irrigators and it is assumed that 200 ML capacity landholder owned on-farm storages for each irrigator would be adequate to lower the summer flows to the recommended flow.

The capital cost of providing these storages is expected to be around $6 million.

Effectiveness

This option would be highly effective in delivering the recommended summer environmental low flows for this reach.

I.14.3 Option C4S3 - Purchase of reach PD entitlements for sale to Bendigo or upstream irrigators

Description

This option involves purchase of all 1,857 ML of private diverter (PD) entitlements downstream of Campaspe Siphon to supply Bendigo urban demand.

Assuming a purchase price of $1,000 per ML, this option would cost $3 million, including a 50% contingency.

Effectiveness
This option would be highly effective in meeting the cease to flow recommendation in this reach, and would partially reduce flows in upstream reaches.

I.14.4 C4S4 - Supply PD demand from adjacent channel systems

Description
A number of landholders have supplies from both a G-MW channel and the Campaspe River. It is assumed that entitlements for these landowners could be supplied from channels. The remaining landholders do not have access to channels and will require the existing channel system to be extended. It is estimated that a total of 20 kms of new channels would be required to supply these properties at a cost of around $6 million.

The cost estimate assumes that the existing channels have sufficient capacity to meet these demands.

Effectiveness
This option would be highly effective in meeting the cease to flow recommendation.

I.15 Campaspe River: Campaspe Siphon to River Murray – Winter Low Flows
A flow of 200 ML/d is recommended during winter every year. However, it is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude if winter flows are delivered from the Campaspe River. If the flows are to be delivered from WWC, then WWC maintenance program would need to be modified.

I.15.1 Option C4W1- Supply from WWC

Description
The WWC has outfall capacity of around 2,300 ML/d at the Campaspe Siphon. All of this would be available for delivering flows to Campaspe River in winter, due to absence of concurrent irrigation demand. Hence, WWC could deliver the required flow from Waranga Basin, but it would need to be managed in such a way that it did not impact on winter channel maintenance works. The existing outfall structure on the WWC is assumed to be adequate to regulate flows to the Campaspe River. This option would however require a modified WWC maintenance program, as routine channel and structure maintenance and/or renewal works are normally performed in winter on most channels. The best possible scenario for supplying the water is WWC is either towards the end of the irrigation season in May/June or start of the season in July/August. This would provide at least 30 days for maintenance works on the channel. This option is not expected

to have any additional costs, and should only require planning of maintenance works to allow the delivery of this flow.

Effectiveness

This option would be highly effective in delivering winter low flows to the Campaspe River.

I.16 Campaspe River: Campaspe Siphon to River Murray – Winter High Flows

A flow of 1,500 ML/d for 4 days twice a year is recommended as winter high flows. This recommendation is not a current requirement and conformance is very poor.

There are no infrastructure or operational constraints to releasing flows of this magnitude.

I.17 Campaspe River: Campaspe Siphon to River Murray – Winter Bankfull Flows

The recommended winter bankfull flow is 9,000 ML/d for two days twice a year. This is not a current requirement and conformance is very poor. The outlet capacity at Eppalock reservoir is the main constraint for delivering this recommended flow.

Four options were investigated:

- C2W1 - Operate Eppalock differently (refer Section I.9.1 above).
- C2W2 - Increase capacity of Eppalock outlet works to 12,000 ML/d at lower storage level (refer Section I.9.2 above).
- C2W3 - Construct pondage downstream of Lake Eppalock (refer Section I.9.3 above).
- C3W1 – Modify Eppalock releases to piggyback on high tributary inflows (refer Section I.13.1 above).
- C4W1 - Supply from WWC (as above)

I.18 Campaspe River – Living Murray Contribution

The specified Living Murray Initiative flow requirements are between an additional 2,000 ML/d for both winter high and winter bankfull flows (refer Chapter 3.5 for details).

Winter High flows

Two options were considered for delivering the winter high flows:

- M1W1 - Increase outlet capacity of Eppalock to 2,200 ML/d at lower storage levels
- C4W1 – Supply from WWC (as above)

I.18.1 Option M1W1 - Increase outlet capacity of Eppalock to 2,200 ML/d at lower storage levels

Description

This option involves construction of new outlet works to increase the release capacity from Lake Eppalock to 2,200 ML/d at low storage levels. The cost of providing additional outlet capacity is expected to be around $2 to $3 million.

Effectiveness

This option would be highly effective in delivering the recommended winter high flow requirements for this reach.

Winter Bankfull flows

Two options were considered for delivering the winter fresh flows:

- M1W1 - Increase outlet capacity of Eppalock to 2,200 ML/d at lower storage levels (as above)
- C4W1 – Supply from WWC (as above)

Appendix J Birches and Tullaroop Creek System Options

In this chapter, options are developed for improving the delivery of the recommended environmental flow regimes. The options are generally based on a need to overcome the current constraints to environmental flow delivery identified in Chapter 6. Options have been grouped by reach and flow component. Each option is described, and comment is then provided on the likely effectiveness of each option in meeting the recommended environmental flow component that it was intended to address within that reach.

Indicative cost estimates have been presented for some options. All costs provided are capital costs only and do not include any allowances for on-going costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that would allow detailed cost estimates to be developed

J.1 Birches Creek: Reach 1 Newlyn Reservoir to Hepburn Race - Summer Low Flows

The recommendation for summer low flows for this reach is 3 ML/d or natural for 6 months of the year. There is no current requirement to comply with this recommendation and the current conformance is only about 53%.

The existing Newlyn outlet can release low flows of around 5 ML/d at low storage levels and thus could meet all summer low flow requirements. Therefore, there are no infrastructure or operational constraints to releasing flows of this magnitude.

J.2 Birches Creek: Reach 1 Newlyn Reservoir to Hepburn Race - Summer Fresh Flows

There are no current requirements to deliver summer fresh flows in this reach. The recommendation is to release a summer fresh flow of 10 ML/d for three days, four times a year or natural. Flows of this magnitude could be delivered when the storage level is high. However, the current outlet will not be able to meet this recommendation at low storage levels.

Two options were considered to meet this flow recommendation:

- B1S1 - Decommission Newlyn Reservoir, and
- B1S2 - Increase Newlyn Reservoir outlet capacity at low storage levels to 10 ML/d

J.2.1 Option B1S1 - Decommission Newlyn Reservoir

Description

This option would involve decommissioning Newlyn Reservoir and thus allowing the Creek to return to a more natural flow regime. It is therefore a “global” option that meets virtually all flow recommendations for this reach, not just summer low flows.

The following works and costs have been assumed

- Remove embankment and structures - $1 million
- Purchase irrigation entitlements ($1,500/ML) - $0.8 million
- Provision of a 100 ML storage and pump for Springhill and Clunes reserve - $1 million
- Provision of storages and pumps for stock and domestic entitlements - $0.2 million

Total cost of this option is $3 million.

Effectiveness

This option would be highly effective in delivering the required environmental flow regime for all flows, not just summer low flows.

J.2.2 Option B1S2 - Increase Newlyn Reservoir outlet capacity at low levels to 10 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the summer fresh flow requirements of 10 ML/d. A pumped outlet was assumed for this option to supplement the estimated 5 ML/d that can be released through the existing outlet at low levels.

The capital cost of providing a permanent electric pump is expected to be around $0.5-1.0 million.

Effectiveness

This option would be highly effective in delivering the required environmental regime for the summer fresh flows.

J.3 Birches Creek: Reach 1 Newlyn Reservoir to Hepburn Race - Winter Low Flows

The recommendation is to release a flow of 10 ML/d, or natural, for six months every year, which could be delivered when the storage level is high. However, the current outlet will not be able to meet this recommendation at low storage levels. Two options were considered to meet this flow recommendation:

- B1S1 - Decommission Newlyn Reservoir as described above (see Section J.2.1 above), and

- B1S2 - Increase Newlyn Reservoir outlet capacity at low levels to 10 ML/d (see Section J.2.2 above).

J.4 Birches Creek: Reach 1 Newlyn Reservoir to Hepburn Race - Winter Fresh Flows

The recommendation for winter fresh flows is a flow for 40 ML/d for five days, three times a year, or natural. These flows could be delivered from Newlyn Reservoir when the storage level is above FSL, through the spillway. However, if the storage level is below FSL, the existing reservoir outlet will not be able to deliver these flows. Two options were identified to address this constraint:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B1W1 - Increase Newlyn Reservoir outlet capacity at low storage levels to 40 ML/d.

J.4.1 Option B1W1 – Increase Newlyn Reservoir outlet capacity at low storage levels to 40 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the winter fresh flow requirement of 40 ML/d. A pumped outlet was assumed for this option to supplement the estimated 5 ML/d that can be released through the existing outlet at low levels.

The capital cost of providing a permanent electric pump is expected to be around $1.5-$2 million

Effectiveness

This option would be highly effective in delivering the recommended winter environmental fresh flow regime.

J.5 Birches Creek: Reach 1 Newlyn Reservoir to Hepburn Race – Winter High Flows

The recommendation winter high flow is 160 ML/d for five days, three times a year, or natural. These flows could be delivered from Newlyn Reservoir when the storage level is above FSL through the spillway. However, if the storage level is below FSL, the existing reservoir outlet will not be able to deliver these flows. Two options were identified to address this constraint:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B1W2 - Increase Newlyn Reservoir outlet capacity at low storage levels to 160 ML/d

J.5.1 Option B1W2 – Increase Newlyn Reservoir outlet capacity at low storage levels to 160 ML/d

Description

This would option involves providing additional outlet capacity at low levels to meet the all winter flow requirements up to the high flow of 160 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of a second outlet capable of providing the winter high flows is expected to be around $2-3 million.

Effectiveness

This option would be highly effective in delivering the recommended winter environmental high flow regime.

J.6 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) - Summer Low Flows

Reach 2 (Birches Creek: Hepburn Race to Lawrence Weir), Reach 3 (Birches Creek: Lawrence Weir to Creswick Creek) and Reach 4 (Tullaroop Creek: Creswick Creek to Tullaroop Reservoir) have been combined because there are no significant regulation points in these reaches, and the recommended environmental flow regimes are of a similar nature for all three reaches. The recommended summer environmental low flow is 5- 10 ML/d, or natural. Conformance is low and is constrained by the existing outlet capacity at both Newlyn Reservoir and Hepburn Lagoon at low storage levels. Four options were investigated:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B1S2 - Increase outlet capacity at low storage levels to 10 ML/d (see Section J.2.2 above).
- B2S1 - Decommission Hepburn Lagoon
- B2S2 - Increase Hepburn Lagoon outlet capacity at low storage levels to 10 ML/d

J.6.1 Option B2S1 – Decommission Hepburn Lagoon

Description

This option involves decommissioning Hepburn Lagoon and thus allowing the Creek to return to a more natural flow regime. It is therefore a “global” option that meets virtually all flow requirements for this reach, not just summer flows.

The following works and costs have been assumed

- Remove embankment and structures - $1 million
- Purchase irrigation entitlements ($1,500/ML) - $0.4 million

- Provision of storages and pumps for stock and domestic entitlements - $0.1 million

Total cost of this option is $1.5 million.

Effectiveness

This option would be highly effective in delivering the recommended environmental flow regime for the summer low and fresh flows.

J.6.2 Option B2S2 – Increase Hepburn Lagoon outlet capacity at low storage levels to 10 ML/d

Description

This option involves providing additional outlet capacity at low levels to meet the summer low flow requirements. A pumped outlet was assumed for this option.

The capital cost of providing a permanent electric pump is expected to be around $0.4-0.8 million.

Effectiveness

This option would be highly effective in delivering the required environmental regime for summer low flows.

J.7 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) - Summer Fresh Flows

The recommended environmental summer fresh flow is between 15 ML/d and 27 ML/d, for three days, four times a year, or natural. As for summer low flow, conformance for both requirements is low and is constrained by the existing outlet capacities at both Newlyn Reservoir and Hepburn Lagoon at low storage levels. Four options were investigated:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B2S1 - Decommission Hepburn Lagoon (as described in Section J.6.1 above)
- B2S3 - Increase Hepburn Lagoon outlet capacity at low storage levels to 27 ML/d
- B2S4 - Increase Newlyn Reservoir outlet capacity at low storage levels to 27 ML/d

J.7.1 Option B2S3 – Increase Hepburn Lagoon outlet capacity at low storage levels to 27 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the summer fresh flow requirements. A pumped outlet was assumed for this option.

The capital cost of providing a permanent electric pump is expected to be around $0.7-1.2 million.

Effectiveness

This option would be highly effective in delivering the required environmental summer fresh flow regime.

J.7.2 Option B2S4 - Increase Newlyn Reservoir outlet capacity at low storage levels to 27 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the summer fresh flow requirements. A pumped outlet was assumed for this option.

The capital cost of providing a permanent electric pump is expected to be around $0.7-1.2 million.

Effectiveness

This option would be highly effective in delivering the required environmental summer fresh flow regime.

J.8 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) - Winter Low Flows

The recommended winter environmental low flow for this reach is between 10- 20 ML/d, or natural. Delivery is constrained by the existing outlet capacity at both Newlyn Reservoir and Hepburn Lagoon at low storage levels. Four options were investigated:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B2S1 - Decommission Hepburn Lagoon (as described in Section J.7.1 above)
- B2S3 - Increase Hepburn Lagoon outlet capacity at low levels to 27 ML/d (as described in Section J.7.1 above)
- B2S4 - Increase Newlyn outlet capacity at low levels to 27 ML/d (as described in Section J.7.2 above)

J.9 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) - Winter Fresh Flows

Winter fresh flows of 55-275 ML/d for five days three times a year, or natural, are recommended for this reach. Delivery is constrained by the existing outlet capacity at both Newlyn Reservoir and Hepburn Lagoon at low storage levels. Four options were investigated:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B2S1 - Decommission Hepburn Lagoon (as described in Section J.7.1 above)
- B2W1- Increase outlet capacity at Hepburn Lagoon at low storage levels to 275 ML/d, and

- B2W2 - Increase outlet capacity at Newlyn Reservoir at low storage levels to 275 ML/d, to provide winter fresh flows

J.9.1 Option B2W1 - Increase outlet capacity at Hepburn Lagoon at low storage levels to 275 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the winter fresh flow requirement of 275 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of providing a second outlet capable of providing the winter fresh flows is expected to be around $3 to $4 million.

Effectiveness

This option would be highly effective in delivering the recommended winter fresh environmental flow regime for this reach.

J.9.2 Option B2W2 - Increase outlet capacity at Newlyn Reservoir at low storage levels to 275 ML/d

Description

This option would involve providing additional outlet capacity at low levels to meet the winter fresh flow requirement of 275 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of providing a second outlet capable of providing the winter fresh flows is expected to be around $3 to $4 million.

Effectiveness

This option would be highly effective in delivering the recommended winter fresh environmental flow regime for this reach.

J.10 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) – Winter High Flows

The recommended winter high flow regime in this reach comprises a flow of 275 ML/d (reducing to 200 ML/d at the downstream end of the reach) for 3 days, twice to three times a year, or natural. Conformance with this recommendation is relatively low, and is constrained by the existing outlet capacity at both Newlyn Reservoir and Hepburn Lagoon at low storage levels. Four options were considered to address this constraint:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)

- B2S1 - Decommission Hepburn Lagoon (as described in Section J.6.1 above)
- B2W1- Increase outlet capacity at Newlyn Reservoir at low storage levels to 275 ML/d (as described in Section J.9.1 above) and
- B2W2 - Increase outlet capacity at Hepburn Lagoon at low levels to 275 ML/d (as described in Section J.9.2 above).

J.11 Birches Creek: Hepburn to Creswick Creek (Reach 2 and 3) and Tullaroop Creek: Creswick Creek to Tullaroop Reservoir (Reach 4) – Winter Bankfull Flows

The recommended winter bankfull flow for this reach is 1,300 ML/d (increasing to 2,580 ML/d at the downstream end of the reach) for one day, once per year, or natural. Conformance with this recommendation is relatively low. As for the summer and winter flows above, releases are constrained by the existing outlet capacity at Hepburn Lagoon. Four options were investigated:

- B1S1 - Decommission Newlyn Reservoir (as described in Section J.2.1 above)
- B2S1 - Decommission Hepburn Lagoon (as described in Section J.6.1 above)
- B2W3 - Increase Hepburn Lagoon outlet capacity to 1,300 ML/d
- B2W4 - Increase Newlyn Reservoir outlet capacity to 1,300 ML/d

J.11.1 Option B2W3 - Increase Hepburn Lagoon outlet capacity to 1,300 ML/d

Description

This option would involve providing additional outlet capacity to meet the bankfull flow recommendation of 1,300 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of providing a second outlet capable of providing the winter bankfull flow is expected to be around $6 to $8 million.

Effectiveness

This option would be highly effective in delivering the recommended winter environmental bankfull flow regime.

J.11.2 Option B2W4 - Increase Newlyn Reservoir outlet capacity to 1,300 ML/d

Description

This option would involve providing additional outlet capacity to meet the bankfull flow recommendation of 1,300 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of providing a second outlet capable of providing the winter bankfull flow is expected to be around $6 to $8 million.

Effectiveness

This option would be highly effective in delivering the recommended winter environmental bankfull flow regime.

Appendix K Loddon System Options

In this chapter, options are developed for improving the delivery of the recommended environmental flow regimes. The options are generally based on a need to overcome the current constraints to environmental flow delivery identified in Chapter 7. Options have been grouped by reach and flow component. Each option is described, and comment is then provided on the likely effectiveness of each option in meeting the recommended environmental flow component that it was intended to address within that reach.

Indicative cost estimates have been presented for some options. All costs provided are capital costs only and do not include any allowances for on-going costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that would allow detailed cost estimates to be developed

K.1 Tullaroop Creek: Reach 2 Tullaroop Creek, Tullaroop Reservoir to Laanecoorie Reservoir – Summer Flows

Environmental flow recommendations in summer for this reach are:

- low flows of 10 ML/d, or natural, every day
- fresh flows of at least 13.5 ML/d for seven days four times per year.

Tullaroop Creek is used for irrigation deliveries to Pyramid Boort Irrigation areas and PDs. It carries flows well in excess of the low flow requirement throughout the summer.

Seven options were investigated:

- T1S1 - Decommission Tullaroop Reservoir
- T1S2 - Pipeline or Channel from Tullaroop to Laanecoorie
- T1S3 - Winterfill storage at Fernihurst and on-farm storages for reach PDs
- T1S4 - On-farm and regional winter-fill storages
- T1S5 - Pipeline from Tullaroop Reservoir to Cairn Curran Reservoir
- T1S6 - Augment capacity of WWC to supply Boort Irrigators currently supplied from Tullaroop
- T1S7 - Enlarge Capacity of Laanecoorie for winter-fill from Tullaroop

K.1.1 Option T1S1 - Decommission Tullaroop Reservoir

Description

This option involves decommissioning Tullaroop Reservoir and purchasing private diverter entitlements to Laanecoorie, thus allowing the creek to return to a more natural flow regime. It is therefore a "global" option that meets most flow requirements for this reach, not just summer flows.

Tullaroop reservoir holds about a third of the total Loddon storage volume and is a vital element of the Loddon system. It also supplies about 1,200 ML of urban entitlement to Central Highlands Water, and about 3,000 ML of private diverters between Tullaroop and Laanecoorie. Decommissioning Tullaroop is expected to have significant impacts on the reliability of water supply to Boort area, downstream private diverters (PDs) and Central Highlands Water. Quantification of these impacts is beyond the scope of this study and will require a more detailed investigation should this option be considered as part of any environmental flow packages.

Cost estimates were not prepared for this option as the required works and impacts could not be fully identified at this stage.

Effectiveness

This option would allow the creek to be run as per the environmental flow recommendations and is highly effective in delivering the environmental flows for this reach during summer months.

K.1.2 Option T1S2 - Pipeline or Channel from Tullaroop to Laanecoorie

Description

This option involves construction of a gravity pipeline or channel from Tullaroop to Laanecoorie to carry the irrigation flows in excess of the environmental flow threshold. The storage level of Tullaroop at 10% capacity is 208.35 m AHD which is about 48 metres above the Laanecoorie FSL of 160.20 m AHD. Table 42 below provides a summary of the option and cost.

- **Table 42 Pipeline/Gravity Option Summary**

	Pipeline Option	Channel Option
Length (km)	30	30
Size	15 km x 2100 mm and 15 km x 1800 mm dia pipeline	Open Channel
Capital Cost ($million)	250	60

Effectiveness

This option would allow the river to be run as per the environmental flow recommendations and is highly effective in delivering the environmental flows for this reach during summer months.

K.1.3 Option T1S3 - Winterfill storage at Fernihurst and on-farm storages for reach PDs

Description

The objective of this option, which would involve a new off-line storage at Fernihurst and on-farm storages for reach PDs, is to store adequate water to meet irrigation demands during the season.

The Loddon system provides supplementary flows to Goulburn system supplies from the Waranga Western Channel of between 0 GL and 140 GL depending on the season. Up to 40 GL of this is sourced from Tullaroop Reservoir. Therefore, a 40 GL storage at Fernihurst would be sufficient to eliminate Boort area demand from Tullaroop Reservoir. It is assumed that the storage would be filled by gravity and pumped out during the irrigation season.

Tullaroop also supplies some 3,000 ML of irrigation water to private diverters along the Creek between the Tullaroop and Laanecoorie reservoirs. It is assumed that twenty 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The capital cost of these storages is expected to be around $190 million.

Effectiveness

This option would allow the river to be run as per the environmental flow recommendations and is highly effective in delivering the environmental flows for this reach during summer months.

K.1.4 Option T1S4 - On-farm and regional winter-fill storages

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages to meet the component of the flow supplied by Tullaroop that would be filled in winter. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

The Loddon system has the potential to deliver up to 140 GL of irrigation water. In order to meet the environmental flow recommendations in summer, most of this flow would need to be supplied in winter. A total storage requirement of 160 GL including loss allowances has been assumed for this option. It is assumed that this could be provided either by larger G-MW owned regional storages or landowner owned on-farm storages. For the purpose of this study, it has been assumed that the storages would comprise:

- 10 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and

- 550 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

These storages would provide a total storage volume of 160,000 ML. The capital cost of providing these storages is expected to be around $1 billion.

Effectiveness

This option would be moderate to highly effective as it would provide storage for majority of the required water use.

K.1.5 Option T1S5 - Pipeline from Tullaroop Reservoir to Cairn Curran Reservoir

Description

This option involves construction of a pipeline or channel from Tullaroop to Cairn Curran to carry the irrigation flows in excess of the environmental flow threshold. The storage level of Tullaroop at 10% storage level is 208.35 m AHD and the Cairn Curran FSL is 208.46 m AHD. A pumped pressure pipeline has been assumed for this option. Table 43 below provides a summary of the option and cost.

Tullaroop also supplies some 3,000 ML of irrigation water to private diverters along the River between the Tullaroop and Laanecoorie reservoirs. It is assumed that sixteen 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters at an estimated cost of around $16 million.

- **Table 43 Pipeline to Cairn Curran**

	Option Details
Length (km)	14
Flow (ML/d)	500
Size	1800 mm pressure main
Capital Cost ($million)	106

Effectiveness

This option is assessed as being highly effective in delivering the environmental flows for this reach during summer months.

K.1.6 Option T1S6 - Augment capacity of WWC to supply Boort Irrigators currently supplied from Tullaroop

Description

This option involves upgrading of the Waranga Western Channel from the Waranga Basin to the Loddon River to carry an additional 500 ML/d to substitute flows that is currently released from Tullaroop. Table 44 below provides a summary of the option and cost.

- **Table 44 Augment WWC by 500 ML/d**

	Option Details
Length (km)	165
Flow (ML/d)	500
Size	Widen existing channel by 5 m
Capital Cost ($million)	260

Effectiveness

This option is assessed as moderately effective in delivering the environmental flows for this reach during summer months, as PD demands between Tullaroop and Laanecoorie would still need to be supplied from the Creek.

