Flow-related environmental issues associated with the Goulburn River below Lake Eildon

A report to the Department of Sustainability and Environment, Victoria
and the
Murray Darling Basin Commission

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Executive Summary

The Murray Darling Basin Commission is investigating the return of environmental flows to the River Murray System via the 'Living Murray' project. This is being done by examining the ecological implications of delivering three reference point volumes along representative regions of the Murray River: 350, 750 and 1500GL per year. The Commission is to report its findings so that the Murray Darling Basin Ministerial Council can consider the reference points at its meeting in October 2003. The Goulburn and Murrumbidgee Rivers are also being considered in the Living Murray project, as they are likely to be central contributors of water should the reference point flows, or similar, be adopted in the future.

The Department of Sustainability and Environment (DSE) approached the Cooperative Research Centre for Freshwater Ecology (CRCFE) and the Cooperative Research Centre for Catchment Hydrology (CRCCH) to convene and manage a Scientific Panel, which will identify the flows necessary to maintain or improve key environmental values in the regulated section of the Goulburn River, which lies between Lake Eildon and the River Murray. As part of its work, the Scientific Panel will:

1) Collate and assess relevant information and data on the condition of the Goulburn River.
2) Undertake a field assessment to confirm environmental/ecological values associated with the river system and support the development of flow-related ecological objectives.
3) Develop an issues paper to identify and establish objectives for the key environmental values/assets of the Goulburn River and their likely flow requirements.
4) Determine the environmental flow regime to sustain the Goulburn River in an ecologically healthy condition, consistent with the Victorian River Health Strategy, the Goulburn Broken Regional Catchment Strategy and the FLOWS method developed for developing environmental flow recommendations in Victoria (NRE 2002).
5) For each of the following scenarios, describe how the water would be used, in terms of a flow regime, to enhance the environmental values of the Goulburn River on a priority basis:
    - current situation (BE requirement for 80GL and 30GL for flooding and water quality)
    - BE requirement + an average annual increase of 70GL from the Goulburn into the Murray (as measured at McCoy's bridge)
    - BE requirement + 150GL extra flow from the Goulburn into the Murray
    - BE requirement + 300GL extra flow from the Goulburn into the Murray
6) Recommend other management actions that are required to sustain the key environmental values/assets of the Goulburn River.

This Issues Paper addresses milestones related to the first three tasks set for the Scientific Panel. It includes comparison of the current regulated flow regime with that expected to occur naturally, the environmental and ecological assets and values associated with the Goulburn River system and flow-related ecological objectives that will serve as the basis for environmental flow recommendations to be developed by the Scientific Panel. Also included are observations on complementary land and water management activities that will help to protect the environmental assets of the Goulburn River.

The project study area includes the Goulburn River and its associated floodplain, downstream from Lake Eildon to the confluence of the River Murray. The river receives releases from Lake Eildon and inflows from tributaries such as the Acheron, Yea, and Broken Rivers (the latter including water from Lake Mokoan), and numerous creeks. Specific environmental flow recommendations will not be required for the tributaries, however, as they have or will be considered through other processes and studies.

The following reaches have been identified for the purposes of this study (Appendix 2):

- Lake Eildon to Molesworth
- Molesworth to Seymour
- Seymour to Nagambie
- Nagambie to Loch Garry
- Loch Garry to the River Murray.

The Scientific Panel visited sites along the Goulburn River between the 22-24 January 2003, including two meetings with local stakeholders with good knowledge of the river at different flow conditions. Supplementary visits were also conducted in February and April 2003.

Streamflow in the Goulburn River below Lake Eildon is variable, both annually and seasonally, and is modified by the following processes:

- The presence and operation of Lake Eildon;
- Diversion of water at Goulburn Weir from the Goulburn River to the East Goulburn Main Channel to supply the Goulburn Murray Irrigation District (GMID) and its associated irrigation supply and drainage schemes;
- Diversion of water to Waranga Basin via the Cattanagh and Stuart Murray canals; and
- Changes to floodplain drainage through the construction of levees;
- Operation of regulators on effluent and anabranch channels downstream of Shepparton (in particular Bunbartha Creek at Lock Garry);
- Operation of Lake Nillahcootie;
- Diversions to and releases from Lake Mokoan (an off-stream storage);
- Diversions at Casey's Weir;
- Private diversions throughout the Goulburn River catchment

The Goulburn River flow regime is further affected by a range of activities within the catchment, including alterations to vegetation, construction of small dams and drainage schemes. Along the riverine plain, artificial levees, block banks and other structures, obstruct flood flows.