K.1.7 Option T1S7 - Enlarge Capacity of Laanecoorie for winter-fill from Tullaroop

Description

This option involves enlarging existing Laanecoorie Reservoir and constructing on-farm storages for reach PDs to store adequate water to meet irrigation demands during the season.

This option is similar to Option T1S3 (refer Section K.1.7 above) except for the storage location, which would be at Laanecoorie. Laanecoorie reservoir currently holds a volume of 6 GL and the existing reservoir capacity would need to be increased by 40 GL providing a total volume of 46 GL. It is assumed that the additional storage be provided by dredging the storage to its original capacity of 20 GL and extending the storage, to provide a total storage volume of 46 GL.

Tullaroop also supplies some 3,000 ML of irrigation water to private diverters along the Creek between the Tullaroop and Laanecoorie reservoirs. It is assumed that twenty 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The capital cost of this storage is expected to be around $370 million.

Effectiveness

This option would allow the river to be run as per the environmental flow recommendations and would be highly effective in delivering the environmental flows for this reach during summer months.

K.2 Tullaroop Creek: Reach 2 Tullaroop Creek, Tullaroop Reservoir to Laanecoorie Reservoir - Winter Flows

Recommended winter environmental flows for this reach are:

- low flows of about 10 ML/d, or natural all year
- fresh flows of 132 ML/d for seven days twice a year
- high flow of 500 ML/d for four days (twice a year, four years in five).

The maximum outlet capacity of the Tullaroop Reservoir is currently restricted to 450 ML/d due to vibration in the outlet works.

K.2.1 Option T1W1 – Eliminate Tullaroop Outlet Vibration

Description

This option involves modifying the Tullaroop outlet to eliminate vibration at flows above 450 ML/d. The capital cost of the works expected to be around $0.5 million.

Effectiveness

This option would be highly effective in delivering recommended winter high flows.

K.3 Tullaroop Creek: Reach 2 Tullaroop Creek, Tullaroop Reservoir to Laanecoorie Reservoir – Anytime High

Recommended environmental flows for this reach are:

- 500 ML/d for four days one event per year, four years in every five years
- 3,000 ML/d for a day once every two years.

There are no infrastructure or operational constraints to release of an anytime high flow of 500 ML/d.

Four options were investigated for release of a 3,000 ML/d anytime high flow:

- T1A1 - Increase Tullaroop outlet capacity to 3,000 ML/d
- T1A2 - Modify Tullaroop releases to piggyback on high tributary inflows
- T1A3 - Construct Pondage downstream of Tullaroop
- T1S1 – As above

SKM

K.3.1 Option T1A1 - Increase Tullaroop outlet capacity to 3,000 ML/d

Description

This option involves providing additional outlet capacity to meet the flow requirements of 3,000 ML/d. A new outlet tower and outlet conduit was assumed for this option.

The capital cost of providing a second outlet capable of providing the anytime high flow is expected to be around $8 to $10 million.

Effectiveness

This option would be highly effective in delivering the recommended anytime high flow of 3,000 ML/d.

K.3.2 Option T1A2 - Modify Tullaroop releases to piggyback on high tributary inflows

Description

This option involves modifying release patterns from Tullaroop to piggyback on high tributary inflows. Currently, releases from Tullaroop are restricted to 450 ML/d due to the issues with vibrations when flows exceed this. However, if the issues with vibrations are fixed then larger flows could be released at higher storage levels.

An analysis of annual maximum flows in this reach was undertaken to determine the feasibility of this option with 450 ML/d and 550 ML/d releases from Tullaroop. This analysis showed

- A release of 450 ML/d would not improve compliance with the recommended anytime high flows; and
- A 550 ML/d release would improve the compliance to from 64% to 80%.

The analysis has also shown that a flow of 2,200 ML/d would be required to reach 100% compliance. This would only be possible with releases from the spillway when the storage is above the spillway crest, which would require levels to be above spillway level more frequently than is currently the case.

Effectiveness

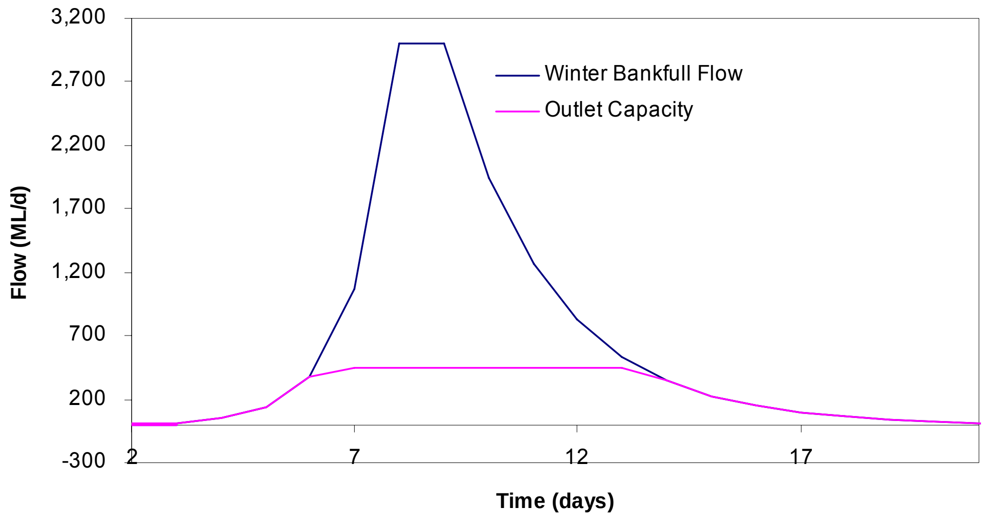
This option is assessed as ineffective as the required releases are constrained by the existing outlet structure capacity.

K.3.3 Option T1A3 - Construct Pondage downstream of Tullaroop

Description

Anytime high flow of 3,000 ML/d is required for a day once every two years. Delivery of flows of this magnitude is only possible when storage levels are above spillway level. However, during low storage levels only a maximum flow of 450 ML/d (refer Figure 37 below) could be delivered through the existing outlet conduit. This constraint could be overcome by constructing a pondage downstream of Tullaroop. Water would be released into the pondage using the existing outlet, and then in turn released from the pondage when required to meet the specified environmental flow requirements. A storage located below Tullaroop with a capacity of around 9,000 ML and a maximum release capacity of 3,000 ML/d would provide the necessary additional flow.

- **Figure 37 Tullaroop Reservoir – Pondage downstream**



The estimated capital cost of the storage and associated works is anticipated to be around $10 to $15 million.

Effectiveness

This option would be highly effective in delivering the recommended anytime high flow recommendation for this reach.

K.4 Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir - Summer cease to flow

The Loddon scientific panel recommended a cease-to-flow for this reach, for two months every four years. Conformance for these requirements is relatively low. The main constraint on this reach is the need to supply irrigation demands in summer, which results in consistently high flows, no cease-to-flow events, and relatively little flow variability. Seven options were considered to address the cease-to-flow component:

- L1S1 - Pipeline or channel from Cairn Curran to Laanecoorie including reach PDs
- L1S2 - Supply from Tullaroop to Laanecoorie and provide on-farm storages to reach PDs
- L1S3 - Pipeline from Cairn Curran to Tullaroop and provide on-farm storages for reach PDs
- L1S4 - Augment capacity of WWC to supply Boort irrigators currently supplied from Cairn Curran
- L1S5 - Enlarge capacity of Laanecoorie for winterfill from Cairn Curran
- L1S6 - Winterfill Storage near Loddon Weir at Fernihurst to cover cease to flow period and provide on-farm storages for reach PDs
- L1S7 - On-farm and regional winter-fill storages to cover cease to flow period

K.4.1 Option L1S1 - Pipeline or channel from Cairn Curran to Laanecoorie including reach PDs

Description

This option involves construction of a pipeline or channel from Cairn Curran to Laanecoorie to carry the irrigation flows in excess of the environmental flow threshold. The storage level of Cairn Curran at 10% of capacity is 194.6 m AHD and the FSL Laanecoorie is 160.2 m AHD. Hence, a gravity pipeline or channel has been assumed for this option. It would also supply all private diverters between Cairn Curran and Laanecoorie. Table 45 below provides a summary of the option and cost.

- **Table 45 Pipeline/Gravity Option Summary**

	Pipeline Option	Channel Option
Length (km)	19	19
Size	15 km x 2100 mm and 15 km x 1800 mm dia pipeline	Open Channel
Capital Cost ($million)	160	36

Effectiveness

This option would allow the river to be run as per the environmental flow recommendation and would be highly effective in delivering the recommended summer cease-to-flow component.

K.4.2 Option L1S2 - Supply from Tullaroop to Laanecoorie and provide on-farm storages to reach PDs

Description

This option would involve supplying Laanecoorie from Tullaroop during the cease-to-flow period. Tullaroop has a storage volume of 73,690 ML at FSL and the flow requirement during the two months could be as high as 70,000 ML assuming maximum Loddon supplement. This would mean the Loddon River would need to carry flows in excess of 1,100 ML/d to achieve this. Also, the Tullaroop outlet structure capacity would be insufficient to deliver this flow rate and would require upgrading. Cost of upgrading the outlet works is expected to be around $3-$5 million.

Alternatively, cease to flow requirement for this could be met, where possible, during low supplement years.

Cairn Curran also supplies some 1,500 ML of irrigation water to private diverters along the River between the Cairn Curran and Laanecoorie reservoirs. It is assumed that ten 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters at an estimated cost of around $10 million.

Total cost of this option would be around $13-$15 million.

Effectiveness

This option would allow the river to be run as per the environmental flow recommendation and would be highly effective in delivering the recommended summer cease-to-flow component.

K.4.3 Option L1S3 - Pipeline from Cairn Curran to Tullaroop and provide on-farm storages for reach PDs

Description

This option involves construction of a pipeline or channel from Cairn Curran to Tullaroop to carry the irrigation flows in excess of the environmental flow threshold. The storage level of Cairn Curran at 10% storage level is 194.6 m AHD and the FSL Tullaroop is 222.8 m AHD. A pumped pressure pipeline has been assumed for this option.

As noted above, Cairn Curran also supplies some 1,500 ML of irrigation water to private diverters along the River between the Cairn Curran and Laanecoorie reservoirs. It is assumed that ten 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters at an estimated cost of around $10 million.

Table 46 below provides a summary of the option and cost.

- **Table 46 Pipeline Option Summary**

	Pipeline Option
Length (km)	14
Flow (ML/d)	750

	Pipeline Option
Size	2400 mm pressure main
Pipeline Capital Cost ($million)	140
On-farm storage cost ($million)	10
Capital Cost ($million)	150

Effectiveness

This option would allow the river to be run as per the environmental flow recommendation and would be highly effective in delivering the recommended summer cease-to-flow component.

K.4.4 Option L1S4 - Augment capacity of WWC to supply Boort irrigators currently supplied from Cairn Curran

Description

This option would involve upgrading of the Waranga Western Channel from the Waranga Basin to the Loddon River to carry an additional 600 ML/d to substitute flow that is currently released from Cairn Curran. Table 47 below provides a summary of the option and cost.

- **Table 47 Augment WWC by 600 ML/d**

	Option Details
Length (km)	165
Flow (ML/d)	600
Size	Widen existing channel by 5 m
Capital Cost ($million)	300

Effectiveness

This option would be only moderately effective in delivering the cease-to-flow recommendation flow for this reach, as PD demands between Cairn Curran and Laanecoorie would still need to be supplied from the River.

K.4.5 Option L1S5 - Enlarge capacity of Laanecoorie for winterfill from Cairn Curran

Description

A larger storage at Laanecoorie would store irrigation that would normally be released from Cairn Curran during summer months. This option would involve enlarging Laanecoorie Reservoir and constructing on-farm storages for reach PDs to store adequate water to meet irrigation demands during the season.

Cairn Curran could deliver volumes up to 100 GL during summer months to meet Boort area and reach PD irrigation demands. Laanecoorie Reservoir currently holds a volume of 6 GL and the existing reservoir capacity needs to be increased by 100 GL providing a total volume of 106 GL. It is suggested that additional storage be provided by dredging the storage to its original capacity of 20 GL and extending the storage to gain a total storage volume of 106 GL. This option is unlikely to be feasible due to lack of suitable land adjacent to Laanecoorie Reservoir to extend the storage.

Cairn Curran also supplies some 1,500 ML of irrigation water to private diverters between Cairn Curran and Laanecoorie reservoirs. It is assumed that ten 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The capital cost of these storages is expected to be around $500 million.

Effectiveness

This option would be highly effective as it would provide additional storage at Laanecoorie that would enable running the reach close to the recommended cease-to-flow regime.

K.4.6 Option L1S6 - Winterfill Storage near Loddon Weir at Fernihurst to cover cease to flow period and provide on-farm storages for reach PDS

Description

The objective of this option involving a new off-line storage at Fernihurst and on-farm storages for reach PDs is to store adequate water to meet irrigation demands during the cease to flow period. A storage size of 40 GL at Fernihurst would be adequate to meet this requirement. The storage would be filled by gravity and pumped out during the irrigation season.

As noted above, Cairn Curran also supplies some 1,500 ML of irrigation water to private diverters between the Cairn Curran and Laanecoorie reservoirs. It is assumed that ten 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The total capital cost of these storages is expected to be around $400 million.

Effectiveness

This option is highly effective as it would provide additional storage that would allow the cease-to-flow requirements to be met.

K.4.7 Option L1S7 - On-farm and regional winterfill storages to cover cease to flow period

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages that would store adequate water to meet irrigation demands during the cease to flow period. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

Similarly to Option L1S6, a total storage requirement of 40 GL has been assumed for this option. This can be provided either by larger G-MW owned regional storages, or landowner owned on-farm storages. For the purpose of the study, it has been assumed that the storages would comprise:

- 4 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and
- 100 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

The capital cost of providing these storages are expected to be around $350 million.

Effectiveness

This option would be moderate to highly effective in meeting the cease-to-flow requirement as it would provide storage for majority of the water use.

K.5 Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir - Summer low and fresh flows

Environmental flow recommendations for this reach are:

- low flows of 20 ML/d or natural from November to April every year
- fresh flows of greater than 35 ML/d for 7 days three times a year.

As for the cease-to-flow component, this is currently constrained by the need to supply relatively constant irrigation flows from Cairn Curran during summer. Conformance is very low for this recommendation and introducing periods of low flows would address this constraint. By introducing low flows, the high flows should act as freshes.

Seven options were considered:

- L1S1 - Pipeline or channel from Cairn Curran to Laanecoorie including reach PDs (as described in Section K.4.1 above)
- L1S2 - Supply more from Tullaroop to Laanecoorie and provide on-farm storages to reach PDs (as described in Section K.4.2 above)
- L1S3 - Pipeline from Cairn Curran to Tullaroop and provide on-farm storages for reach PDs (as described in Section K.4.3 above)
- L1S4 - Augment capacity of WWC to supply Boort irrigators currently supplied from Cairn Curran (as described in Section K.4.4 above)
- L1S5 - Enlarge capacity of Laanecoorie for winterfill from Cairn Curran (as described in Section K.4.5 above)
- L1S8 - New Winter-fill Storage near Loddon Weir at Fernihurst to cater for irrigation supplies from Cairn Curran
- L1S9 - On-farm and regional winter-fill storages to cater for irrigation supplies from Cairn Curran

K.5.1 Option L1S8 - New Winter-fill Storage near Loddon Weir at Fernihurst to cater for irrigation supplies from Cairn Curran

Description

The objective of this option, which would involve a new off-line storage at Fernihurst, is to store adequate water to meet irrigation demands during the season and this option is similar to Option L1S5 above. A storage size of 100 GL has been assumed at Fernihurst. The storage would be filled by gravity and pumped out during the irrigation season.

As noted above, Cairn Curran also supplies some 1,500 ML of irrigation water to private diverters between the Cairn Curran and Laanecoorie reservoirs. It is assumed that ten 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The total capital cost of these storages is expected to be around $1 billion.

Effectiveness

This option is highly effective as it would provide additional storage that would enable the reach to be run close to the recommended flow regime.

SKM

K.5.2 Option L1S9 - On-farm and regional winter-fill storages to cater for irrigation supplies from Cairn Curran

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages that would be filled in winter. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

The Loddon system has the potential to deliver up to 140 GL of irrigation water. In order to meet the environmental flow recommendations in summer, most of this flow needs to be supplied in winter. A total storage requirement of 160 GL including loss allowances has been assumed for this option. This can be provided either by larger G-MW owned regional storages or landowner owned on-farm storages. For the purpose of this study, it has been assumed that the storages would comprise:

- 10 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and
- 550 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

These storages would provide a total storage volume of 160,000 ML. The capital cost of providing these storages are expected to be around $1 billion.

Effectiveness

This option would be moderate to highly effective as it would provide storage for majority of the water use.

K.6 Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir - Winter flows

Winter flow recommendations for this reach are:

- Low flow of 35 ML/d or natural from May to October every year
- Fresh flow of greater than 181 ML/d for 25 days three times a year
- High flow of 3,000 ML/d for four days every four years
- Over bank flows greater than 3,000 ML/d for four days every year

There are no infrastructure or operation constraints to meet winter low, fresh or high flows.

The Cairn Curran reservoir level was analysed to identify years in which releases greater than 3,000 ML/d (ie high flows and overbank flows) could be achieved during winter (June-August), spring (August-November) or any time. It was considered possible to achieve 3,000 ML/d releases, when the reservoir level was greater than the spillway crest level. This analysis showed that the opportunity to release occurs in most years, but not all. Therefore, the current infrastructure can not deliver full conformance with both the high and overbank flow recommendations.

Two options were investigated to overcome this constraint:

- L1W1 - Enlarge Cairn Curran outlet works capacity to 3,000 ML/d
- L1W2 - Construct pondage downstream of Cairn Curran

K.6.1 Option L1W1 - Enlarge Cairn Curran outlet works capacity to 3,000 ML/d

Description

This option would involve construction of new outlet works to increase the release capacity to 3,000 ML/d at low storage levels. The cost of providing additional outlet capacity is expected to be around $8-10 million based on similar projects elsewhere.

Effectiveness

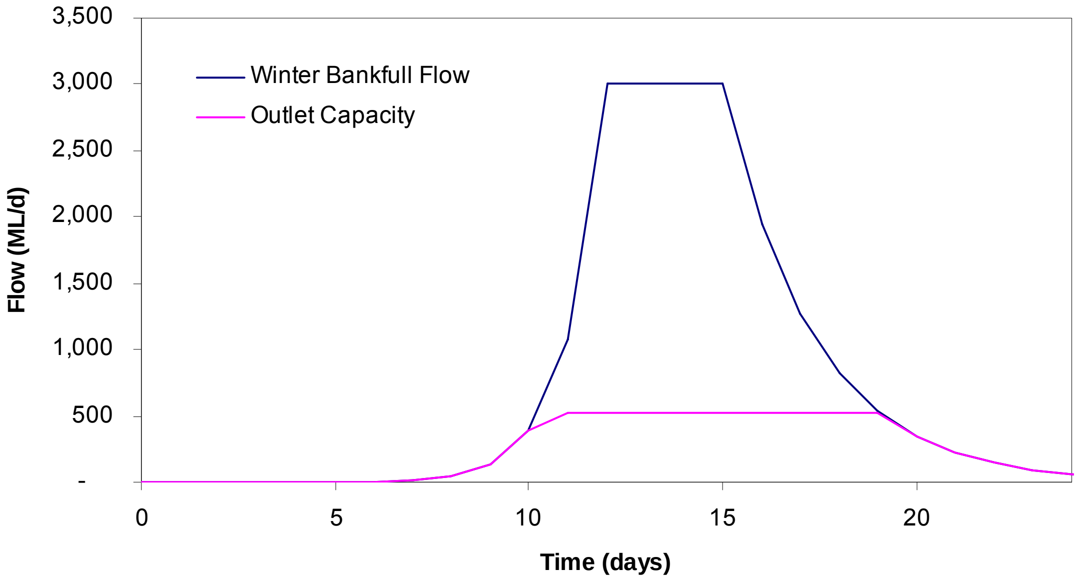
This option would be highly effective in delivering the environmental flows for this reach during winter.

K.6.2 Option L1W2 - Construct pondage downstream of Cairn Curran

Description

Winter overbank flows of 3,000 ML/d are required for 4 days every year. Delivery of flows of this magnitude is possible when the storage levels are above spillway sill. However, during low storage levels only a maximum flow of 524 ML/d (refer to Figure 38) could be delivered through the outlet conduit necessitating the need for a pondage to store the water and release it when required. The pondage is required to store a volume of about 13,000 ML and to have maximum release capacity of about 3,000 ML/d.

▪ **Figure 38 Loddon River – Winter Flows below Cairn Curran**



The capital cost of pondage and associated works is anticipated to cost around $6-8 million depending on site condition.

Effectiveness

This option would be highly effective in delivering the winter environmental overbank flow recommendations.

K.7 Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir - Anytime high flows

An anytime high flow of 3,000 ML/d for four days is recommended every year.

The existing outlet could not meet the flow requirements during low storage levels. Two options were investigated to overcome this constraint:

- L1W1 - Enlarge Cairn Curran outlet works capacity to 3,000 ML/d (as described in Section K.6.1 above)
- L1W2 - Construct pondage downstream of Cairn Curran (as described in Section K.6.2 above)

K.8 Loddon River: Laanecoorie Reservoir to Loddon Weir - Summer Flows

Summer environmental flow recommendations for this reach are:

- low flows of 15-19 ML/d, or natural,
- fresh flows of 52-61 ML/d for 11-13 days three times a year.

Delivery of these flows is constrained by the need to supply irrigation demands to this reach from Laanecoorie during the summer months. The four options considered were:

- L2S1 - Pipeline or channel from Laanecoorie to Loddon Weir
- L2S2 -Winterfill Storage near Loddon Weir at Fernihurst and on-farm storages for all PDs
- L2S3 - On-farm and regional winter-fill storages
- L2S4 - Augment capacity of WWC to supply Boort irrigators

All these options would also require increased regulatory capacity at Serpentine and Bridgewater weirs (see also Option L2W1 below).

K.8.1 Option L2S1 - Pipeline or channel from Laanecoorie to Loddon Weir

Description

This option would involve construction of a pipeline or channel from Laanecoorie to Loddon Weir to carry the irrigation flows in excess of the environmental flow threshold. The storage level of Laanecoorie at 10% capacity is 157.03 m AHD and Loddon Weir FSL is 106.87 m AHD. A gravity pipeline has been considered for this option. Table 48 below provides a summary of the option and cost.

- **Table 48 Pipeline/Gravity Option Summary**

	Pipeline Option	Channel Option
Length (km)	75	75
Size	2100 mm pipeline	Open Channel
Capital Cost ($million)	700	150

Effectiveness

This option would allow the river to be run as per the summer environmental flow recommendations, and would therefore be highly effective in delivering the environmental flows for this reach during summer months.

K.8.2 Option L2S2 - Winterfill Storage near Loddon Weir at Fernihurst and on-farm storages for all PDs

Description

The objective of this option involving a new off-line storage at Fernihurst is to store adequate water to meet irrigation demands during the season, which are supplied by the Loddon storages. A storage size of 160 GL has been assumed at Fernihurst including loss allowance. The storage would be filled by gravity and pumped out during the irrigation season.

Laanecoorie also supplies some 18,000 ML of irrigation water to private diverters between Laanecoorie reservoir and Loddon Weir. It is assumed that one hundred 200 ML on-farm storages would be provided as part of this option to meet the summer irrigation demands for these diverters.

The total capital cost of these storages is expected to be around $1.2 billion.

Effectiveness

This option would be highly effective as it would provide additional storage that would enable running the reach close to the recommended summer flow regime.

K.8.3 Option L2S3 - On-farm and regional winterfill storages

Description

This option would involve providing a combination of regional storages at strategic locations and on-farm storages that would be filled in winter. Water would be delivered by gravity to these storages and pumped out to meet irrigation demands.

As noted above, the Loddon system has the potential to deliver up to 140 GL of irrigation water. In order to meet the environmental flow recommendations in summer, most of this flow would need to be passed in winter. A total storage requirement of 160 GL including loss allowances has been assumed for this option. This can be provided either by larger G-MW owned regional storages or landowner owned on-farm storages. For the purpose of this study, it has been assumed that the storages would comprise:

- 10 No. G-MW owned regional storages each of 5,000 ML capacity, built and maintained by G-MW; and
- 550 No. landholder owned on-farm storages each of 200 ML capacity built to a lower standard and maintained by landowners.

These storages would provide a total storage volume of 160,000 ML. The capital cost of providing these storages are expected to be around $1 billion.

Effectiveness

This option would be moderate to highly effective as it would provide storage for majority of the water use.

K.8.4 Option L2S4 - Augment capacity of WWC to supply all Boort irrigators

Description

This option involves upgrading of the Waranga Western Channel from the Waranga Basin to Loddon River to carry an additional 700 ML/d to substitute flows that are currently released from Tullaroop and Cairn Curran. Table 49 below provides a summary of the option and cost.

- **Table 49 Augment WWC by 700 ML/d**

	Pipeline Option
Length (km)	165
Flow (ML/d)	700
Size	Widen existing channel by 5 m
Capital Cost ($million)	320

Effectiveness

This option is assessed as moderately effective in delivering the environmental flows for this reach during summer months, as PD demands between Tullaroop/Cairn Curran and Loddon Weir would still need to be supplied from the Loddon River/Tullaroop Creek.

K.9 Loddon River: Laanecoorie Reservoir to Loddon Weir - Winter Low flows

The recommended winter low flow for this reach is 52-61 ML/d from May to October every year. Current conformance is poor for low flows. Flows can be released from Laanecoorie, however, the regulatory capacity of Serpentine Weir for low flows has been identified as a constraint. The following option was considered:

- L2W1 - Increase regulatory capacity of Serpentine and Bridgewater Weirs

K.9.1.1 Option L2W1 - Increase regulatory capacity of Serpentine and Bridgewater Weirs

Description

This option involves improving the regulatory capacity of Serpentine and Bridgewater Weirs to allow winter flow releases by adding a radial gate to the existing structures. Total capital cost of this option is expected to be around $300,000.

Effectiveness

This option would be highly effective in enabling the recommended low flows to be released from Serpentine Weir.

K.10 Loddon River: Laanecoorie Reservoir to Loddon Weir - Winter fresh flows

Fresh flows of 400-900 ML/d are required for 7 days twice a year. There are no infrastructure or operational constraints to delivery of these flows.

K.11 Loddon River: Laanecoorie Reservoir to Loddon Weir - Winter high flows

The Loddon scientific panel recommended a flow of 7,300 ML/d for one day every two years. There are no infrastructure or operational constraints to delivery of this flow.

SKM

K.12 Loddon River: Laanecoorie Reservoir to Loddon Weir - Winter overbank flows

The Loddon scientific panel recommended delivery of a flow of 13,000 ML/d for two days every three years. There are no infrastructure or operational constraints to delivery of this flow.

K.13 Loddon River: Loddon Weir to Kerang Weir - Summer low flow

The recommended summer low flow for this reach is 7-12 ML/d from November to April every year. Conformance is reasonably high and the flows are met in 87% of the days. Regulating smaller flows of this magnitude is difficult to control at the Loddon weir with its configuration. In addition sporadic and/or unauthorised diversions by irrigators during low electricity tariff periods and/or water leaking out through the 12 Mile Creek regulator also threaten the delivery of these flows for the entire reach. Three options were considered to address these issues:

- L3S1 - Flume gates on Loddon weir to control low flows
- L3S2 - Improved management of sporadic diversions to ensure low flow requirements are maintained
- L3S3 - Repair Twelve Mile Creek regulator

K.13.1 Option L3S1 - Flume gates on Loddon Weir to control low flows

Description

The current configuration of Loddon Weir does not allow much flexibility in making environmental releases for summer low flows. However, G-MW is currently modifying the Loddon Weir to allow improved regulation of small releases.

Effectiveness

This option would be highly effective in delivering required low environmental flows during summer.

K.13.2 Option L3S2 - Improved management of sporadic diversions to ensure low flow requirements are maintained

Description

A number of irrigators in this reach do not order water but use it when the river flows, and thus can sometimes divert water intended for environmental purposes. This option would introduce water ordering and metering to all users and to ensure they do not divert over and above their orders.

Effectiveness

This option, in conjunction with the previous and following options (refer Sections K.13.1 and K.13.3), would be highly effective in delivering required low environmental flows during summer.

K.13.3 Option L3S3 - Repair Twelve Mile Creek Regulator

Description

The existing 12 Mile Creek regulator is not water proof and leakage during low flow periods is a significant factor in Loddon Weir release not reaching the full length of the river. This option involves fixing the leakage by installing sealed doors.

The capital cost of this option is expected to be around $200,000.

Effectiveness

This option, in conjunction with the previous two options (refer Sections K.13.1 and K.13.2), would be highly effective in delivering required low environmental flows during summer.

K.14 Loddon River: Loddon Weir to Kerang Weir - summer fresh flows

The environmental flow recommendation is delivery of summer fresh flows greater than 50 ML/d for 14 days every year. There are no infrastructure or operational constraints to the delivery of this flow.

K.15 Loddon River: Loddon Weir to Kerang Weir - winter low flows

The environmental flow recommendation is a winter low flow of greater than 61 ML/d from May to October every year. There are no infrastructure or operational constraints to delivery of this flow, if winter flows are to be supplied from the Loddon System. If the flows are to be supplied from WWC, there will be some distribution to the winter maintenance program on WWC. The maintenance program for the WWC would therefore need to be modified under this option.

K.15.1 Option L3W1- Supply from WWC

Description

WWC would have spare capacity in winter to meet this flow requirement. This option would however require a modified WWC maintenance program, as routine channel and structure maintenance and/or renewal works are normally performed in winter on most channels. The best possible scenario for supplying the water is WWC is either towards the end of the irrigation season in May/June or start of the season in July/August. This would provide at least 30 days for maintenance works on the channel. This option is not expected to have any additional costs, and should only require planning of maintenance works to allow the delivery of this flow.

Effectiveness

This option would be highly effective in delivering winter low flows to the Loddon River.

SKM

K.16 Loddon River: Loddon Weir to Kerang Weir - winter over bank flows

An over bank flow of greater than 400 ML/d from July to October for seven days twice a year is recommended. There are no infrastructure or operational constraints to delivery of this flow.

K.17 Loddon River: Kerang Weir to River Murray - summer low flow

The environmental flow recommendation is

- a summer low flow is 7-12 ML/d from November to April every year.
- a summer fresh flow is 50 ML/d or greater for 14 days from January to February every year.

Delivery of these flows is currently constrained by the need to supply PD demands, which are significantly higher than this, from Kerang Weir during summer. Delivery of summer low flow is also constrained by limited ability to regulate low flow releases from Kerang Weir.

Two options to overcome this constraint were considered:

- L4S1 - Pipeline or channel from Kerang Weir to River Murray, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d
- L4S2 - On-farm storages, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d

K.17.1 Option L4S1 - Pipeline or channel from Kerang Weir to River Murray plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d

Description

This option would involve:

- Construction of a pipeline or channel from Kerang Weir to the River Murray to carry irrigation flows in excess of the environmental flow threshold. Gravity pipeline and channel options have been considered.
- Modification of Kerang Weir – Kerang Weir is a fixed crest structure and does not have any capability to regulate small releases downstream. Under this option, it would be modified to incorporate a regulating structure for low flow releases.

A summary of the option and cost are provided in Table 50 below.

Table 50 Pipeline/Gravity Option Summary

	Pipeline Option	Channel Option
Length (km)	90	90
Size	1200 mm dia	Open Channel
Capital Cost ($million)	300	90

Effectiveness

This option would allow the river to be run as per the summer environmental low flow recommendations, and would therefore be highly effective in delivering the environmental flows for this reach during summer months.

K.17.2 Option L4S2 - On-farm storages plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d

Description

This option would involve:

- Providing on-farm storages to be filled in winter. Water would be pumped in and out to meet irrigation demands. It is assumed that landholder owned on-farm storages each of 200 ML capacity would be adequate to lower the summer flows to the recommended flow.
- Modification of Kerang Weir – see Section K.17.1 above.

The capital cost of providing these storages and weir modification works is expected to be around $4-5 million.

Effectiveness

This option would be highly effective in delivering the recommended summer environmental low flows for this reach.

K.18 Loddon River: Kerang Weir to River Murray - winter low flows

The environmental flow recommendation is a winter low flow of greater than 61 ML/d from May to October every year. There are no infrastructure or operational constraints to delivery of this flow.

K.19 Loddon River: Kerang Weir to River Murray - winter high flows

A winter high flow of greater than 400 ML/d from July to October for seven days twice a year is recommended. There are no infrastructure or operational constraints to delivery of this flow.

K.20 Loddon River: Kerang Weir to River Murray - winter over bank flows

An over bank flow of greater than 1,200 ML/d from July to October for seven days twice a year is recommended. There are no infrastructure or operational constraints to delivery of this flow.

K.21 Loddon River – Living Murray Contribution - summer high flows

The specified Living Murray Initiative flow requirement is an additional 500 ML/d in summer for 1-2 months between November and April (refer Chapter 7 for details). This would result in a total flow of 510 ML/d in the Loddon River. There are no infrastructure or operational constraints to delivery of this flow.

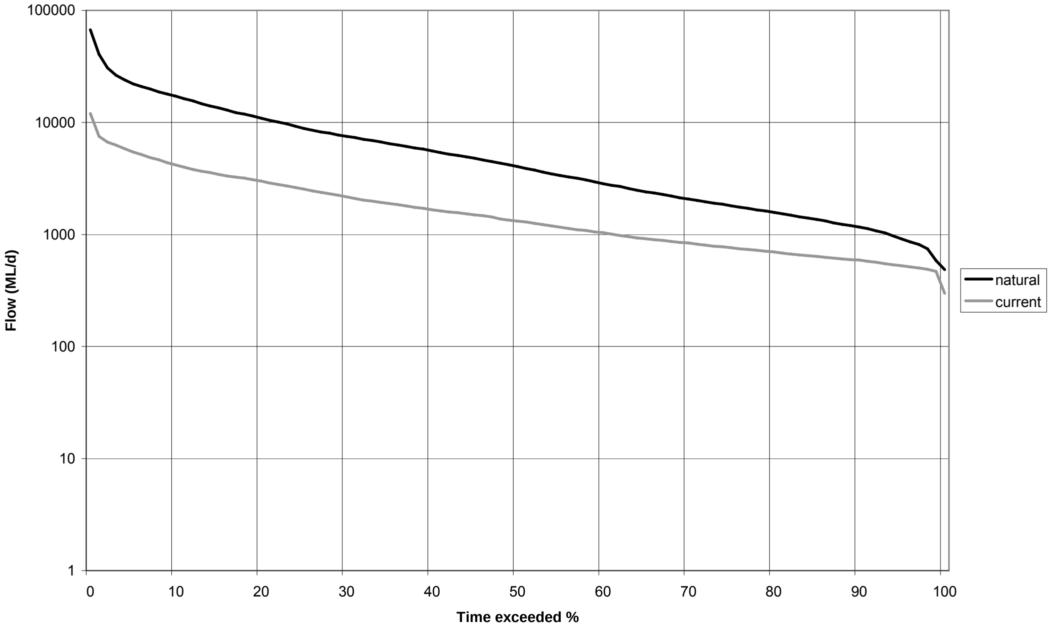
K.22 Loddon River - Living Murray Contribution - winter high flows

The specified Living Murray Initiative flow requirement is an additional 500 ML/d in winter for 1-2 months between May and October (refer Chapter 3.7 for details). This would result in a total flow of 561 ML/d in the Loddon River. There are no infrastructure or operational constraints to delivering this flow if delivered from the Loddon System. However if the flows were to be supplied from WWC, there would be some disruption to the winter maintenance program on WWC. The maintenance program for the WWC would therefore need to be modified under this option.

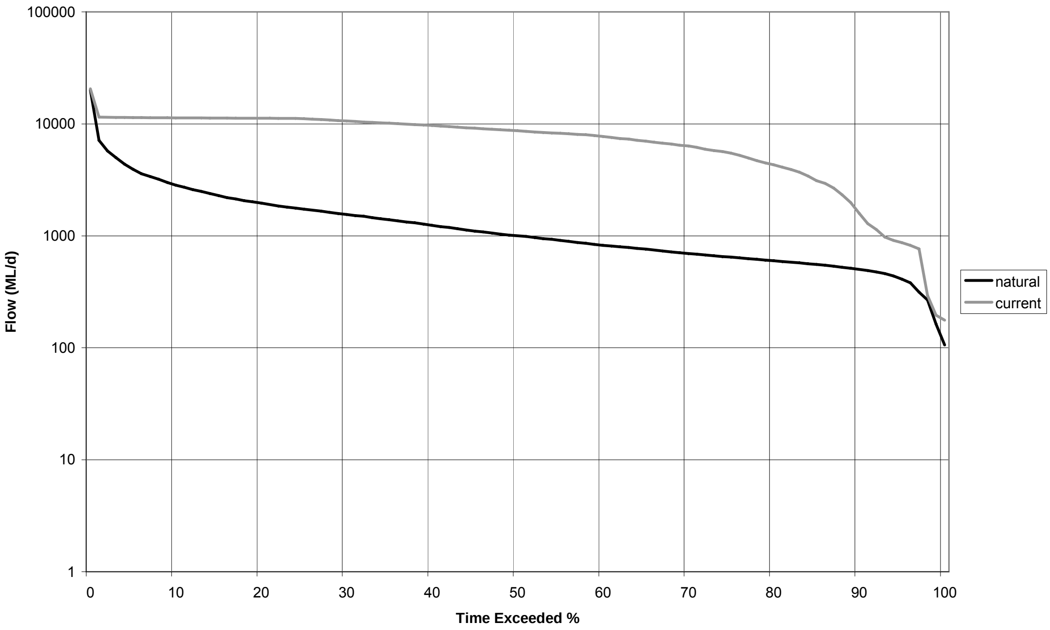
- L3W1- Modified WWC maintenance program to reduce frequency of maintenance (as above)

Appendix L Flow Duration Curves

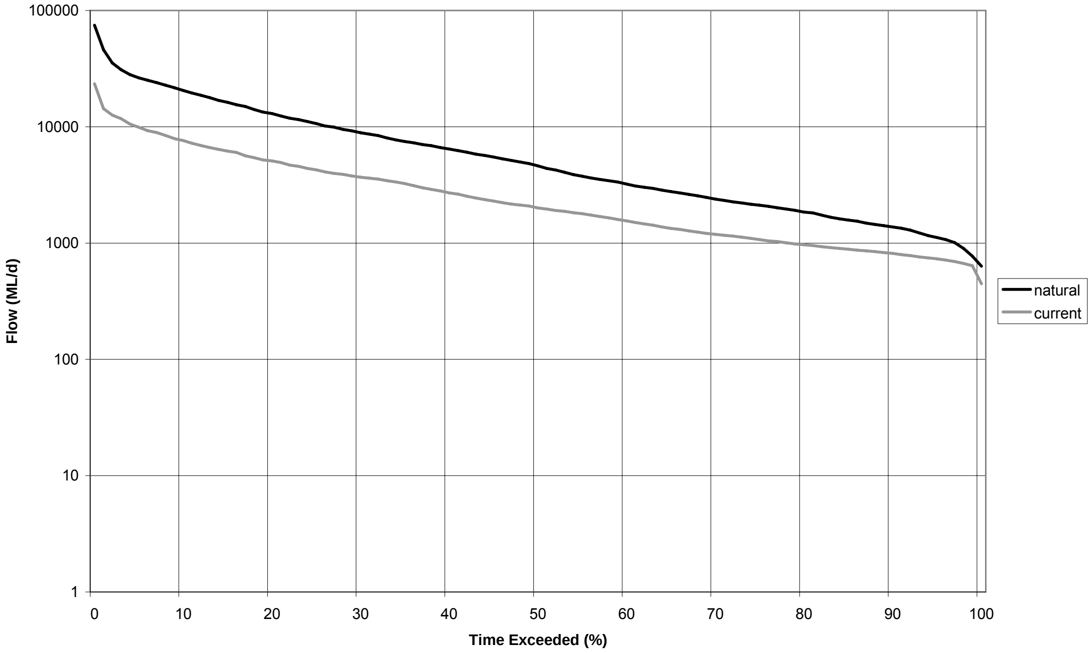
L.1 Goulburn River and Broken Creek



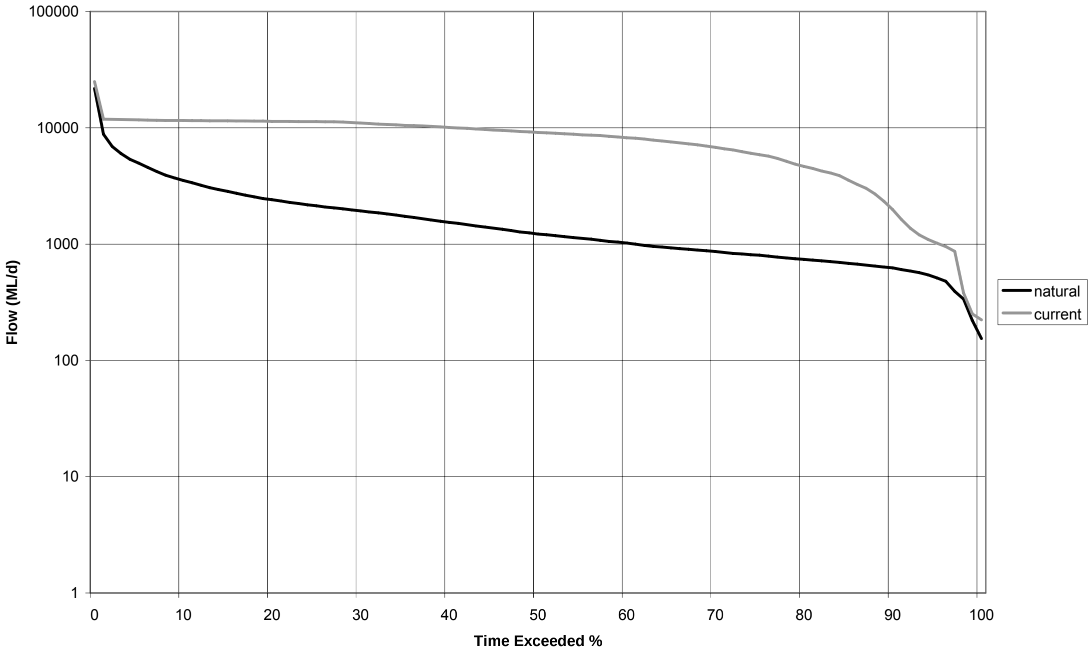
- **Figure 39: Flow duration curve for non-irrigation season in Goulburn River Reach 1, Lake Eildon to Molesworth**



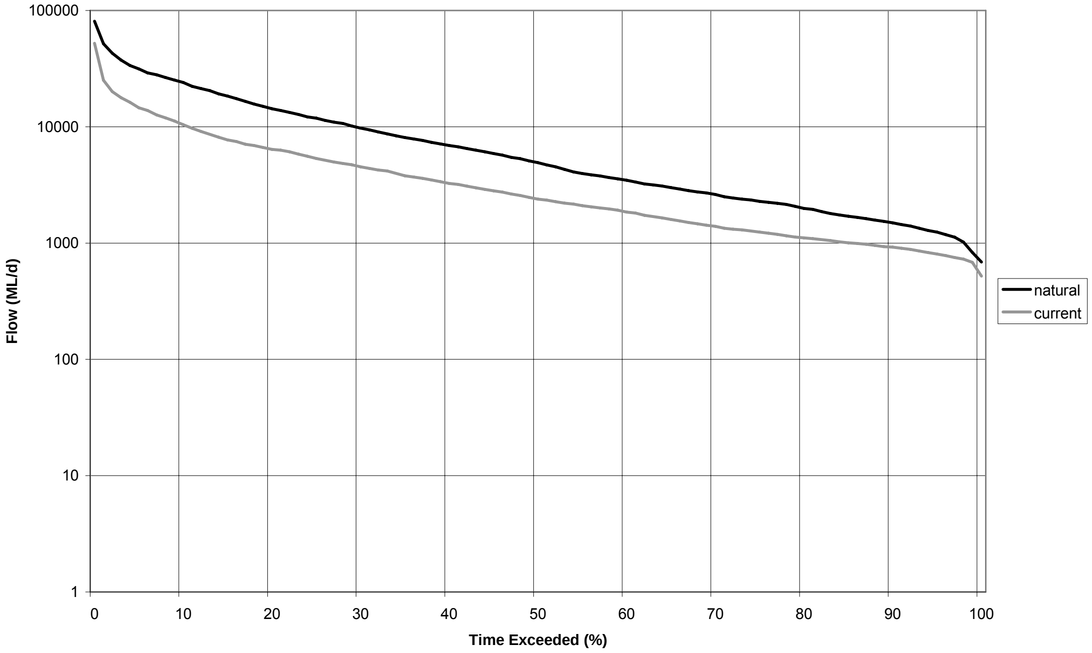
- **Figure 40: Flow duration curve for summer (Dec-May) in Goulburn River Reach 1, Lake Eildon to Molesworth**



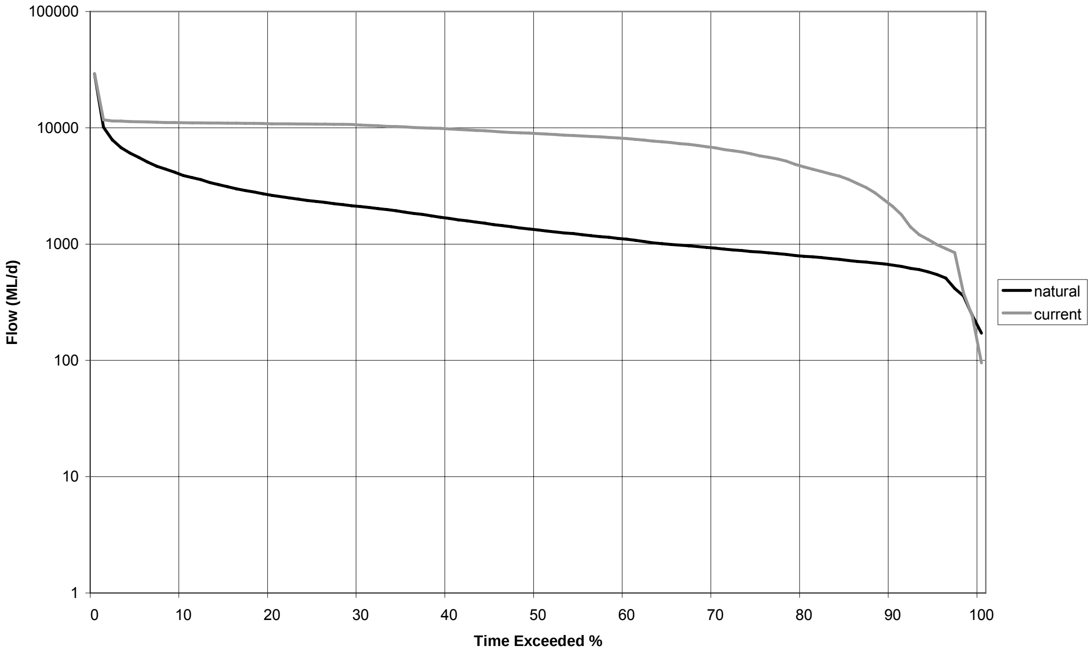
■ **Figure 41: Flow duration curve for non-irrigation season in Goulburn River Reach 2, Molesworth to Seymour**