Lake Eildon and its operation has affected the hydrology of the Goulburn River by:

- Causing a reversal of the season pattern of flow (e.g. maximum flow in summer and autumn, minimum flows in winter and spring);
- Altering flow duration by truncating the high flows (maximum flow reduced), increasing medium sized flows and decreasing low flows;
- Decreasing the return frequency of flood events
- Decreasing the flood magnitudes for a given return frequency; and
- Decreasing downstream sediment loads.

The 'flow reversal' that results from regulated releases from Lake Eildon is most pronounced immediately downstream of the dam. The monthly flow pattern measured at Alexandra is now much less variable than natural and the highest monthly flows now occur in February-March rather than August-September. The impact of Lake Eildon has also reduced flood frequency, as a flow event that has a 10-year average recurrence interval (ARI) under the current flow regime had a 1-year ARI under the natural flow regime. Floodwaters captured by the dam are then released as higher than natural mid and low-flows over summer-autumn.

The pattern of monthly flow downstream at Murchison in Reach 4 is similar to that of the natural flow regime but has been greatly dampened due to the diversion of water at Goulburn Weir. A flow event with a 10-year ARI under the current flow regime is equivalent to an event with a 2-year ARI under the natural flow regime.

Initiatives such as the Victorian River Health Strategy and the Goulburn Broken Regional strategy provide guiding principles for the Goulburn Scientific Panel in terms of assessing river condition and making recommendations to improve river health within a water management context. These principles may also serve as broad rehabilitation objectives that serve as the basis of environmental flow recommendations. The Goulburn Scientific Panel has developed the following vision for the Goulburn River as it develops environmental flow recommendations: 'a *healthy working river that supports a diversity of natural ecosystems and processes, thereby sustaining the community of the Goulburn-Broken catchment'*.

The key ecological and environmental assets of the study area were considered by the Scientific Panel from the perspective of geomorphology, connection of the river with its floodplain and associated wetlands, aquatic and floodplain vegetation, native fish populations, macroinvertebrate populations and water quality. The values associated with these key assets were categorised according characteristics related to naturalness, representativeness, diversity and richness, rarity and special features. The risks posed by the current flow regime and management to key ecological processes and functions then form the basis of flow-related ecological objectives to be achieved through environmental flow recommendations. As outlined in the FLOWS method, recommendations have two features: (i) they define the component of the flow regime to be modified (e.g. low flow, bankfull flow) and (ii) they identify the timing (e.g. seasonality) and nature of releases (e.g. to provide 10 cm depth of riffle habitat).

It should be noted that the Scientific Panel has yet to fully consider and quantify the nature of the threats posed to environmental assets by aspects of the current flow and management regime for the Goulburn River, particularly on a reach by reach basis. The development of more detailed flow-related objectives is an iterative process that will be completed as the project progresses.

The Scientific Panel will consider a number of operational and environmental constraints as it develops detailed environmental flow recommendations. The ecological condition of the Goulburn River is the result of many factors operating at different spatial and temporal scales. Many of these factors may not be directly related to the flow regime of the river but can certainly reduce or confound the potential effects of environmental flows when they are delivered. For example, factors such as Goulburn Weir being a barrier to fish movement and colder than natural water temperatures below Lake Eildon, in isolation or together, can reduce the effectiveness of environmental flows recommended to re-establish or enhance native fish populations between Lake Eildon and Lake Nagambie.

The Scientific Panel will comment on the following constraints as it develops environmental flow recommendations and acknowledge potential adverse social or economic impacts:

- The capacity to release large volumes of water from Lake Eildon (outlet structure release capacity 17,500 ML/d) and the potential for minor flooding, with potential bed and bank erosion and damage to infrastructure and assets;
- The potential that the ecological outcomes expected with additional releases may be negated if the water temperature is too cold. It is recognised that ameliorating cold water releases poses risk to trout fisheries and trout farms;
- The Panel does not have sufficient resources to model the salinity implications of any recommendations. The MDBC may be approached to undertake salinity modelling at a future date;
- Lack of flexibility in operations due to level of commitments and extensive rules for operating Lake Eildon and associated hydroelectricity power generation;
- High demands for Goulburn water from outside of the catchment and potential future demands, for example in providing more water for the Murray River;
- Balancing differences in the volumes required to inundate floodplain areas in middle reaches with that of downstream reaches;
- Unknown but extensive changes to surface and connections (eg small block banks, excavated channels into out of wetlands)
- Land management practices
- The maintenance of Lake Nagambie as an important recreation and social amenity.