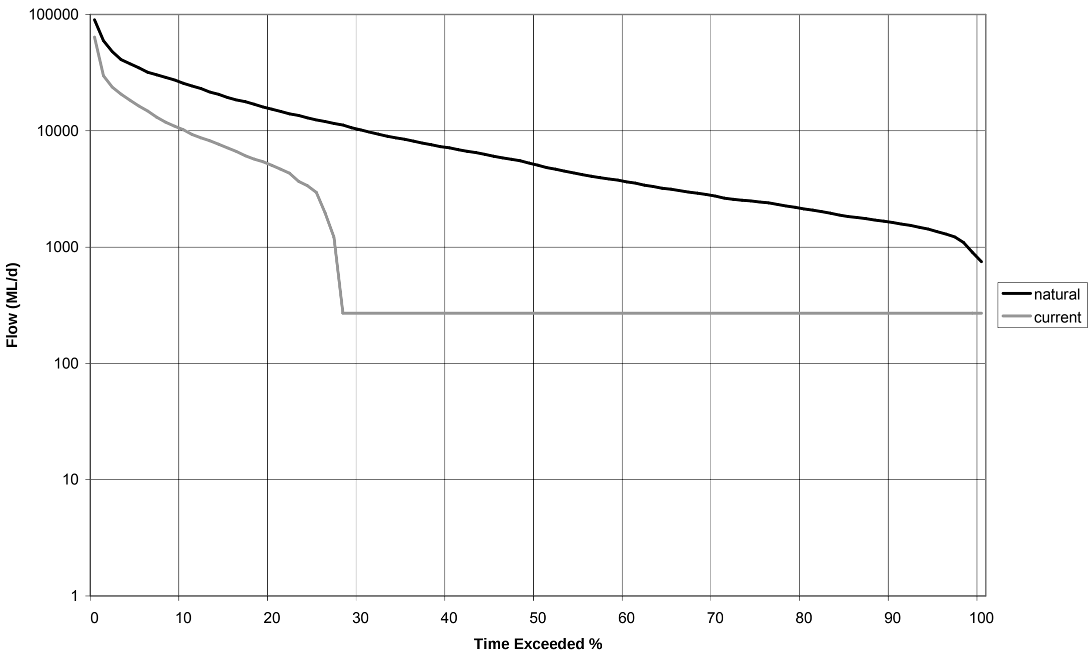
■ **Figure 42: Flow duration curve for summer (Dec-May) in Goulburn River Reach 2, Molesworth to Seymour**



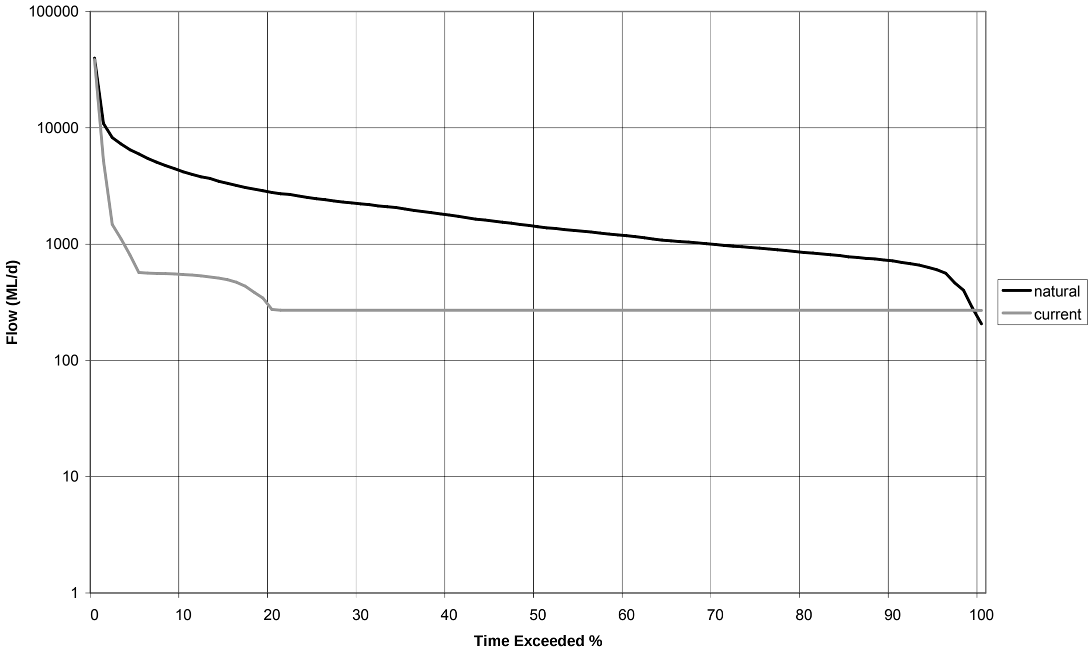
- **Figure 43: Flow duration curve for non-irrigation season in Goulburn River Reach 3, Seymour to Nagambie**



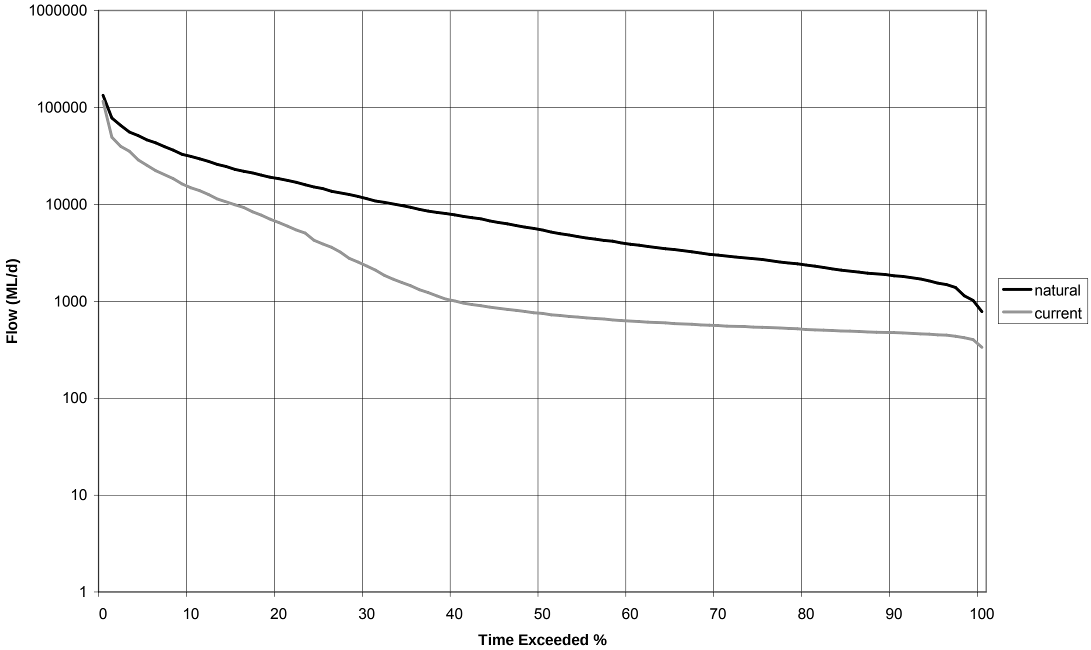
- **Figure 44: Flow duration curve for summer (Dec-May) in Goulburn River Reach 3, Seymour to Nagambie**



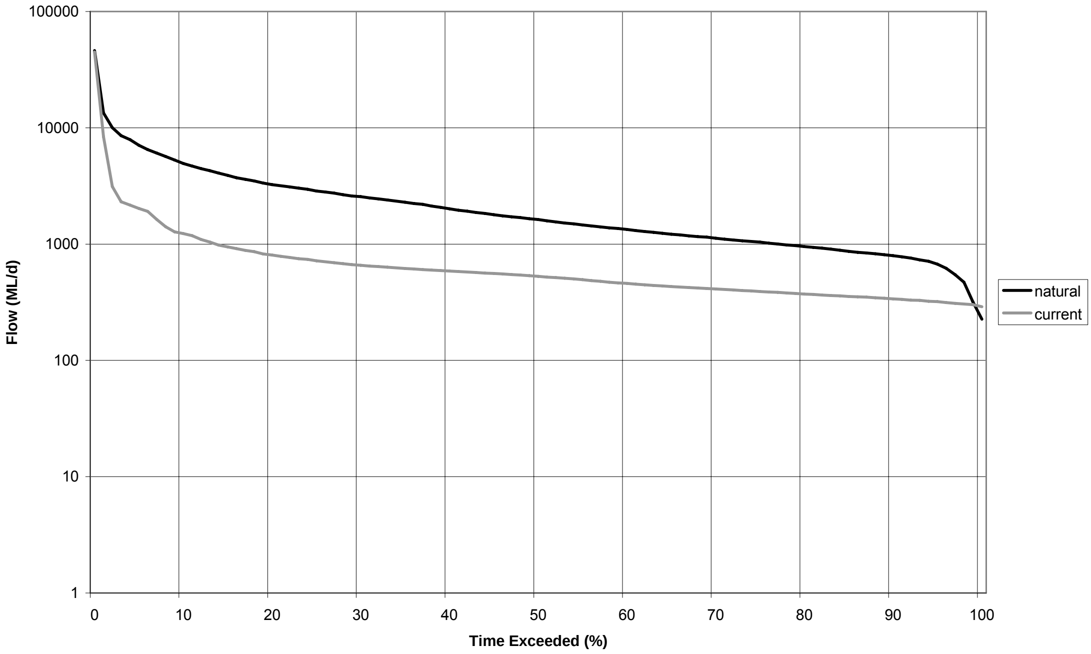
- **Figure 45: Flow duration curve for non-irrigation season in Goulburn River Reach, Nagambie to Loch Garry**



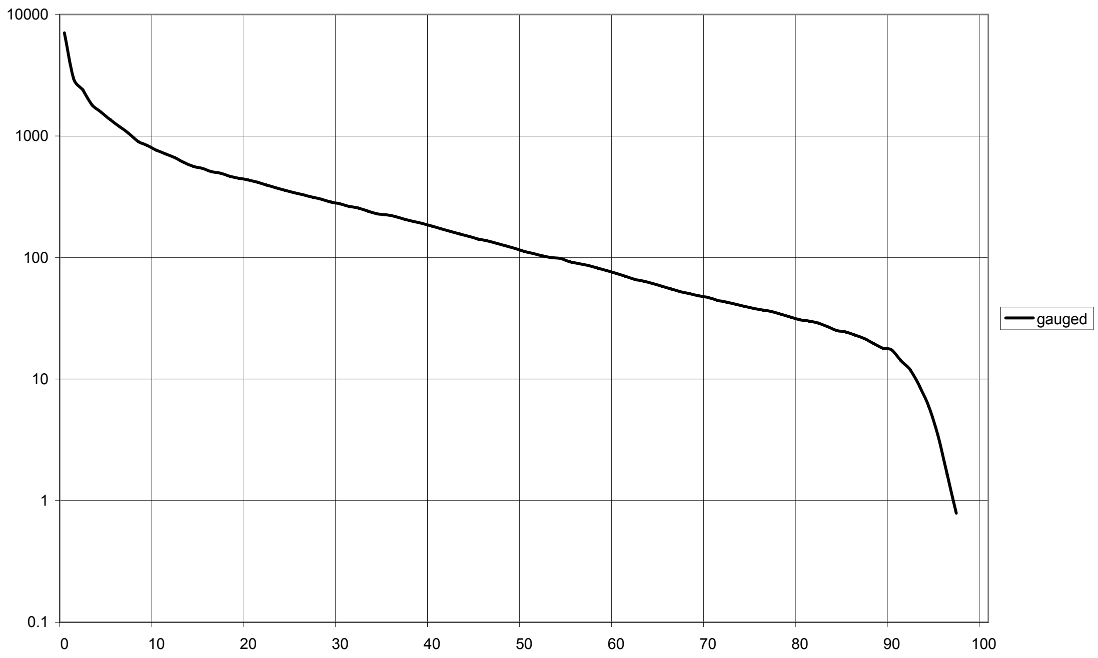
- **Figure 46: Flow duration curve for summer (Dec-May) in Goulburn River Reach 4, Nagambie to Loch Garry**



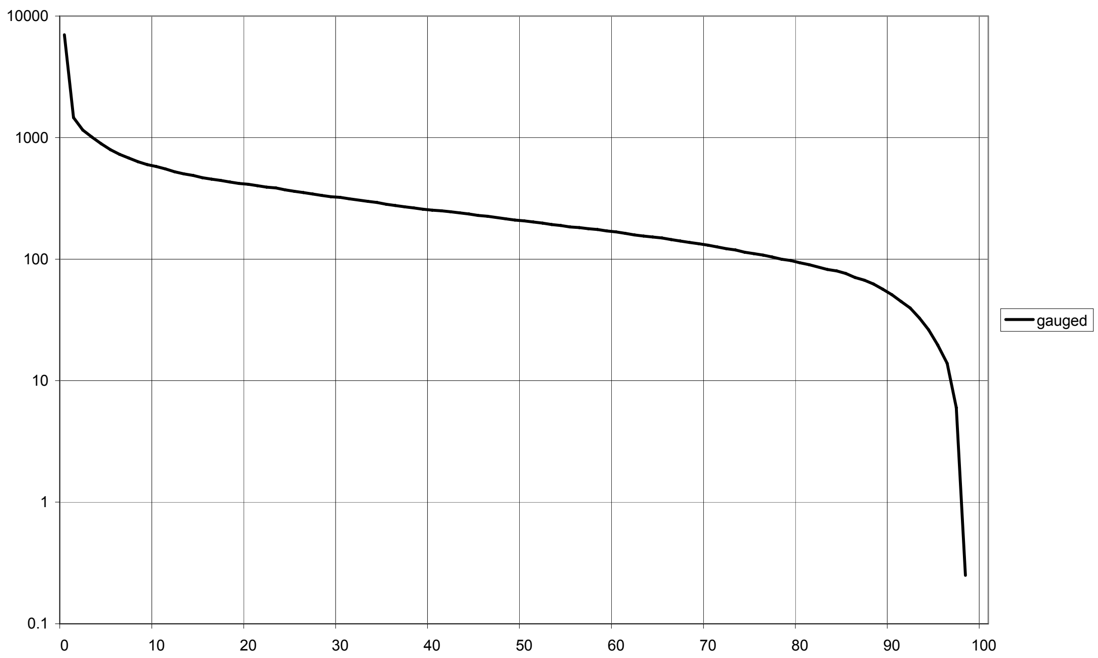
- **Figure 47: Flow duration curve for non-irrigation season in Goulburn River Reach 5, Loch Garry to the River Murray**



- **Figure 48: Flow duration curve for summer (Dec-May) in Goulburn River Reach 5, Loch Garry to the River Murray**

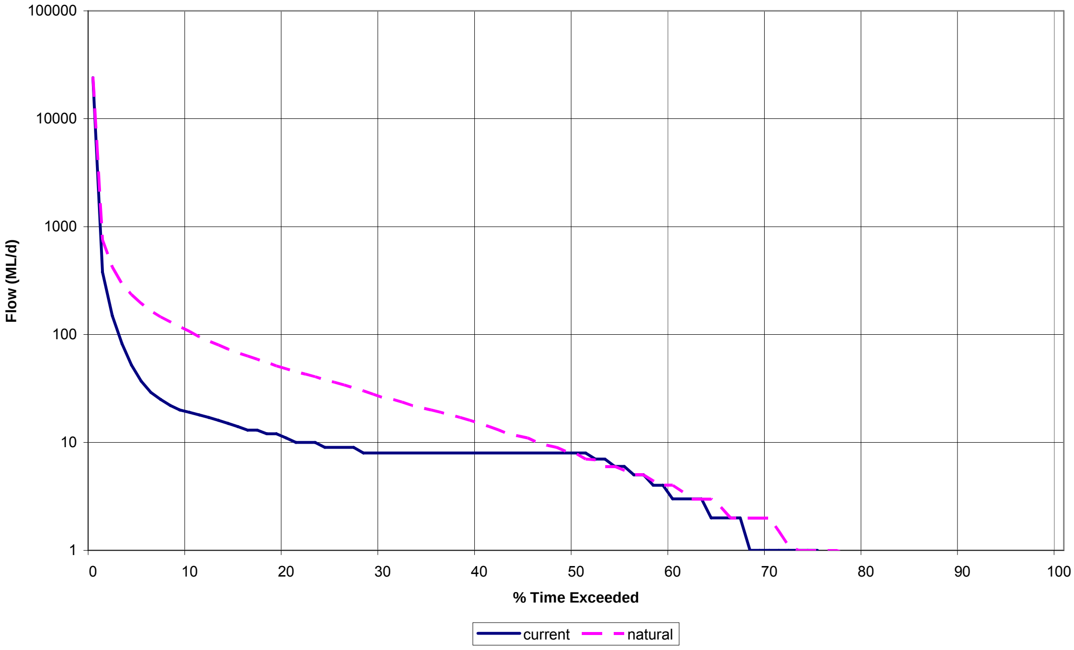


■ **Figure 49: Flow duration curve for non-irrigation season in Broken Creek at Casey's Weir**

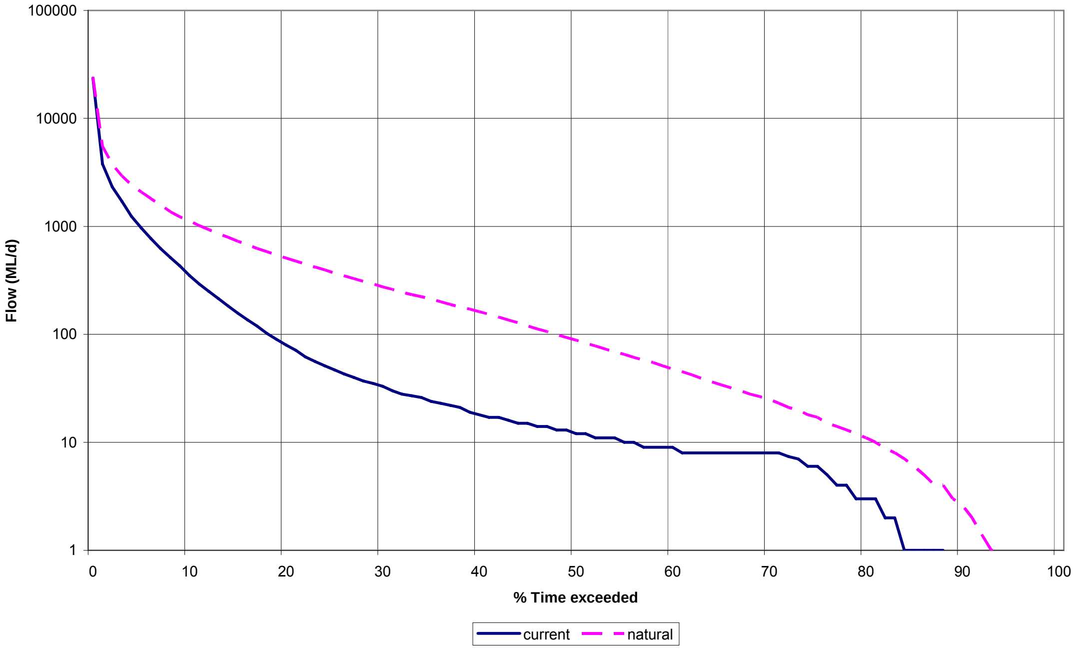


■ **Figure 50 : Flow duration curve for summer (Dec-May) in Broken Creek at Casey's Weir**

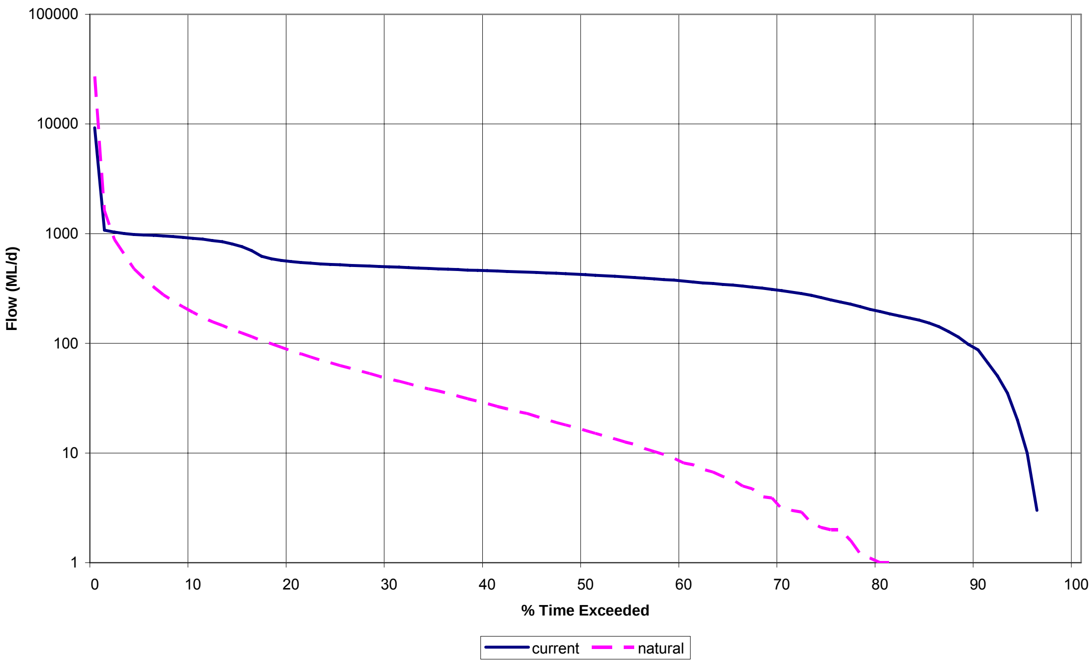
L.2 Campaspe River



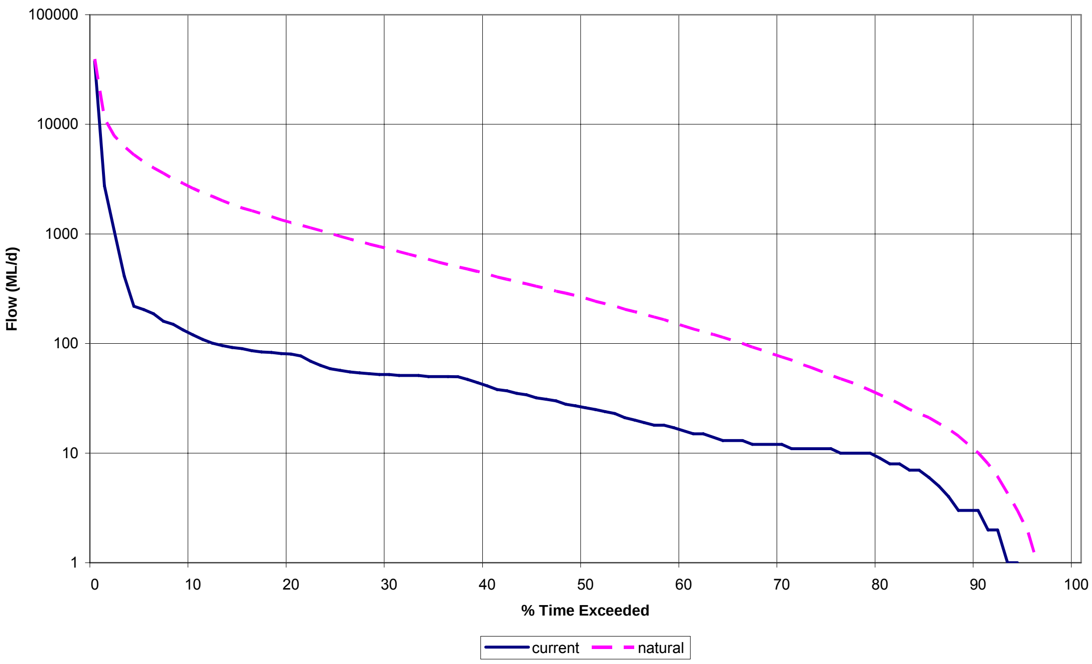
- **Figure 51: Flow duration curves during irrigation season in Reach 1, Malmsbury Reservoir to Lake Eppalock**



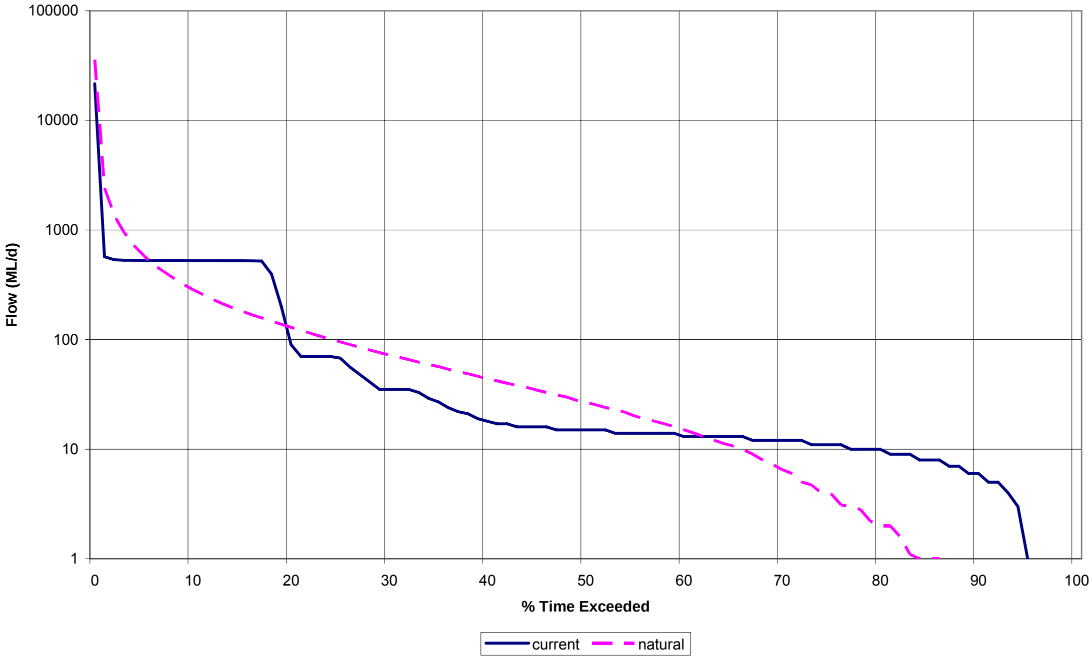
- **Figure 52: Flow duration curves during non-irrigation season in Reach 1, Malmsbury Reservoir to Lake Eppalock**



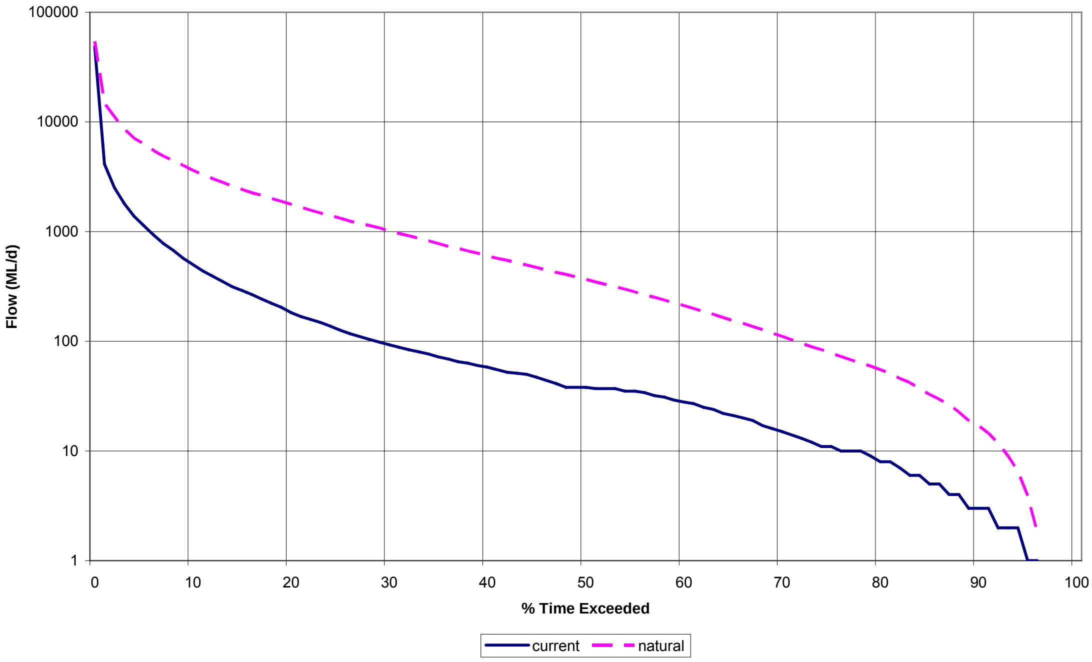
■ **Figure 53: Flow duration curves during irrigation season in Reach 2, Lake Eppalock to Campaspe Weir**



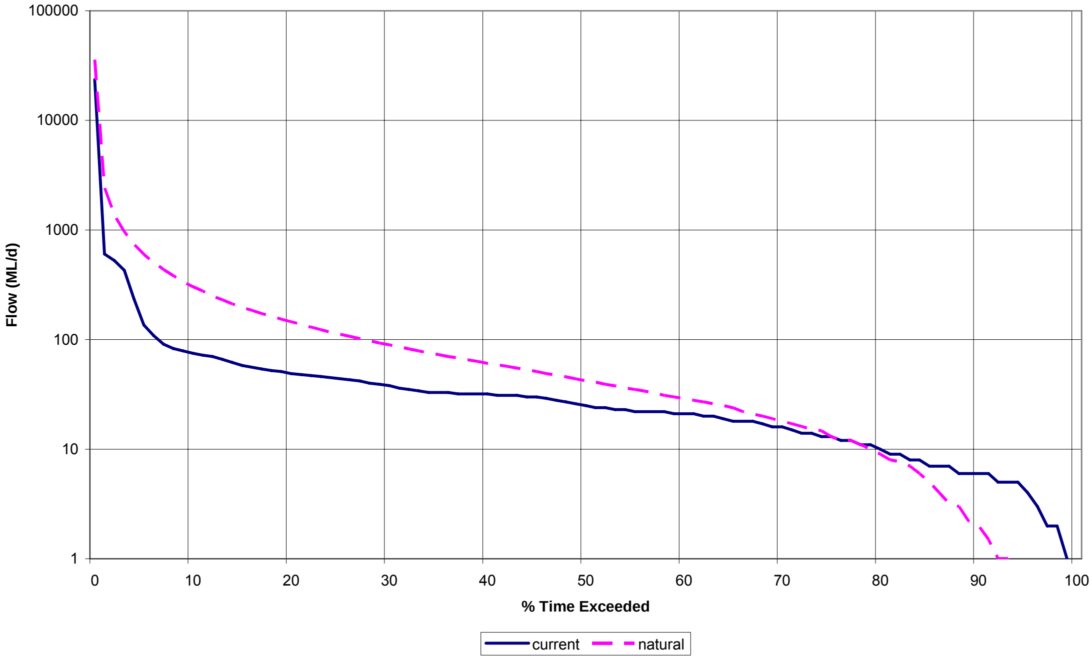
■ **Figure 54: Flow duration curves during non-irrigation season in Reach 2, Lake Eppalock to Campaspe Weir**



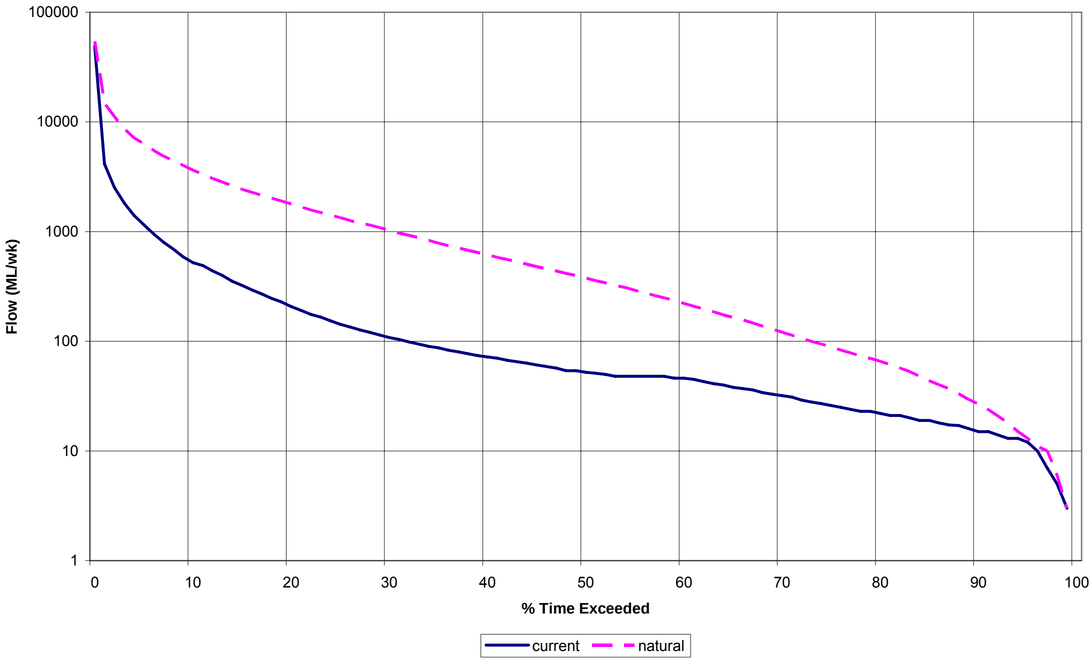
■ **Figure 55: Flow duration curves during irrigation season in Reach 3, Campaspe Weir to Campaspe Siphon**



■ **Figure 56: Flow duration curves during non-irrigation season in Reach 3, Campaspe Weir to Campaspe Siphon**

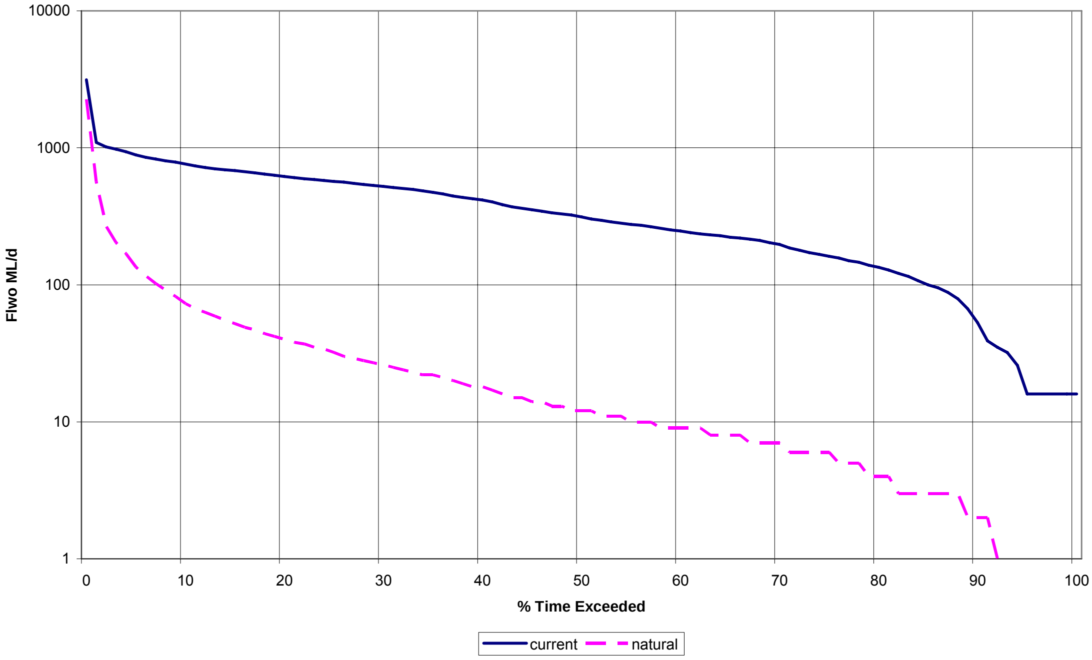


- **Figure 57: Flow duration curves during irrigation season in Reach 4, Campaspe Siphon to the River Murray**

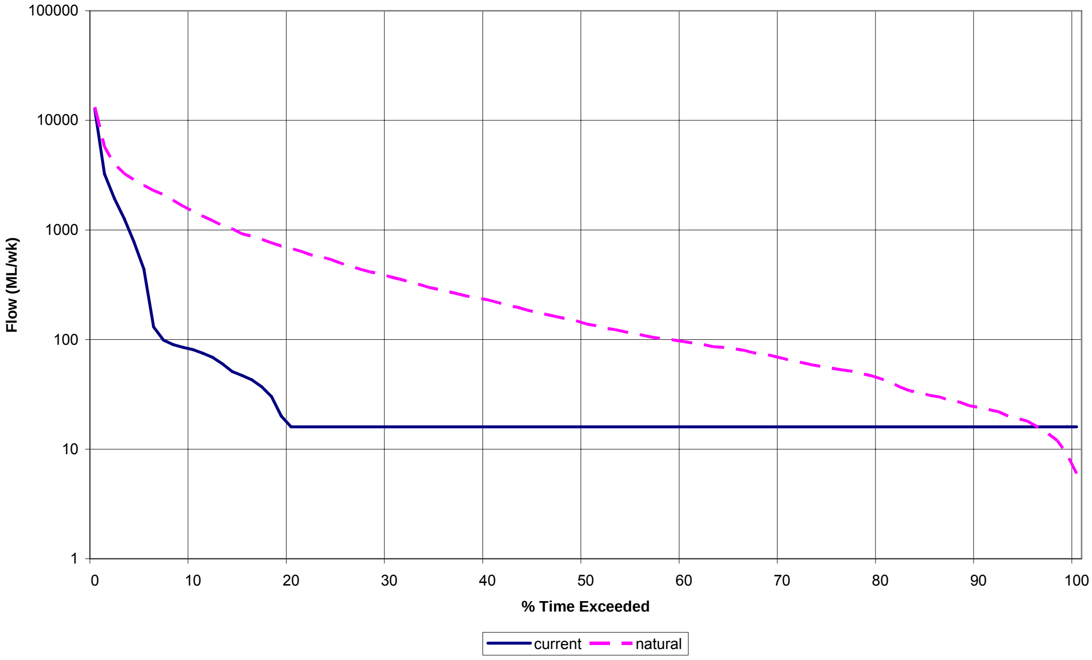


- **Figure 58: Flow duration curves during non-irrigation season in Reach 4, Campaspe Siphon to the River Murray**

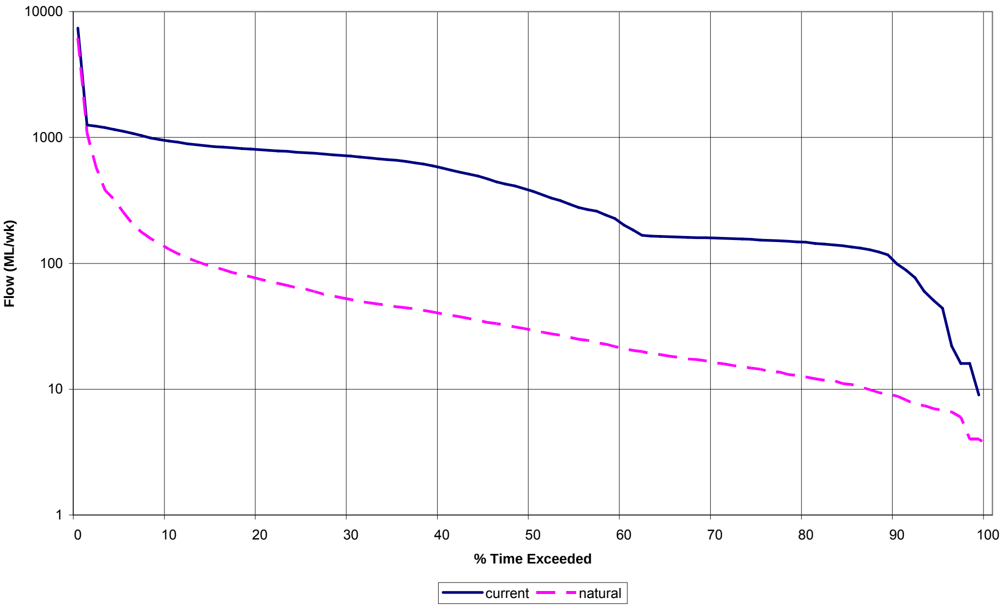
L.3 Loddon River and Tullaroop Creek



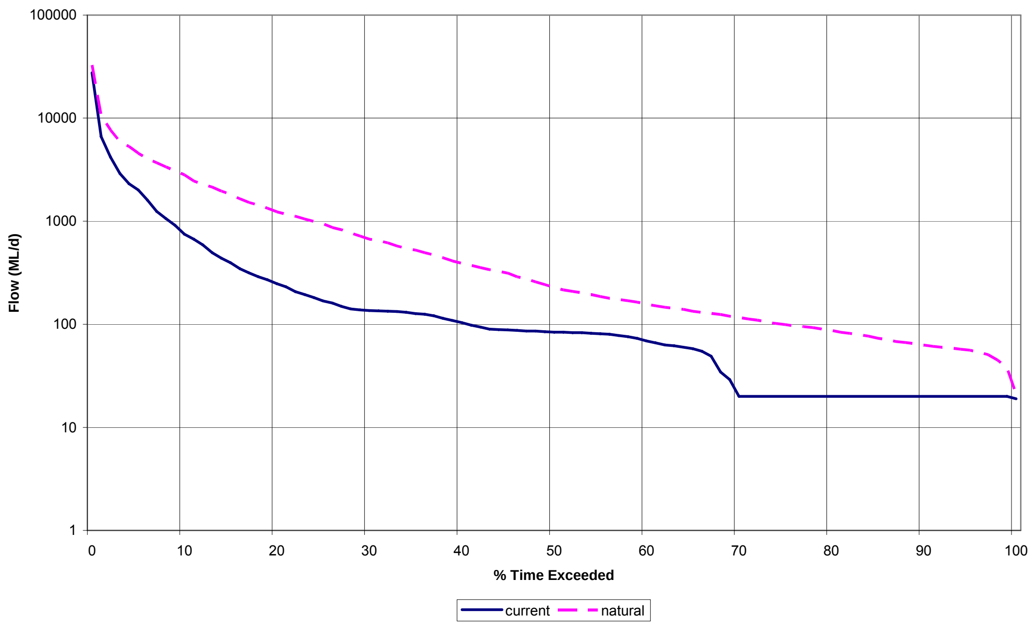
- **Figure 59: Flow duration curve for irrigation season in Reach 1, Cairn Curran Reservoir to Laanecoorie Reservoir**



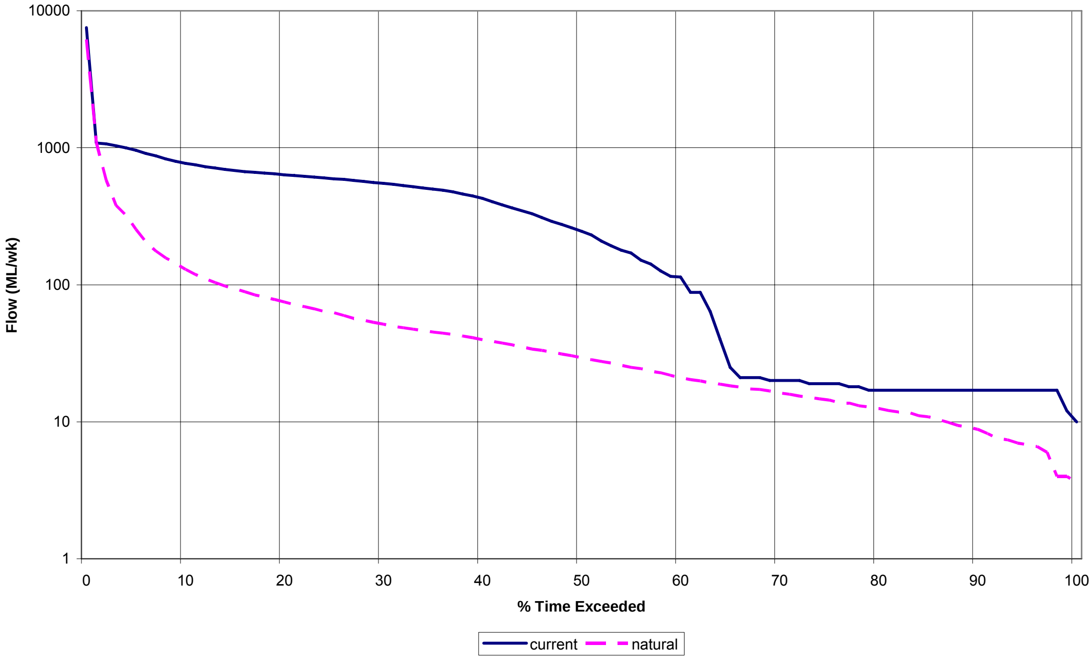
- **Figure 60: Flow duration curve during non-irrigation season in Reach 1, Cairn Curran Reservoir to Laanecoorie Reservoir**



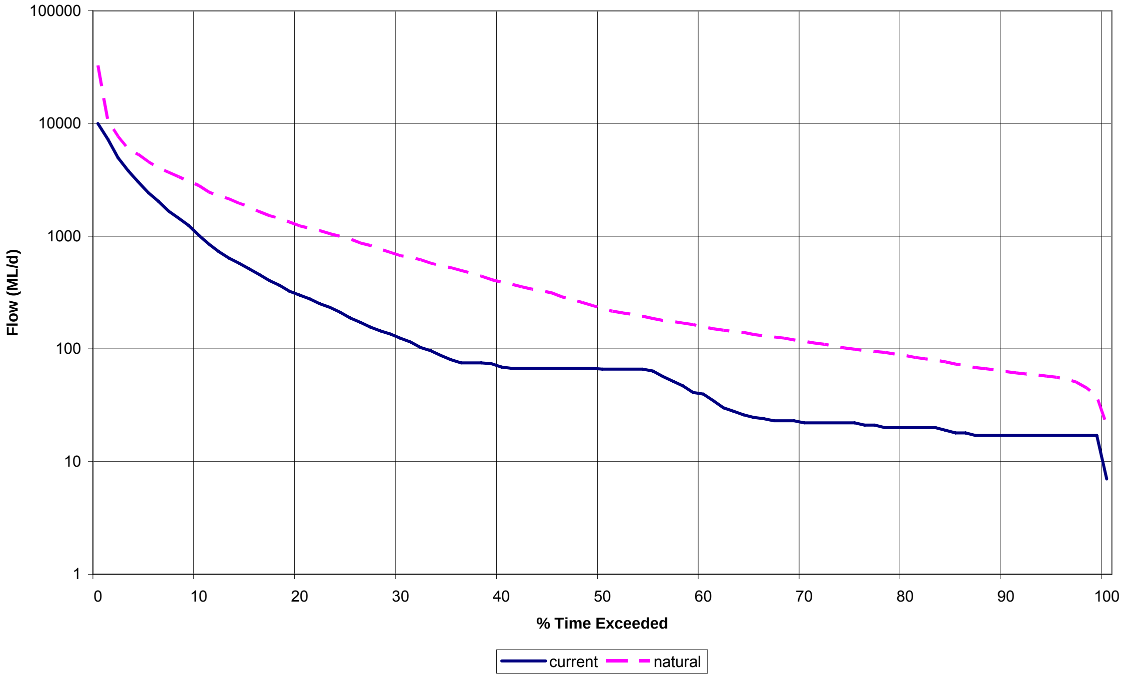
- **Figure 61: Flow duration curve during the irrigation season in Reach 3a, Laanecoorie Reservoir to Serpentine Weir**