The Scientific Panel will also consider the following complementary (non flow-related) management actions that may be required required to increase the likelihood of successful ecological outcomes:

- Amelioration of cold water releases from Lake Eildon;
- Retention of the ban on gravel extraction from the river;
- Review and removal of unnecessary levees and block banks;
- Exclusion of livestock from the riparian zone;
- Continuation of rabbit control measures;
- Provision of fish passage past Goulburn Weir;
- Continuation of carp control strategies;
- Continued implementation of the Goulburn Broken water quality and revegetation strategies.

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Ian Park	Local landholder
Ross Pogue	Local landholder
Nick Roberts	Shepparton Implementation Committee
Hugh Robertson	Deakin University
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Keith Ward	North East Catchment Management Authority
Russel Wealands	Goulburn Broken Catchment Management Authority
Ross Wealhouse	Local landholder

Appendix 1 Contents

A1-1 INTRODUCTION

The Murray-Darling Basin Ministerial Council has directed the Murray Darling Basin Commission to investigate the return of environmental flows to the River Murray System. This is being done using three reference points: 350, 750 and 1500GL per year. Council will consider information produced on these reference points in October 2003. The Commission has in turn established '*the Living Murray'* project to consider the ecological implications of the three reference points for eight river regions along the Murray and lower Darling system. The Goulburn and Murrumbidgee Rivers are also being considered in the Living Murray project, as they are likely to be central contributors of water should the reference point flows, or similar, be adopted in the future. The Commission will consider ecological, social and economic factors when evaluating the three reference point flows.

The Goulburn River is the largest Victorian tributary to the Murray system. The contribution required from the Goulburn River in meeting the reference point flows is not yet known. Interim coarse estimates can be based on Cap volumes, which suggest that contributions of 70, 150 and 300GL may be required from the Goulburn System. However, the implications of delivering these reference points for the ecology and condition of the Goulburn River are not clear. Thus, an environmental flows study of the Goulburn River is recognised as an important step toward understanding the environmental needs of this major tributary. The output of such a study will be an important factor when opportunities for securing additional flows for the River Murray are considered by the Living Murray project.

The Department of Sustainability and Environment (DSE) approached the Cooperative Research Centre for Freshwater Ecology (CRCFE) and the Cooperative Research Centre for Catchment Hydrology (CRCCH) to convene and manage a Scientific Panel, which will identify the flows necessary to maintain or improve key environmental values in the regulated section of the Goulburn River, which lies between Lake Eildon and the River Murray. As part of its work, the Scientific Panel intends to:

1) Collate and assess relevant information and data on the condition of the Goulburn River.
2) Undertake a field assessment to confirm environmental/ecological values associated with the river system and support the development of flow-related ecological objectives.
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5) For each of the following scenarios, describe how the water would be used, in terms of a flow regime, to enhance the environmental values of the Goulburn River on a priority basis:
    - current situation (BE requirement for 80GL and 30GL for flooding and water quality)
    - BE requirement + an average annual increase of 70GL from the Goulburn into the Murray (as measured at McCoy's bridge);
    - BE requirement + 150GL extra flow from the Goulburn into the Murray;
    - BE requirement + 300GL extra flow from the Goulburn into the Murray.

6) Recommend other management actions that are required to sustain the key environmental values/assets of the Goulburn River.

Provision of advice on the social and economic issues associated with the use of water for environmental purposes will be undertaken by the GBCMA using the 'RIVAS' decision support tool.

It is also intended that the Goulburn Scientific Panel will be used as a Regional Evaluation Group (REG) within the Living Murray project. This is a separate but related task to be funded by the MDBC. The appointment of this Panel as the REG for the Goulburn River will provide synergies with the Living Murray project.

1.1 Purpose

This Issues Paper addresses milestones related to the first three tasks set for the Scientific Panel. The following discussion will consider the scope of the study area and compare the current regulated flow regime with that expected to occur in the absence of Lake Eildon, Goulburn Weir and water diversions (i.e. the natural flow regime expected with current land use). The environmental and ecological values associated with the Goulburn River system will be summarised, along with current and emerging threats to those values. Flow-related ecological objectives for each reach will also be outlined. These objectives will serve as the basis for environmental flow recommendations that will be developed by the Scientific Panel part of stage 2, along with observations on complementary land and water management activities that will help to protect the environmental values of the Goulburn River. An overview of the Flows process is outlined below (Figure A1.1).