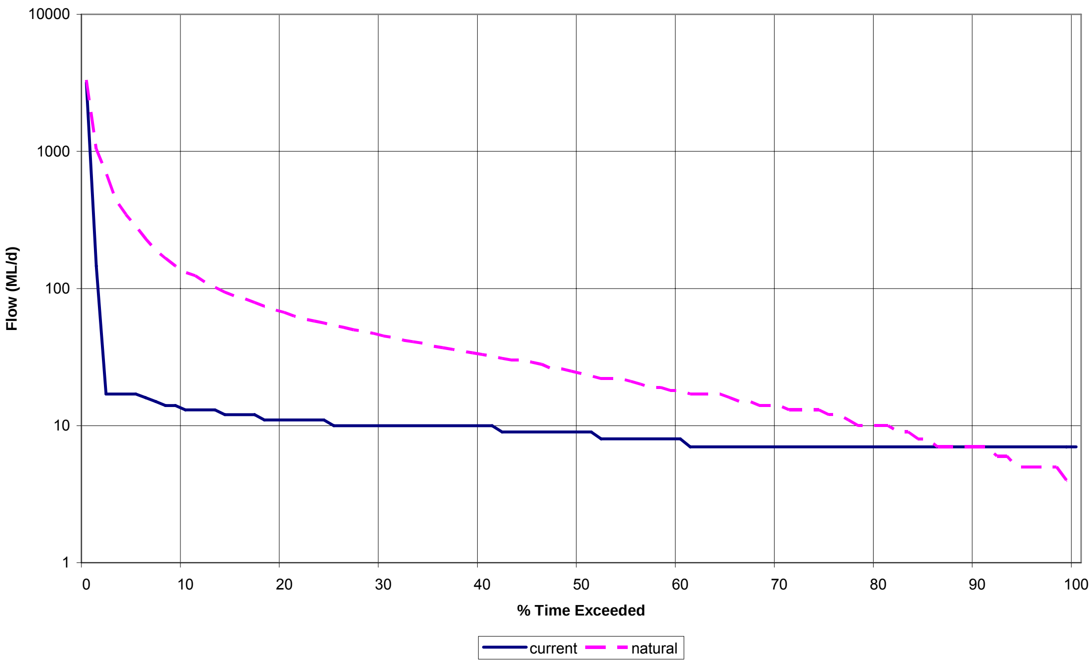
- **Figure 62 Flow duration curve during the non-irrigation season in Reach 3a Laanecoorie Reservoir to Serpentine Weir**



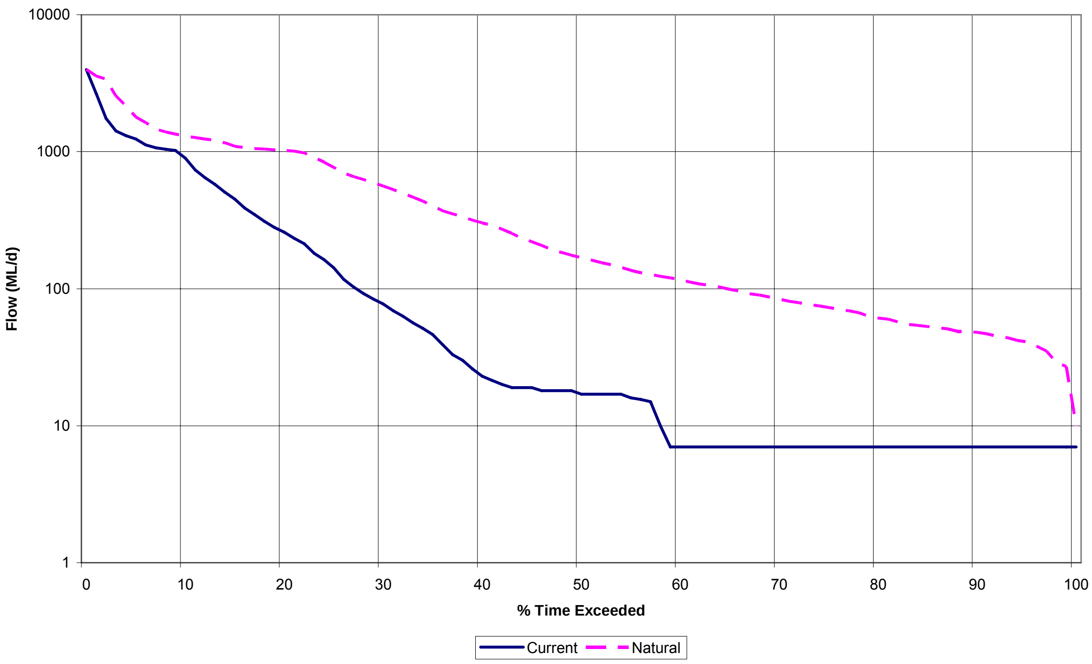
▪ **Figure 63: Flow duration curve during the irrigation season in Reach 3b, Serpentine Weir to Loddon Weir**



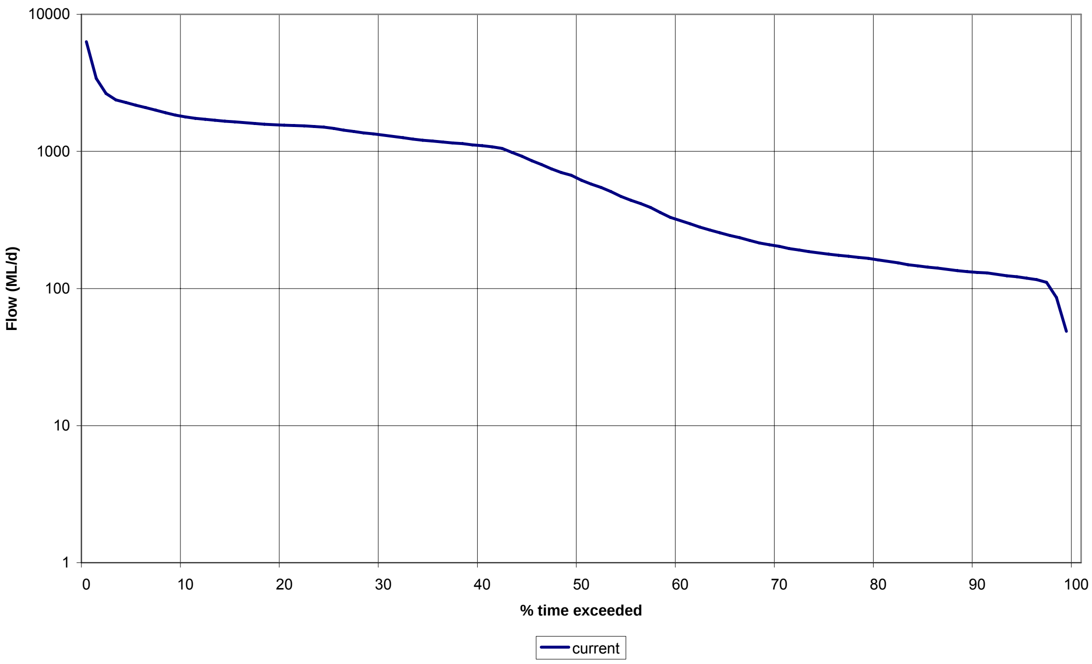
▪ **Figure 64: Flow duration curve during the non-irrigation season in Reach 3b, Serpentine Weir to Loddon Weir**



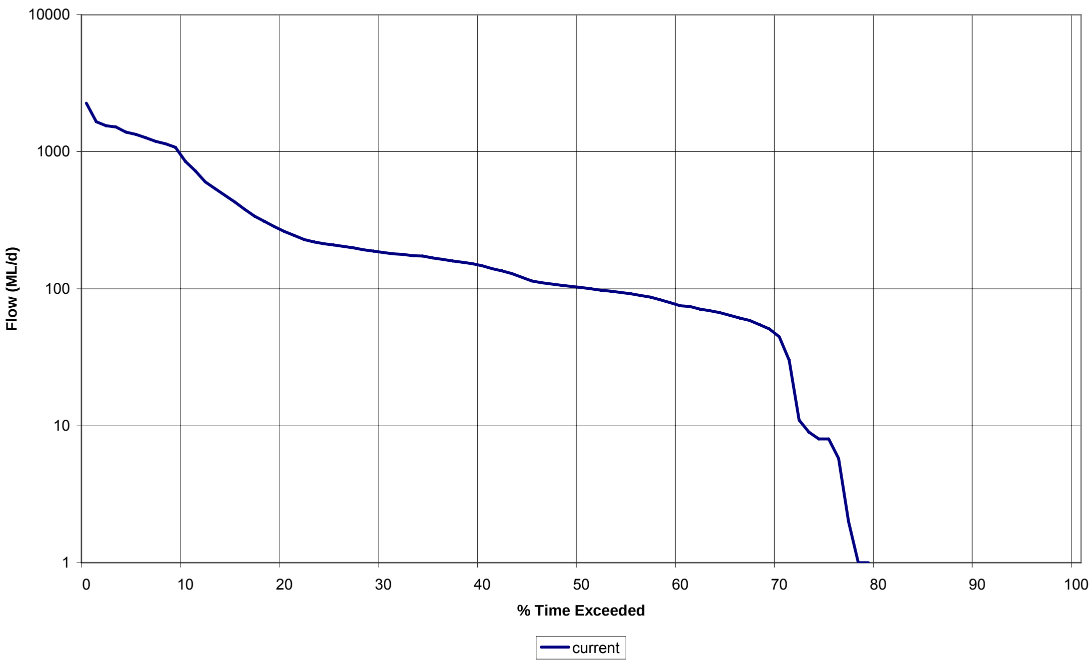
- **Figure 65: Flow duration curve during the irrigation season in Reach 4, Loddon Weir to Kerang Weir**



- **Figure 66: Flow duration curve during the non-irrigation season in Reach 4, Loddon Weir to Kerang Weir**



■ **Figure 67: Flow duration curve during the irrigation season in Reach 5, Kerang Weir to the River Murray**



■ **Figure 68: Flow duration curve during the non-irrigation season in Reach 5, Kerang Weir to the River Murray**

L.4 Birches Creek

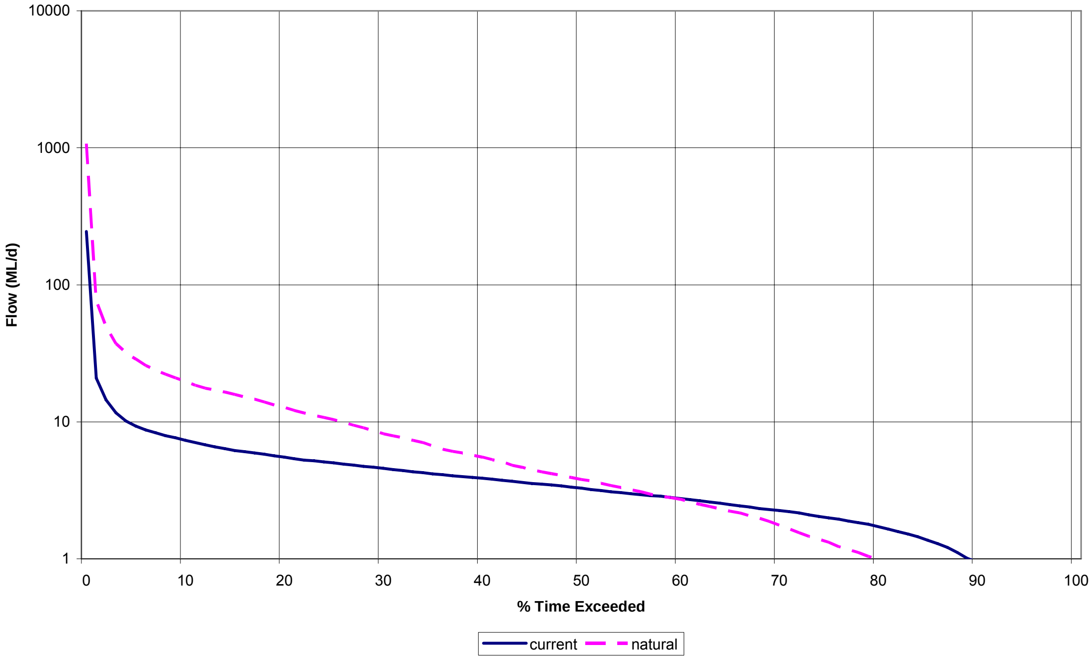


Figure 69: Flow duration curves during irrigation season in Reach 1, Birches Creek: Newlyn Reservoir to the confluence with Hepburn Race

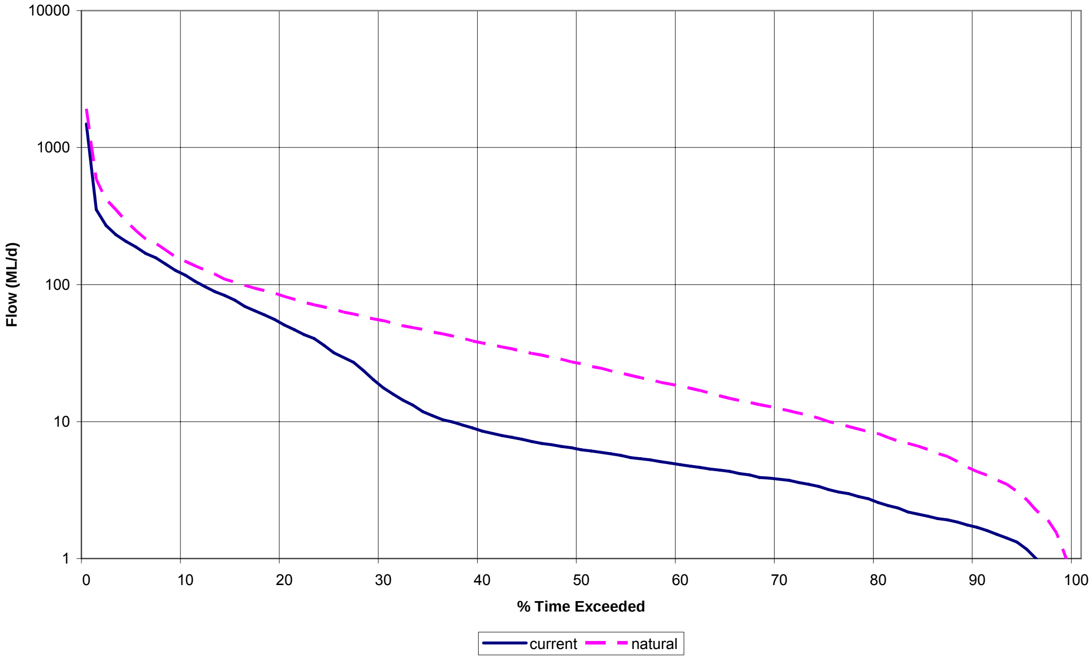
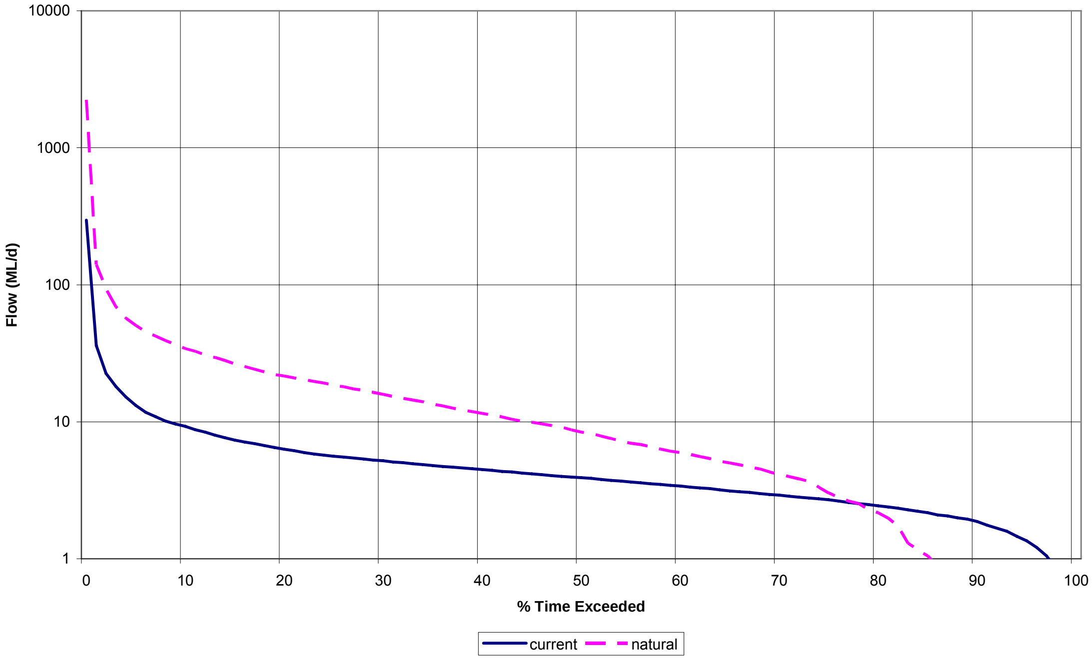
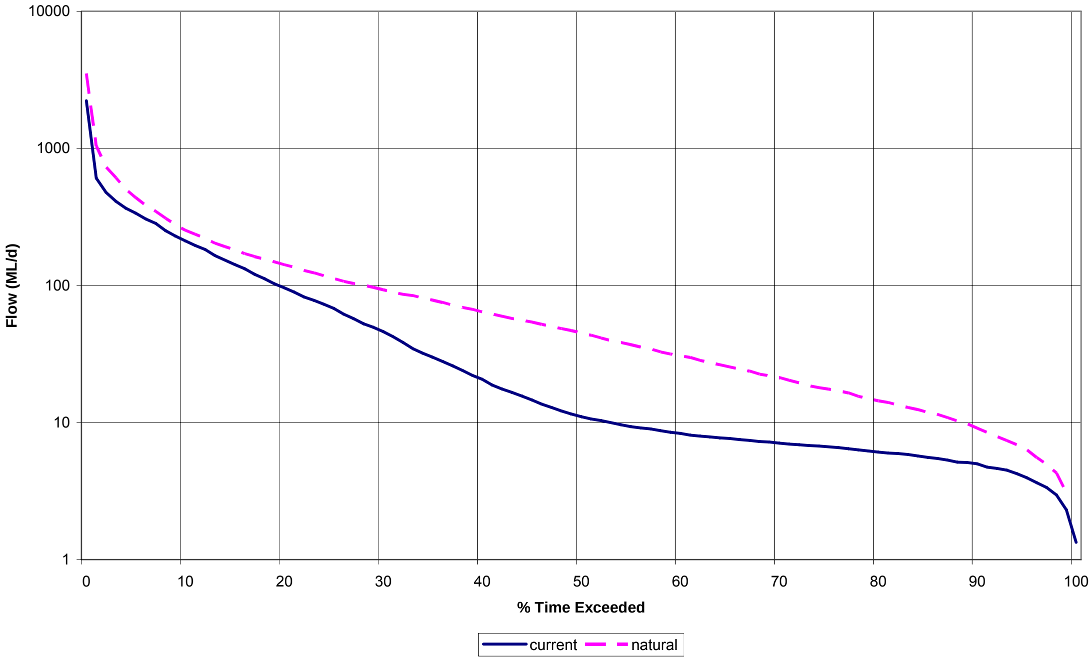


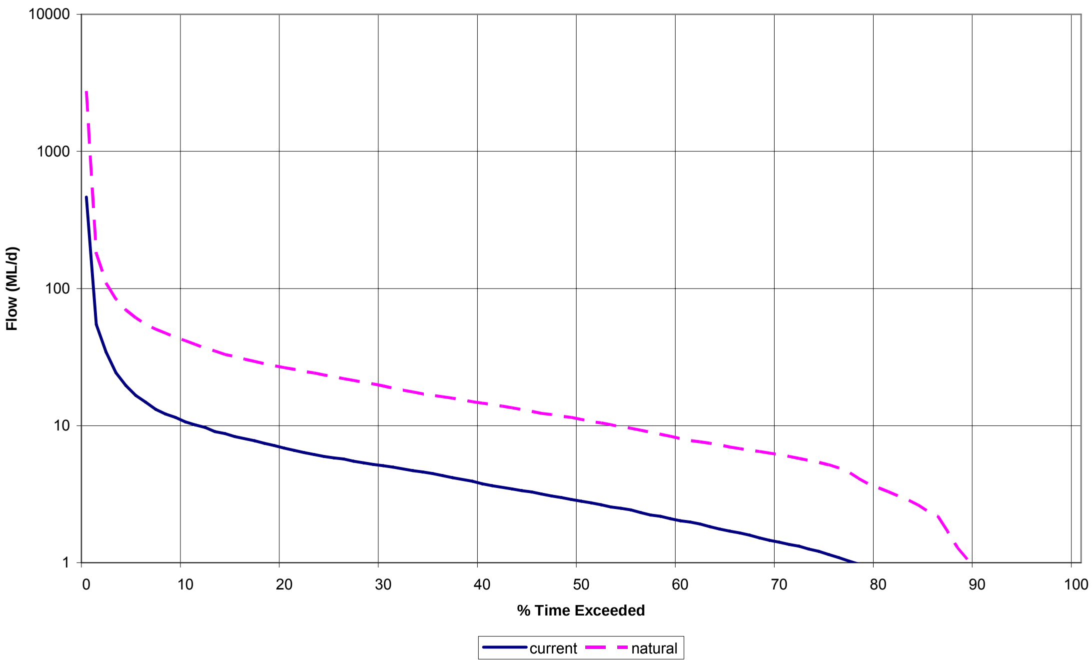
Figure 70: Flow duration curves during non-irrigation seas on Reach 1, Birches Creek: Newlyn Reservoir to the confluence with Hepburn Race



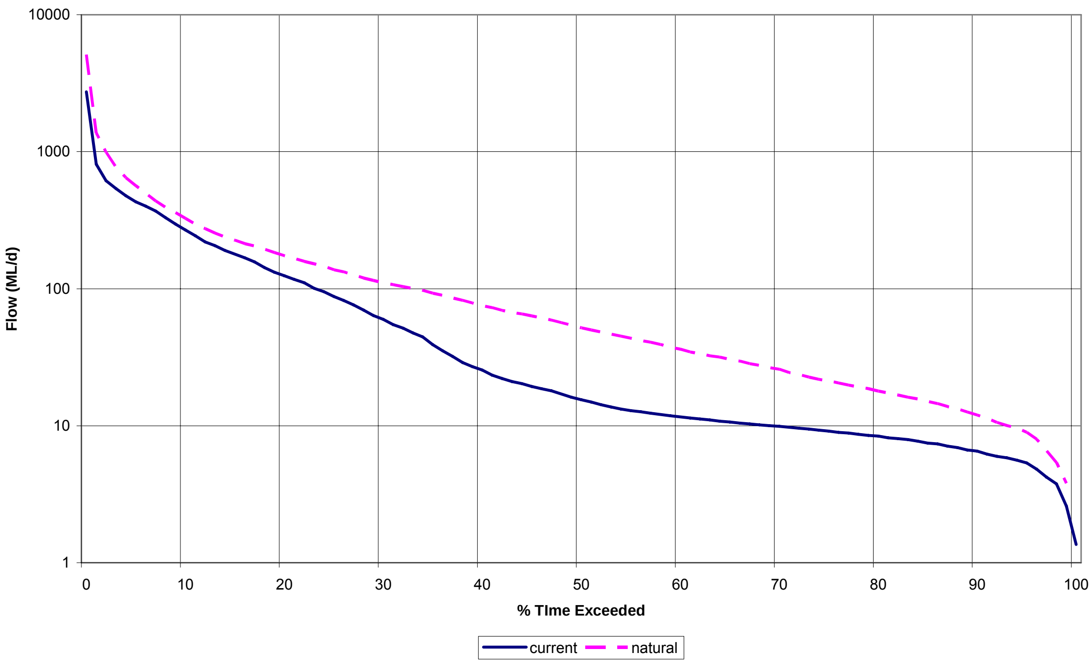
■ **Figure 71: Flow duration curves during irrigation season in Reach 2, Birches Creek: Hepburn Race to Lawrence weir**



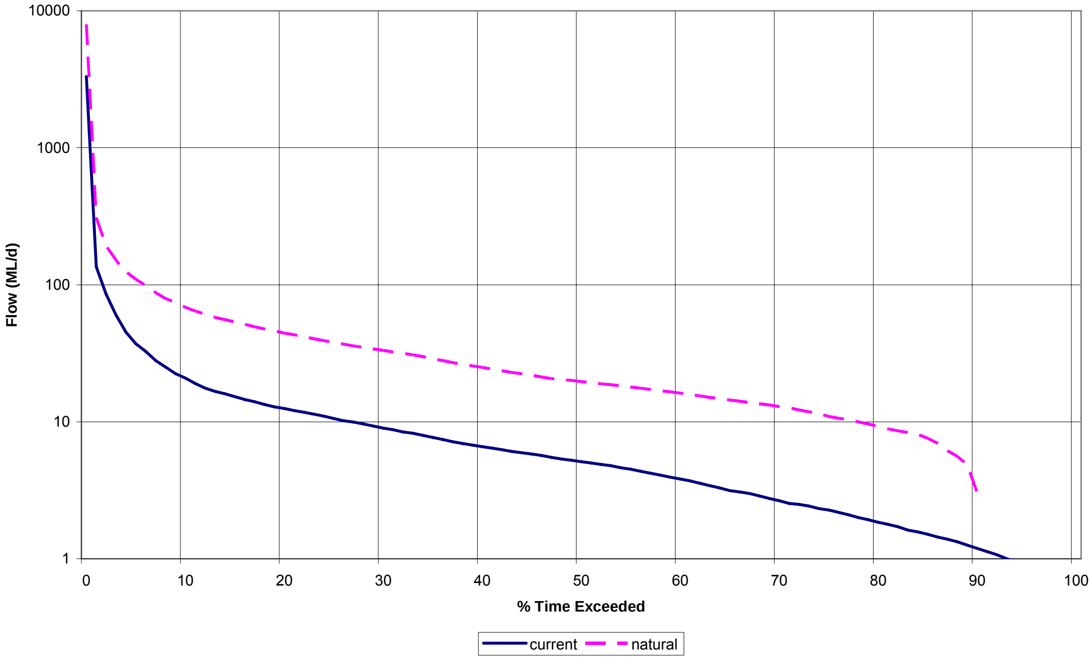
■ **Figure 72: Flow duration curves during non-irrigation season in Reach 2, Birches Creek: Hepburn Race to Lawrence weir**



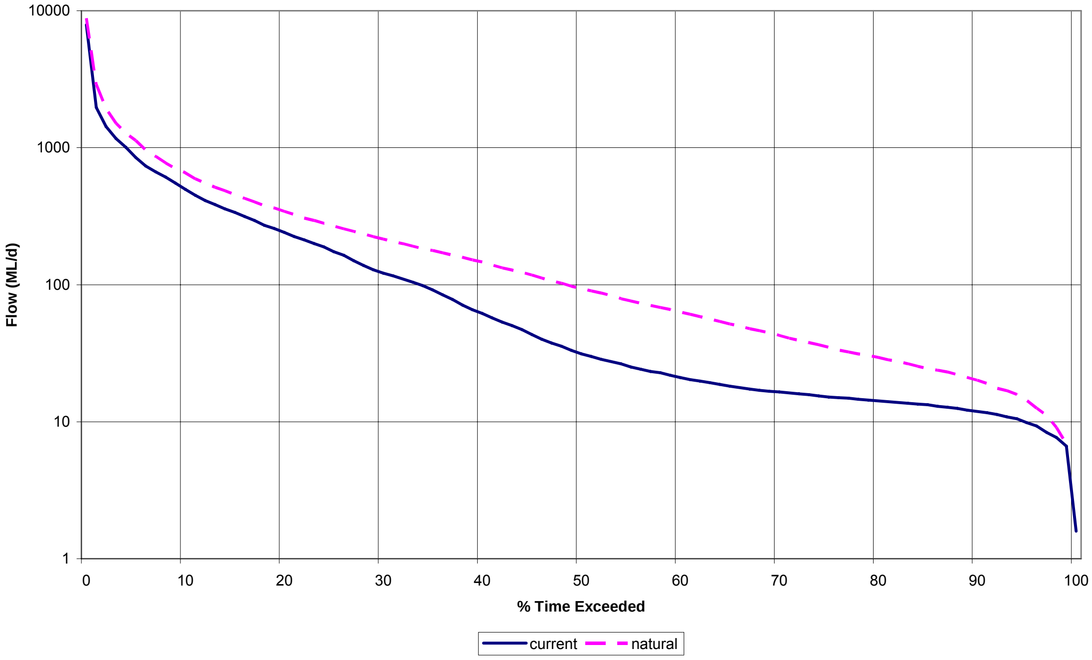
■ **Figure 73: Flow duration curves during irrigation season in Reach 3, Birches Creek: Lawrence weir to the confluence with Creswick Creek**



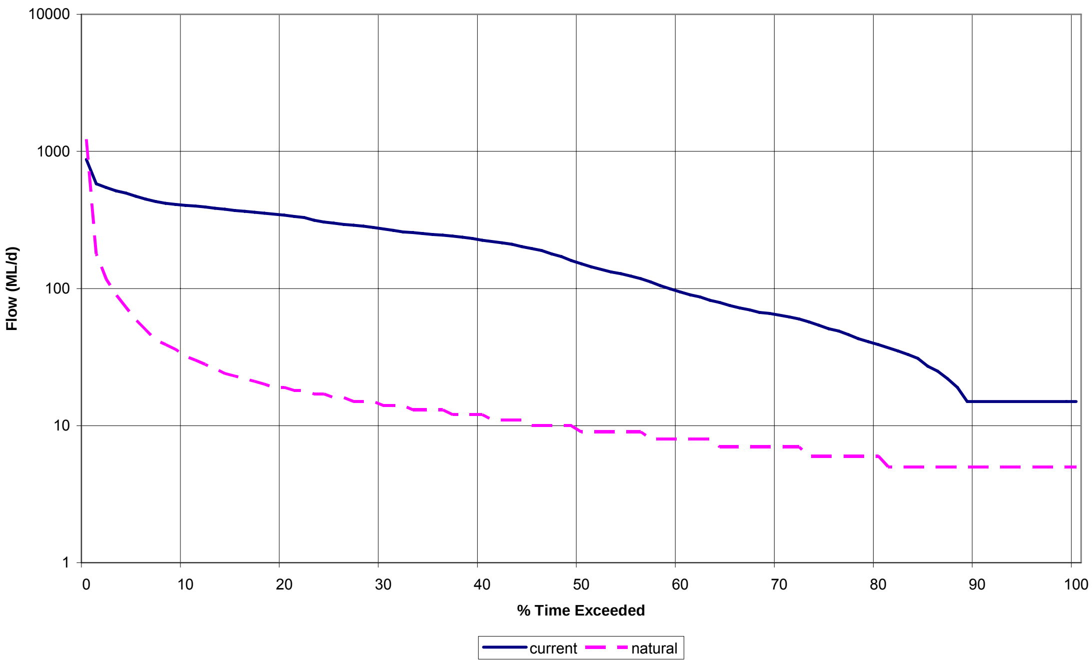
■ **Figure 74: Flow duration curves during non-irrigation season in Reach 3, Birches Creek: Lawrence weir to the confluence with Creswick Creek**



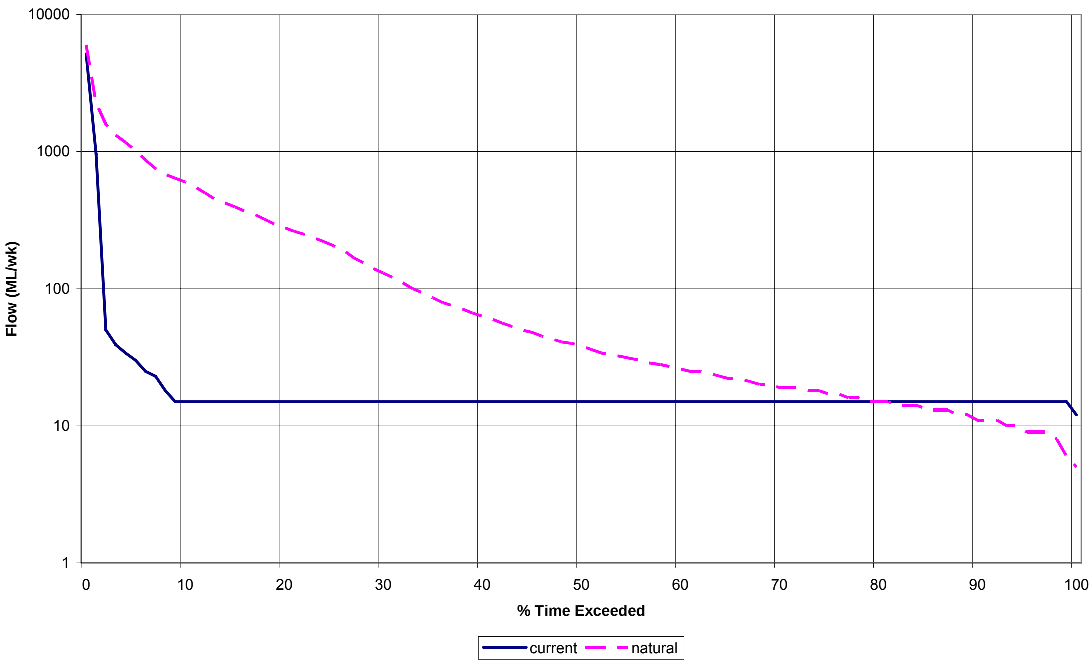
- **Figure 75: Flow duration curves during irrigation season in Reach 4, Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir**



- **Figure 76: flow duration curves during non-irrigation season in Reach 4, Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir**

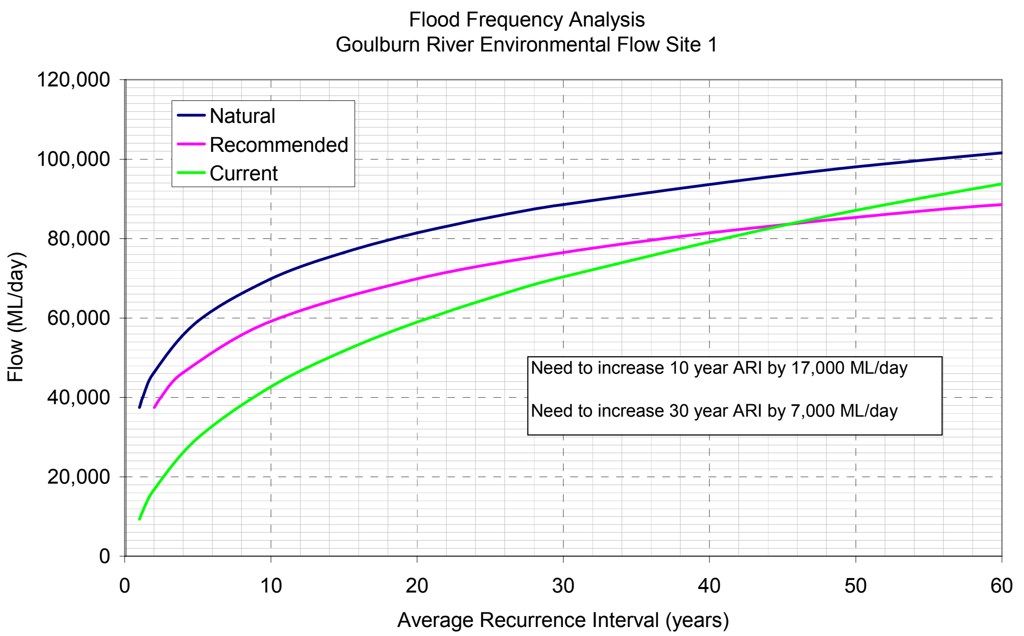


- **Figure 77: Flow duration curve during the irrigation season in Reach 2, Tullaroop Reservoir to Laanecoorie Reservoir**

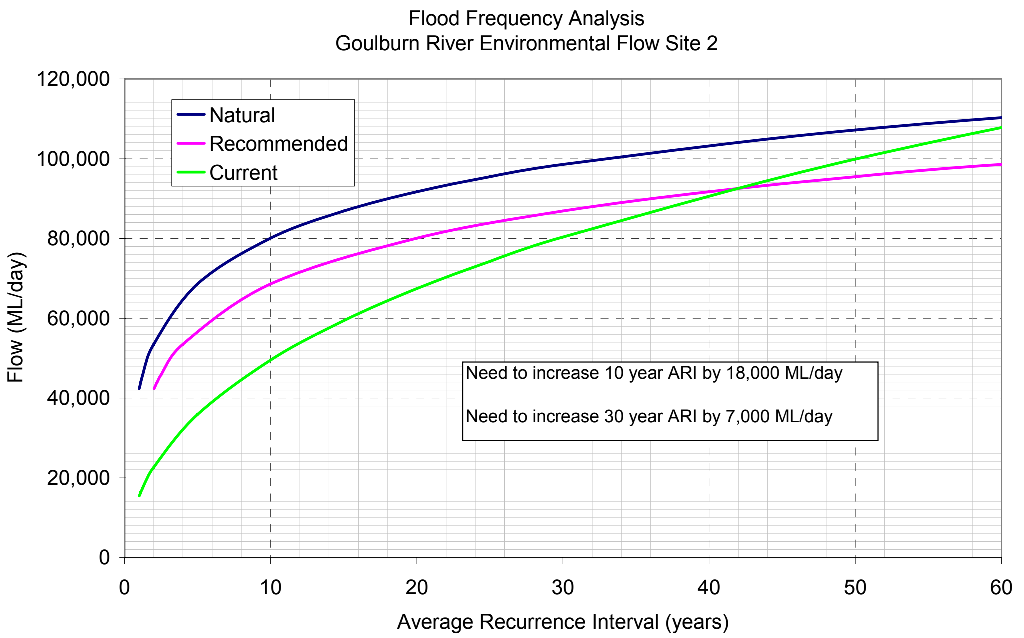


- **Figure 78: Flow duration curve during the non-irrigation season in Reach 2, Tullaroop Reservoir to Laanecoorie Reservoir**

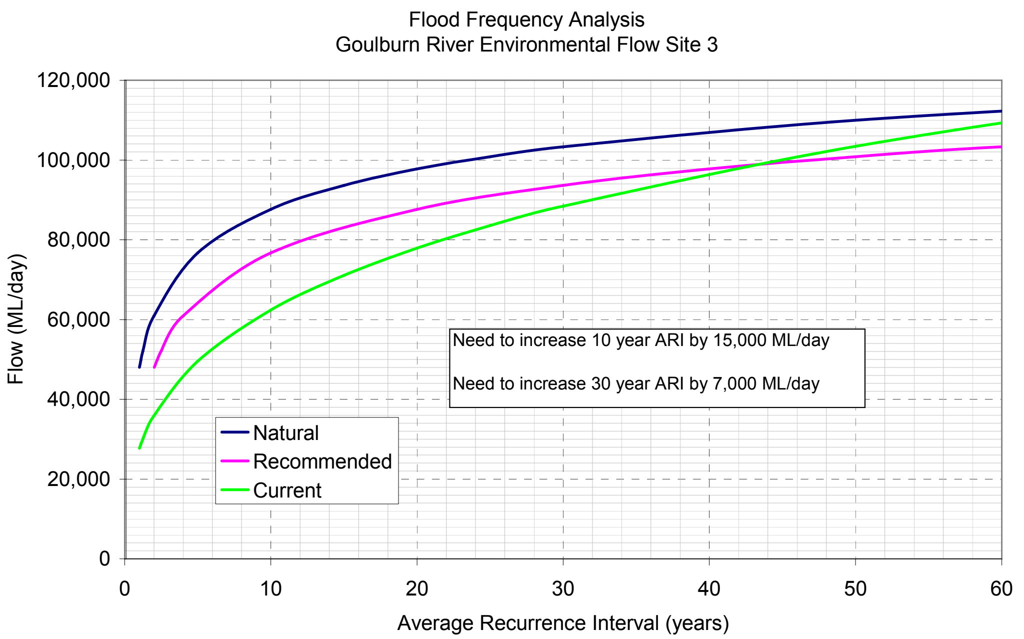
Appendix M Goulburn System Flood Frequency Analyses



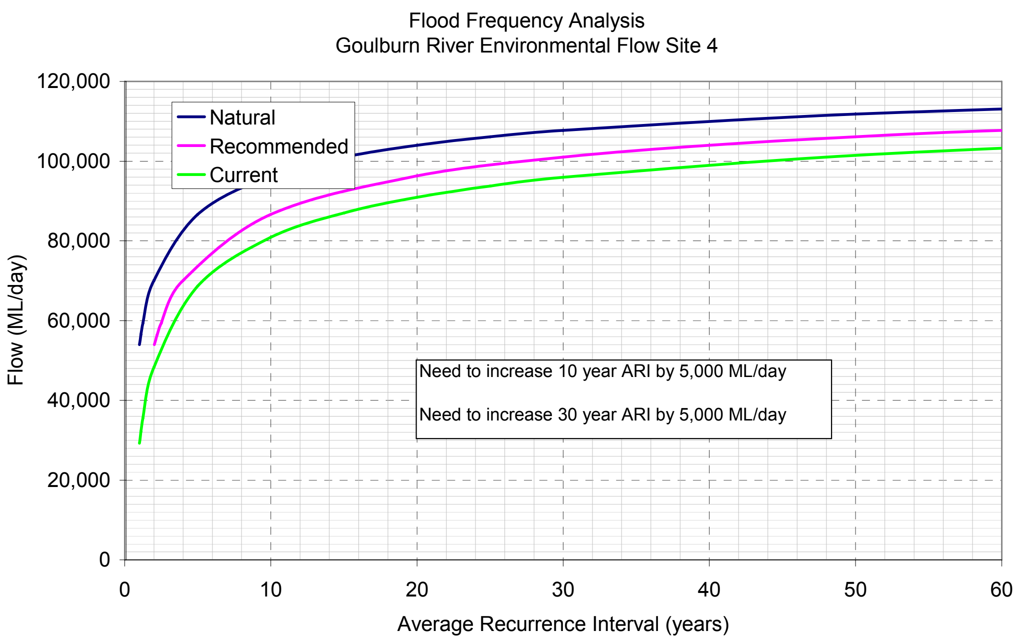
▪ **Figure 79 Natural, recommended and current flood frequency in environmental flow Reach 1, Lake Eildon to Molesworth**



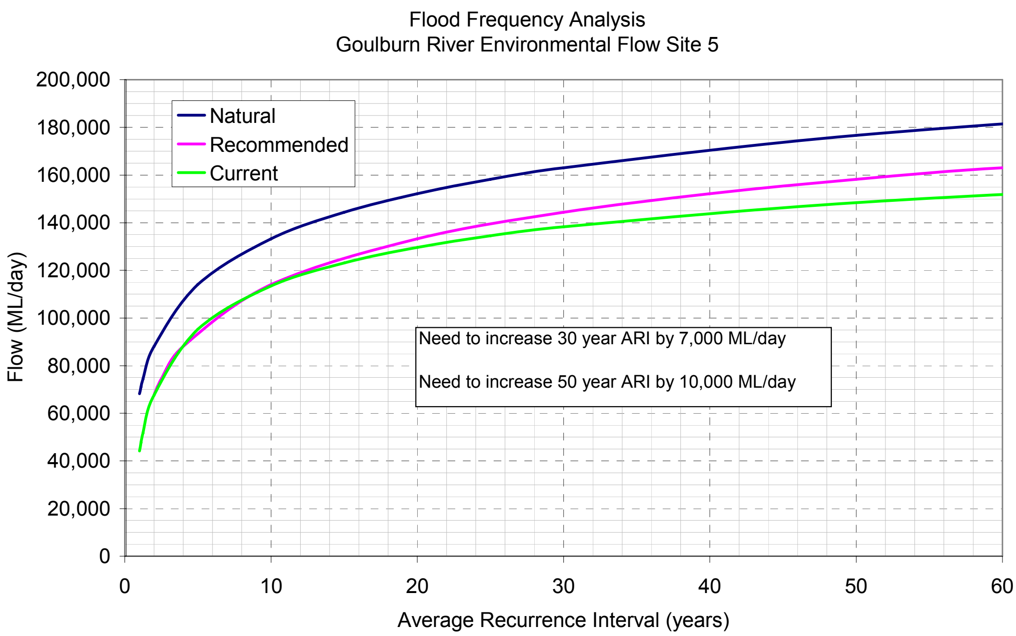
▪ **Figure 80 Natural, recommended and current flood frequency in environmental flow Reach 2, Molesworth to Seymour**



- **Figure 81 Natural, recommended and current flood frequency in environmental flow Reach 3, Seymour to Nagambie**



- **Figure 82 Natural, recommended and current flood frequency in environmental flow Reach 4, Nagambie to Loch Garry**



■ **Figure 83 Natural, recommended and current flood frequency in environmental flow Reach 5, Loch Garry to the River Murray**

SKM

Appendix N Irrigation Area Outfalls

■ Table 51 - Shepparton Irrigation Area

Outfall Name	Map ref	Type	98/99 Volume	Initial Destination	Final Destination	Environmental Effects
1	1	Drop Bar	588	Castle Ck	Castle Ck	Some benefit
2	2	Drop Bar	472	Goulburn River	Goulburn River	Beneficial
8/2	3	Door	33	Seven Creeks	Seven Creeks	Beneficial
3B	4	Drop Bar	154	Honeysuckle Ck	Honeysuckle Ck	Some benefit
4	5	Drop Bar	181	Honeysuckle Ck	Honeysuckle Ck	Some benefit
6	6	Drop Bar	269	Seven Creeks	Seven Creeks	Some benefit
7	7	Pipe Mace meter	129	Kialla Lakes	Kialla Lakes (Broken River)	Beneficial - freshens late
8	8	Door	423.6	Broken Creek	Broken Creek	Beneficial
BROKEN O/F	9	Door	430	Broken Creek	Broken River	Unknown
8/10	10	Drop Bar	0	DR 9	Broken River	Generally negative Some benefit in drain dilution
10/10	11	Drop Bar	8	DR 8A	Broken River	
11/10	12	Door	1	DR 8	Broken River	
13/10	13	Door	52	DR 2/6	Broken River	
2/13/10	14	Drop Bar	2	DR 4/6	Broken River	
1/14/10	16	Door	10	DR 3/6	Broken River	
16/10	17	Door	28	DR 5	Broken River	
10	18	Drop Bar and Door	443	DR 2	Broken River	
20/10	19	Door	4	DR 2	Broken River	
15/10	20	Door	2	DR 2	Broken River	
MID 1/10	21	Drop Bar	375	DR 2	Broken River	
10/1/10	22	Door	0	DR 3A/2	Broken River	
LOWER 1/10	23	Pipe	60	DR 2	Broken River	
2/11	24	Door	0	DR 10/3	Reedy Swamp	Can provide a benefit at final destination (Reedy Swamp) due to reduction in natural Goulburn Floods Water Quality Issue
3/11	25	Door	0	DR 3	Reedy Swamp	
4/11	26	Drop Bar	8	DR 3	Reedy Swamp	
7/11	27	Over/Under Door	200	DR 10/3	Reedy Swamp	
12/12	30	Door	155	DR 3	Reedy Swamp	
2/12/12	28	Spillway		8/3	Reedy Swamp	
3/12/12	31	Door	56	DR 3/3	Reedy Swamp	
2/15/12 xx	32	Drop Bar		DR 7/4	Goulburn River	Negative
15/12 xx	33	Door		DR 5/4	Goulburn River	Negative
17/12	93	Drop Bar	104	DR 3	Reedy Swamp	Can provide a benefit
18/12 xx	35	Spillway		DR 4	Goulburn River	Negative
19/12 xx	36	Drop Bar		Reedy Swamp	Reedy Swamp	Can provide a benefit
20/12 xx	37	Drop Bar		DR 4	Goulburn River	Negative
UPPER 12	38	Drop Bar	2061	DR 4	Goulburn River	Negative
21/12	39	Door	6	DR 11	Broken Creek OR Goulburn Creek	Negative
1/22/12	40	Door	9	Goulburn River	Goulburn River	Beneficial
22/12	41	Drop Bar	570	Loch Garry	Loch Garry	Can provide a benefit
23/12	42	Drop Bar	212	DR 11	Pine Lodge Ck - Broken Ck	Negative
HICK'S O/F	43	Drop Bar	3242	Broken Creek	Broken Creek	Beneficial
38/12	44	Door	14	Broken Creek	Broken Creek	Beneficial
LOWER 12	45	Drop Bar	935	Broken Creek	Broken Creek	Beneficial
2/14 xx	46	Drop Bar		DR 14/4	Goulburn River	Negative
3/14 xx	47	Blocked Off		DR 15A/4	Goulburn River	Negative
4/14 xx	49	Drop Bar		DR 4	Goulburn River	Negative
7/14A xx	50	Drop Bar		DR 9/4	Goulburn River	Negative
14A	51	Drop Bar	515	DR 4	Goulburn River	Negative
2/8/14	52	Door	10	DR 12/4	Pine Lodge Ck - Broken Ck	Negative
3/8/14	53	LMO	223	DR 4	Goulburn River	Negative
8/14A	54	Drop Bar	1328	DR 11	Pine Lodge Ck - Broken Ck	Negative
2/1/15	55	Drop Bar	6	DR 5/11	Pine Lodge Ck - Broken Ck	Negative
1/1/15	56	Drop Bar	142	DR 5/11	Pine Lodge Ck - Broken Ck	Negative
2/15	57	Door	35	DR 1/5/11	Pine Lodge Ck - Broken Ck	Negative
MID 15	59	Drop Bar	25	DR 5/11	Pine Lodge Ck - Broken Ck	Negative
15	60	Theiss	1220	DR 11	Pine Lodge Ck - Broken Ck	Negative
3/17	61	Drop Bar	108	DR 11	Pine Lodge Ck - Broken Ck	Negative