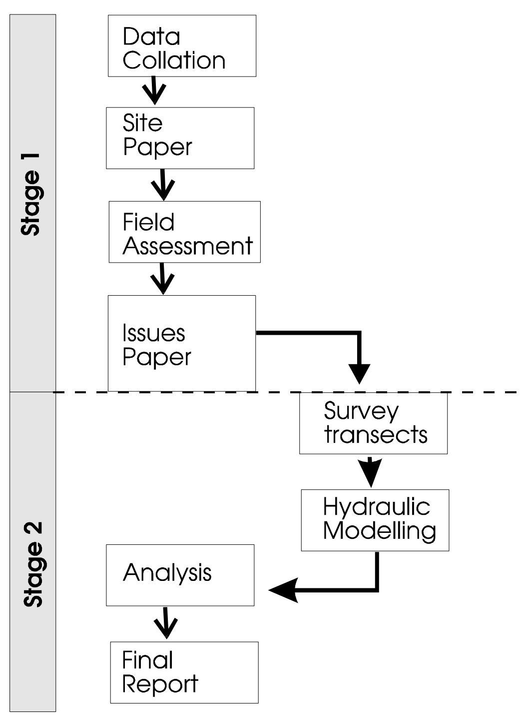

Figure A1.1: Outline of the FLOWS method (from DNRE 2002)

A1-2 STUDY AREA

The project study area includes the Goulburn River and its associated floodplain, downstream from Lake Eildon to the confluence of the River Murray (Figure A1.2). The river receives releases from Lake Eildon and inflows from tributaries such as the Acheron, Yea, and Broken Rivers (the latter including water from Lake Mokoan), and numerous creeks. However, specific environmental flow recommendations will not be required for the tributaries, as they have or will be considered through other processes (e.g. Broken River Bulk Water Entitlement process, current investigations on the future of Lake Mokoan and streamflow management plans). The outputs from these studies will be valuable sources of information as environmental flow recommendations are developed for the Goulburn River.

The environmental flow requirements of the Goulburn River system will be assessed for representative reaches. Specific attention will also be given to the floodplain billabongs, including those between Lake Eildon and Goulburn Weir and on the floodplains of the lower Goulburn. A review of potential representative reaches and surveying of the cross sectional profile of the Goulburn River commenced in August 2002. The following reaches have been identified for the purposes of this study (Appendix 2):

- Lake Eildon to Molesworth
- Molesworth to Seymour
- Seymour to Nagambie
- Nagambie to Loch Garry
- Loch Garry to the River Murray.

The Scientific Panel visited sites along the Goulburn River between the 22-24 January 2003, and twice met with local stakeholders (near Alexandra on the 22nd January and at Murchison on the 23rd January) with good knowledge of the river at different flow conditions (Appendix 6). Panel members also conducted supplementary visits on the 28th February (near Yea) and 16th April (near Seymour, lower Goulburn floodplain). The sites visited by the Panel are listed in Table A1.1.