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▪ Table 52 - Central Goulburn Irrigation

Outfall Name	Map ref	Type	98/99 Volume (Ml)	Initial Destination	Final Destination	Environmental Effects
15/6/4	1	SCADA & Thiess	1823	Goulburn River	Goulburn River	Positive
Lower 6/4	2	Wheel	336	Surplus	Carson's Creek	Positive
11/4	3	Knife Edge	136	Ardmona Main Drain	Goulburn River	Negative
14/4	4	Wheel	223	1/8	Goulburn River	Negative
25/4	5	Drop Bar Check	392	Coomboona Drain	Goulburn River	Negative
27/4	6	Drop Bar Check	151	Undera Main Drain	Goulburn River	Negative
9/3/6	7	Wheel	20	Mosquito Creek	Mosquito Creek	Negative
19/6	8	SCADA & Thiess	3864	Ardmona Main Drain	Goulburn River	Negative
5/19/6	9	Drop Bar Check	216	Rodney Main Drain	Goulburn River	Negative
6/19/6	10	Drop Bar Check	333	Ardmona Main Drain	Goulburn River	Negative
7/19/6	11	Door	545	Well's Creek	Muroes Wetland - Goulburn River	See below*
20/6	12	Thiess	431	DR7	Yambuna Creek (Kanyapella Basin)	Negative
No.11 5/27/6	13	Drop Bar Check	71	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
No.12 5/27/6	14	Drop Bar Check	592	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
No. 12A	15	Drop Bar Check	147	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
No. 13	16	Wheel	57	Randall Main Drain	Goulburn River	Negative
no. 14	17	SCADA & Thiess	3120	DR1	Goulburn River	Negative
No.15	18	SCADA	1339	DR3	Yambuna Creek (Kanyapella Basin)	Negative
16/8	19	Wheel	1019	DR4	Yambuna Creek (Kanyapella Basin) - Floodway	Negative
19/8	20	Wheel	104	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
No. 6	21	SCADA	2863	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
No.10 9	22	SCADA	1833	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
7/9 (Morgan's)	23	Wheel	71	DR11 (Deakin)	Beattie Depression - Murray River	Negative
7/9 (River)	24	Wheel	110	Deakin Main Drain	Beattie Depression - Murray River	Negative
9/7/9	25	Wheel	55	DR11 (Deakin)	Beattie Depression - Murray River	Negative
10/7/9	26	Drop Bar Check	4	DR11	Beattie Depression - Murray River	Negative
12/9	27	Drop Bar Check	305	DR3 (Deakin)	Beattie Depression - Murray River	Negative
1/12/9	28	Drop Bar Check	355	Deakin Main Drain	Beattie Depression - Murray River	Negative
2/12/9 (Deakin sp	29	SCADA	679	Deakin Main Drain	Beattie Depression - Murray River	Negative
2/12/9	30	Wheel	547	Deakin Main Drain	Beattie Depression - Murray River	Negative
9/2/12/9	31	Wheel	49	DR6 (Deakin)	Beattie Depression - Murray River	Negative
13/2/12/9	32	Wheel	114	DR 2/7 (Deakin)	Beattie Depression - Murray River	Negative
17/2/12/9	33	Shared Wheel	90	Deakin Main Drain	Beattie Depression - Murray River	Negative
4/12/9	34	Wheel	202	DR3/3 (Deakin)	Beattie Depression - Murray River	Negative
14/9	35	Drop Bar Check	134	DR3 (Deakin)	Beattie Depression - Murray River	Negative
36787 18/9	36	Wheel	347	DR19	Beattie Depression - Mosq Ck - Murray River	Negative
5/19/9 (McGills)	37	Drop Bar Check	0	Mosquito Ck Dep Drain	Beattie Depression - Murray River	Negative
19/9 (Olivers)	38	SCADA	2129	DR 2 (Deakin)	Beattie Depression - Murray River	Negative
19/9 (River)	39	SCADA	1221	?	Murray River	Negative
5/19/9	40	Wheel	181	DR12	Beattie Depression - Murray River	Negative
8/19/9	41	Drop Bar Check	34	DR5 (MCDD)	Beattie Depression - Murray River	Negative
9/19/9	42	Door	117	DR9 (MCDD)	Beattie Depression - Murray River	Negative
15/19/9	43	Door	6	Mosquito Ck Dep Drain	Beattie Depression - Murray River	Negative
16/19/9	44	Drop Bar Check	75	DR3 (MCDD)	Beattie Depression - Murray River	Negative
20/19/9	45	Drop Bar Check	44	DR1 (Deakin)	Beattie Depression - Murray River	Negative
24/19/9	46	Drop Bar Check	0	Deakin Main Drain	Beattie Depression - Murray River	Negative
23/9	47	Wheel	325	DR19	Beattie Depression - Mosq Ck - Murray River	Negative
2/28/9	48	Wheel	449	DR8	Beattie Depression - Mosq Ck - Murray River	Negative
20/28/9	49	Wheel	280	DR1 (Tongala)	Warrigal Creek	Negative
31/28/9	50	Wheel	61	Wyuna Main Drain	Yambuna Creek (Kanyapella Basin)	Negative
33/9 (1)	51	Wheel	107	DR4	Yambuna Creek (Kanyapella Basin) - Floodway	Negative
33/9 (2)	52	Wheel	174	DR4	Yambuna Creek (Kanyapella Basin) - Floodway	Negative
34/9	53	Drop Bar Check	454	DR2	Yambuna Creek (Kanyapella Basin) - Floodway	Negative
6/34/9	54	Wheel	86	Coram Main Drain	Yambuna Creek (Kanyapella Basin) - Floodway	Negative
2/36/9	55	Shared Wheel	51	Coram Main Drain	Yambuna Creek (Kanyapella Basin) - Floodway	Negative

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Table 53 - Rochester Irrigation Area

Outfall Name	Map ref	Type	Capacity	98/99 Volume	Initial Destination	Final Destination	Environmental Effects
T11	1	LMO		43	Re-Use	Surplus to Greens Lake	Negative
T14	2	LMO		17	Re-Use	Surplus to Greens Lake	Nutrients can create water
T16	3	LMO		10	Re-Use	Surplus to Greens Lake	quality issues
1	4	LMO		213	Re-Use	Kanyapella Basin	
5	5	Open		aban			
6	6	Open		41	DR 10/6	Murray River	Negative
1/6	7	Open		aban			
2/6	8	Open		24	DR 4/6	Murray River	Negative
5/6	9	SMO		73	DR 1/5/6	Murray River	Negative
8	10	LMO		281	DR 1/6	Murray River	Negative
8 Glass	11	LMO		330	Re-Use	Dr 1/6 then Murray River	Positive
11/8	12	Open		6	DR 6 (Rochy)	Deakin then Murray River	Negative
2/11	13	LMO		80	DR 4	Campaspe River	Negative
5/11	14	Open		16	Deakin Main	Murray River	Negative
13/11	15	Open		18	Deakin Main Drain	Murray River	Negative
18/11	16	Open		83	Deakin Main Drain	Murray River	Negative
12	17	Open		0	Campaspe River	Campaspe River	Positive
14	18	LMO		456	Re-Use	Murray River	Positive
14 AUTO	19	LMO		509	Re-Use	Murray River	Positive
14 FINK	20	LMO		173	Bamawn Main Drain	Murphy Swamp	See Below
1/14	21	Open		0	Campaspe River	Campaspe River	Positive
3/14	22	LMO		397	Rochy Main Drain	Campaspe River	Negative
1/3/14	23	Open		1	DR 1A/2	Campaspe River	Negative
2/1/3/14	24	LMO		42	Campaspe River	Campaspe River	Positive
16	25	Open		0	Ch 14	Murphy Swamp	
18	26	LMO		28	DR 5/3	Murphy Swamp	
20A	27	Open		70	DR 1/1	Murphy Swamp	
20B	28	LMO		297	Bamawn Main Drain	Murphy Swamp	
2/20	29	LMO		425	DR 1 (Bamawn)	Murphy Swamp	Generally negative
6/20	30	LMO		79	Bamawn Main Drain	Murphy Swamp	
8/20	31	LMO		42	Bamawn Main Drain	Murphy Swamp	Refer to Richardson's
14/20	32	LMO		4	DR 2/1	Murphy Swamp	lagoon and Murphy's
15/20	33	SMO		4	DR 2/1	Murphy Swamp	Swamp Mgt Plan
16/20	34	LMO		17	DR 2/1	Murphy Swamp	Nutrients from Lockington
21	35	LMO		300	DR 1/6/1	Murphy Swamp	Main Drain and Bamawn
22	36	LMO		29	DR 4/6/1	Murphy Swamp	Drain
3/23	37	LMO		338	DR 5/1	Murphy Swamp	Water levels high
6/23	38	LMO		118	DR 3	Murphy Swamp	in summer
8/23	39	LMO		188	DR 1	Murphy Swamp	Death of river red gums
10/23	40	LMO		341	DR 1	Murphy Swamp	
24	41	SMO		25	DR 3	Murphy Swamp	
25	42	LMO		126	DR 2/3	Murphy Swamp	
26	43	Open		38	DR 3/11/3	Murphy Swamp	
27	44	LMO		620	DR 1/1/3	Murphy Swamp	
1/27	45	LMO		362	DR 4	Murphy Swamp	
1/1/27	46	LMO		195	DR 1/1/3	Murphy Swamp	
29	47	LMO		166	DR 2/1/7	Murphy Swamp	
29 Haines	48	LMO		205	Re-Use	Murray River	
30	49	LMO		492	DR 2/9	Murphy Swamp	
2/30	50	Open		18	DR 1/7	Murphy Swamp	

■ Table 54 - Pyramid Hill - Boort Irrigation Area

Outfall name	Map ref	Type	98/99 Volume	Initial Destination	Final Destination	Environmental Effects
1/3/1	1	Open	0		Bullock Ck	Negative[1]
2/3/1	2	Open	8		Re-Use/Bullock Ck	Negative[1]
3/1	3	Open	93		Bullock Ck	Negative[1]
7/5/1	4	SMO	88		Bullock Ck	Negative[1]
6/12/5/1	5	LMO	55		Bullock Ck	Negative[1]
12/5/1	6	Open	0		Bullock Ck	Negative[1]
4/12/5/1	7	Open	11		Bullock Ck	Negative[1]
16/5/1	8	Open	10		Bullock Ck	Negative[1]
5/1	9	Open	0		Bullock Ck	Never used
1/10/1	10	SMO	7		Calivil Ck	Negative[2]
5/10/1	11	LMO	15		Calivil Ck	Negative[3]
10/10/1	12	LMO	82		Nine Mile Ck	Negative[1]
19/10/1	13	SMO	17		Re-Use	
20/10/1	14	Measured to Nine Mile	3		Re-Use/Nine Mile Ck	Negative[1]
10/1	15	Measured by NRU	300		Re-Use	N/A
10/1	16	LMO	118		Calivil Ck	Negative[2]
10/1	17	LMO	78		Main Macorna Drain	Negative[2]
12/1	18	LMO	108		Re-Use	
13/1	19	LMO	103		Calivil Ck	Negative[2]
9/16/1	20	SMO	75	Western Depression	Calivil Ck	Negative[2]
17/1	21	SMO	0		Calivil Ck	Negative[2]
20/1	22	LMO	30		Calivil Ck	Negative[2]
23/1	23	LMO	34		Calivil Ck	Negative[2]
24/1	24	Open	1427	No 1 Drain	Pyramid Ck	No effect
6/24/1	25	Open	0	Main Macorna Drain	Calivil Ck	Negative[2]
7/24/1	26	Open	6	Main Macorna Drain	Calivil Ck	Negative[2]
24/1	27	Open	21	Main Macorna Drain	Calivil Ck	Negative[2]
31/1	28	Measured by NRU	150		No 1 Drain	No effect
No 1	60	Measured by NRU	80		Main Macorna Drain	Negative[2]
No 12 (Penny Royal)	29	Open	1288		Penny Royal Ck	Negative[3]
No 12 (Nine Mile Ck)	30	Open	29		9 Mile Ck	Negative[1]
4/12	31	LMO	94		Re-Use	
4/4/12	32	Measured by NRU	6		Calivil Ck	Negative[2]
8/12	33	Measured by NRU	50		9 Mile Ck	Negative[1]
8/12	34	LMO	260		9 Mile Ck	Negative[1]
9/12	35	Open	0		Main Macorna Drain	Negative[2]
No 12	36	Open	10		Main Macorna Drain	Negative[2]
1/12	37	Flood water only	11		Loddon River	No effect
1/12	38	Utilised No. 12	0		Serp Ck	Never used
1/13	39	Open	69		9 Mile Ck	Negative[1]
1/1/12	40	Open	11		12 Mile Ck	Negative[1]
2/1/1/12	41	Open	0		12 Mile Ck	Negative[1]
No 1	42	Open	0		Kinypaniel	Negative[1]
No 2	43	Open	0		Kinypaniel	Negative[1]
1/2/2	44	Open	0		Kinypaniel	Negative[1]
No 2	45	Open	0		Loddon River	No effect
No 2	46	Open	26		Loddon River	No effect
9/2	47	Open	818		Loddon River	No effect
9/2	48	Open	185		Loddon River	No effect
3/2/8/2	49	Open	64		Loddon River	No effect
1/9/2	50	Open	60		Loddon River	No effect
8/2	51	Open	48		Loddon River	No effect
2/8/2	52	Open	39		Loddon River	No effect
Lake Boort	53	Open	0		Lake Boort	Seasonal[5]
Little Lake Boort	54	Open	323		Little Lake Boort	Positive[4]

Table 55 - Torrumbarry Irrigation Area

Outfall Name	Map ref	Type	98/99 Volume	Initial Destination	Final Destination	Environmental Effects
3/6/1 Farret	1	LMO	0	Dr 17	Barr Creek	Negative
3/7/6/1 Keely	2	LMO	25	Dr 18	Barr Creek	Negative
6/1 High School	3	Recorder	109	Dr 17	Barr Creek	Negative
1/2/1 Waters	4	Recorder	0	Privale Drain	Barr Creek	Negative
4/2/1 Hawken	5		0	Dr 6/20	Barr Creek	Negative
5/2/1 Crichton	6	LMO	4	Dr 20	Barr Creek	Negative
7/1 Golding	7	LMO	29	Barr Ck Drain	Barr Creek	Negative
1/7/1 Robbins	8	LMO	12	Dr 25	Barr Creek	Negative
14/1 Cooke	9	LMO	50	Dr 16	Barr Creek	Negative
2/10/1 Douglas	10	Drop Bars	19	Dr 23	Barr Creek	Negative
1/2 Hore	11	LMO	0	Dr 2/8/14	Barr Creek	Negative
15/1 Major	12	Recorder	0	Cohuna Drain 14	Barr Creek	Negative
20/1 Henty	13	LMO	0	Dr 7	Barr Creek	Negative
1/21/1 Grills	14	Door	0	Dr 7/20	Barr Creek	Negative
1/22/1 Crichton	15		0	Dr 2/13	Barr Creek	Negative
1/1/2/3 Barr Park	16	Door	0	Dr 12	Barr Creek	Negative
2/2/3 Simons	17	LMO	33	Barr Ck	Barr Creek	Negative
12/2/3 Joblings	18	Drop Bars	0	Dr 1/3	Barr Creek	Negative
7/3 Spence	19	LMO	18	Picaninny Barr Ck	Barr Creek	Negative
6/5 McNeil	20	Door	0	Dr 3	Barr Creek	Negative
5 Girdwood	21	Door	0	Dr 4	Barr Creek	Negative
1/4 McDonald	22	Door	0	Dr 3/4	Barr Creek	Negative
16/4 Murray	23	Recorder	172	Koondrook Dr 1	Barr Creek	Negative
1 McKnight	24	Recorder	905	Kerang Dr 1	Barr Creek	Negative
31/1 Angel	25	LMO	9	Cavil Ck Dr	Barr Creek	Negative
32/1 McKinley	26	Recorder	56	Barr Ck	Barr Creek	Negative
35/1 Wren	27	Door	0	Kerang Dr 1	Barr Creek	Negative
11/5 Lacey	28	Door	35	Barr Ck	Barr Creek	Negative
5 Hein	29	Recorder	156	Natural Drain to the The	Barr Creek	Negative
7/2 Kerr	30	LMO	47	Nine Mile Ck	Barr Creek	Negative
3/7/2 Hanley	31	Door	0	Cavil Ck Dr	Barr Creek	Negative
3/5/1/7 Baulch	33	LMO	34	The Glut	Barr Creek	Negative
5/1/7 Baulch	34	LMO	5	The Glut	Barr Creek	Negative
Gun Ck Yarran	35	Doors	1006	Yarran Ck	Murray River	Negative
2/11/4 Tyres	36	Drop Bars	139	Dr 4	Murray River	Little impact
11/4 Hobson	37	Drop Bars	404	Murray River	Murray River	No impact
6/4 Watsons	38	Recorder	0		Bush	Emergency Only
11/4 Ashwin	39	Drop Bars	9	Murray River	Murray River	Emergency Only
17/4 Hope	40	Door	0	Dr 4	Murray River	Negative
21/4 Lyons	41		7	Murrabit Dr	Murray River	Negative
23/4 Waddingham	42	Door	0	Drain 2	Murray River	Negative
25/4 Bryer	43	Automatic Door	2690	Murray River	Murray River	No impact
26/4 Carey	44	LMO	0	Dr 1	Murray River	Negative
No 1 McKnight	45	LMO	0	Barr Ck	Loddon River	No impact
No 4	46	Drop Bars	904	Loddon River	Loddon River	No impact
6 McKnight	47	LMO	0	Loddon River	Loddon River	No impact
6 Heffers	48	Drop Bars	72	Loddon River	Loddon River	No impact
No 1/7	49	Doors	952	Loddon River	Loddon River	No impact
2/3 McDonalds	50	Recorder	410	McDonald's Swamp	McDonald's Swamp	Positive
1/7/2 Hirds	51	Door	3	NRE Channel	Hirds Swamp	Regulated
4/7/2 Johnsons	52	Door	424	NRE Channel	Johnson's Swamp	Regulated
2/14/2 Fosters	53	Door	40	Outfall Channel	Foster's Swamp	Negative
3/17/2 Murphy	54	Drop Bars	0	Lake Murphy	Lake Murphy	Timing Issue
3/17/2 Brandy	55	Door	0	Lake Wandella	Lake Wandella	Negative
28/2 Lake Elizabeth	56	Automatic Door	782	Lake Elizebeth	Lake Elizabeth	Negative
10/1 Young	57	LMO	0	Dr 1/1/20	Reuse Systems	Positive, lowers Barr Ck inflows
14/1 Cooke	58	LMO	39	Dr 1/4	Reuse Systems	Positive, lowers Barr Ck inflows

Table 56 - Murray Valley Irrigation Area

Outfall Name	Map ref	Type	Capacity (Ml/d)	98/99 Volume (Ml)	Initial Destination	Final Destination	Environmental Effects
6 Main End	1		50	534	Broken Ck	Broken Ck	Positive*
26A/6 Flanners	2			212	Broken Ck	Broken Ck	Positive*
20/6	3	Drop Bar	30	855	DR 13	Broken Ck	Negative
13/6 End	4	LMO		775	DR 13	Broken Ck	Negative
13/6 Middle	5			204	DR 13	Broken Ck	Negative
21A/6 Jewells	6		50	145	Broken Ck	Broken Ck	Positive*
19A Vallende	7		35	538	DR 1/13	Broken Ck	Negative
15A/6 Bourkes	8	SMO		65	DR 1/13	Broken Ck	Negative
15/6	9	Drop Bar	30	381	Broken Ck	Broken Ck	Positive*
14/6	10	Door	15	483	DR 2/18	Broken Ck	Negative
10/8/6	11		3	0	Dr 1/18	Broken Ck	Negative
8/6	12	Drop Bar	30	381	Broken Ck	Broken Ck	Positive*
4/8/6	13		30	319	Broken Ck	Broken Ck	Positive*
9/6 End	14	Drop Bar		1084	Active flow path DR 10 catchment	Barmah Forest	Negative
5 Main	15	Drop Bar		1321	DR 9	Tullah Ck - Barmah	Negative: Refer to Souter (1996) of FEG(1990-5)
23/5	16	Drop Bar		605	DR 9		
20/5	17	Drop Bar		722	DR 1/7		
15/5	18	Drop Bar		326	DR 6	Tongalong Ck - Barmah	Negative: In forest works performed to aleviate unseasonal forest flooding
14/5	19	SMO		4	DR 2/7/6		
3/5	20	Drop Bar		809	DR 6		
12/5	21	SMO		166	DR 7/6		
9/5	22	Door		501	DR 7	Broken Ck	Some benefit in dilution of drain flows
9/6 Middle	23	Door		4	DR 10		
6/5	24	SMO		354	DR 10		
7/5	25	LMO		254	DR 7/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
2A/5	27	Door		2	DR 2/11/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
7/2	28	Door		893	DR 5	Murray River	Negative
2/6/1	29	Door		198	DR 4/3	Sheepwash Ck	Negative
6/1	30			295	DR 5/3	Sheepwash Ck	Negative
5/1	31			200	DR 3	Sheepwash Ck	Negative
1/5/1	32			333	DR 2/7/3	Sheepwash Ck	Negative
4 Main	33	Drop Bar		95	Broken Ck	Broken Ck	Positive*
5/3	34	Drop Bar		690	Mackatah Dep	Broken Ck	Some benefit
3 Main	35	Drop Bar		851	Wild Dog Ck	Broken Ck	Some benefit
6/6	36			32	Broken Ck	Broken Ck	Positive*
1/2/5	37			28	DR 5/11/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
2/5	38			704	DR 11/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
9/2	39	Drop Bar		810	DR 1/10/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
1/9	40			51	DR 2/10/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
2 Main	41	Drop Bar		1087	DR 5	Murray River	Some Benefit
10/2	42	Drop Bar		408	DR 5	Murray River	Some Benefit
8A/2	43	Door		0	DR 16/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
8/2	44	Door		0	DR 18/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
1/7F/2	45			0	DR 10/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
5 Main	46			10	DR 24/6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
17/2	47	Drop Bar		68	DR 6	Tongalong Ck - Barmah	Negative @ Tongalong Ck
12/6	48		12	449	DR 9/13	Broken Ck	Negative
12/7/2	49			232	DR 3	Sheepwash Ck	Negative
6 Main DR 18	50			14	DR 18	Broken Ck	Negative

* Beneficial where channel outfalls are freshening up the stream. Some benefit where drainage flows are being diverted