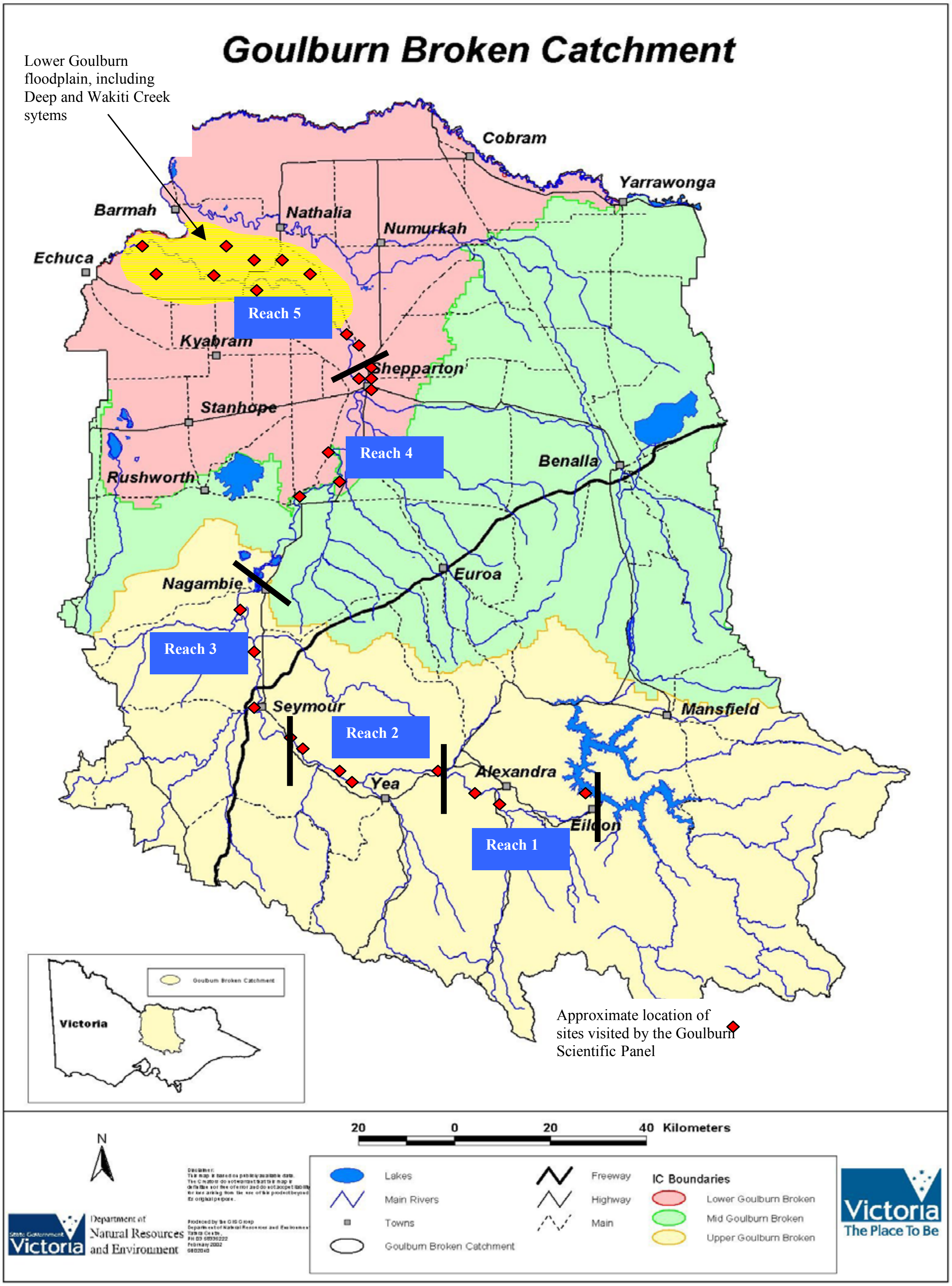

Figure A1.2: Map of the Goulburn catchment (courtesy DSE) including study area and locations visited by the Goulburn Scientific Panel.

Table A1.1: Sites visited by the Goulburn Scientific Panel

Site Number	Reach	Location
January 2003		
1	Lake Eildon to Molesworth	Eildon dam
2	Lake Eildon to Molesworth	Downstream of Alexandra - Binns-McRaes Rd
3	Lake Eildon to Molesworth	Upstream of Alexandra - Breakaway Bridge (Hobans Rd)
		Molesworth Bridge
4	Molesworth to Seymour	Ghin Ghin Bridge
5	Molesworth to Seymour	Downstream of Homewood - Bryants Rd
6	Molesworth to Seymour	Trawool Bridge
7	Molesworth to Seymour	Horseshoe Lagoon
8	Molesworth to Seymour	Murchison
9	Nagambie to Loch Garry	Toolamba Bridge
10	Nagambie to Loch Garry	Jolly’s Bend
11	Nagambie to Loch Garry	Mooroopna – Watts Rd
12	Nagambie to Loch Garry	Gemmills Swamp
13	Nagambie to Loch Garry	Cut off meander near Gemmills Swamp
14	Nagambie to Loch Garry	Reedy Swamp
15	Nagambie to Loch Garry	Hurricane Point and Loch Garry
16	Loch Garry to the River Murray	Pogues Road
17	Loch Garry to the River Murray	McCoys Bridge
18	Loch Garry to the River Murray	Wyuna – Murrumbidgee Road
19	Loch Garry to the River Murray	Downstream of Kanyapella - Stewart’s Bridge
20	Loch Garry to the River Murray	
April 2003		
1	Molesworth to Seymour	Homewood Reserve
2	Seymour to Nagambie	Seymour
3	Seymour to Nagambie	Mitchelton Rd
4	Seymour to Nagambie	Tabilk Lagoon
5	Lower Goulburn floodplain	Deep Creek at Rathbones Rd
6	Lower Goulburn floodplain	Deep Creek at Murray Valley Highway
7	Lower Goulburn floodplain	Deep Creek at Griffiths Lane
8	Lower Goulburn floodplain	Deep Creek at Kotupna-Barmah Rd
9	Lower Goulburn floodplain	Wakiti Lagoon at Old School Rd

A1-3 RIVER REGULATION AND OPERATION

Mean annual streamflow for the Goulburn Basin is approximately 3,040,000 ML, with an average flow of approximately 1,340,000 ML in the Goulburn River below Goulburn Weir and an average flow of approximately 1,977,000 ML below Shepparton (DWR 1989). Streamflow is variable, both annually and seasonally, and is modified by the following processes:

- The presence and operation of Lake Eildon;
- Diversion of water at Goulburn Weir from the Goulburn River to the East Goulburn Main Channel to supply the Goulburn Murray Irrigation District (GMID) and its associated irrigation supply and drainage schemes;
- Diversion of water to Waranga Basin via the Cattanagh and Stuart Murray canals; and
- Changes to floodplain drainage through the construction of levees;
- Operation of regulators on effluent and anabranch channels downstream of Shepparton (in particular Bunbartha Creek at Lock Garry);
- Operation of Lake Nillahcootie;
- Diversions to and releases from Lake Mokoan (an off-stream storage);
- Diversions at Casey's Weir;
- Private diversions throughout the Goulburn River catchment

The flow regime of the Goulburn River is further affected by a range of activities within the catchment, including alterations to vegetation, construction of small dams and drainage schemes. Along the riverine plain, artificial levees, block banks and other structures, obstruct flood flows.

Previous assessments of the impact of regulation on the flow regime of the Goulburn River have been described by Erskine (1996), Gippel and Finlayson (1993) and Nathan (1992). The operation of Lake Eildon, Goulburn Weir and Loch Garry are discussed in the following sections. Changes to river form (geomorphology) and the effect of flood levees are discussed in Chapter 5.

3.1 Lake Eildon

Lake Eildon is located on the Goulburn River in its upper catchment, immediately below the junction with the Delatite River. The original storage (Sugarloaf Reservoir) was constructed between 1915 and 1929 to supply irrigated farmland in the Goulburn-Murray Irrigation District (GMID). It was modified in 1929 and again in 1935 to increase the storage capacity to 377,000 ML (GMW 2003). However, Sugarloaf Reservoir was still limited in its capacity to meet the growing demand for water in the Goulburn Valley, particularly in drought years. The storage was enlarged to its present capacity (3,390,000 ML) between 1951 and 1955 and renamed Lake Eildon. Details on the dam are listed in Table A1.3.

Lake Eildon has the capacity to meet irrigation needs over at least two drought seasons. The storage takes approximately 7 years of average inflow to fill when at low levels, whilst still providing releases to meet downstream demand. While not designed as a flood control storage, Lake Eildon has considerable potential to mitigate floods in the Goulburn River (GMW 2003). During large floods, releases are made on the rising limb of the flood to increase its capacity to store the flood peak thereby extending the duration of the flood but reducing its peak magnitude.

Water is released from storage via 10 portals (2m diameter) at the base of a 72m concrete tower. Water leaves the outlet tower and flows via a 7m outlet tunnel to a hydro-electric power station (currently operated by Southern Hydro Limited). The outlet capacity is approximately 17,500 ML/d at full supply level, although releases are usually maintained at or below 9,500 ML/d to avoid localised flooding downstream of the storage (bankfull discharge in the Goulburn River immediately below Lake Eildon is approximately 11,000 ML/d). When the storage is full, water can also leave via the 300,000 ML/d spillway, which is controlled by 3 vertical lift gates. The storage was last at full supply level in 1996. The last flood occurred in 1993. GMW intends to increase the capacity of the spillway to approximately 500,00 ML/d in the near future to comply with new safety regulations for large dams.

A 5,200 ML pondage below the dam temporarily detains water discharged from the power station. The pondage was built to increase the operational flexibility of the power station at the dam and to re-regulate releases in the Goulburn River. The pondage weir comprises a long low earth embankment with a concrete gravity spillway structure close to the northern end. This contains three 20 m wide and 7.3 m high vertical lift gates through which irrigation water and floods are released. Rules that govern the maximum rate of rise and fall of regulated releases are described in section 3.2.

3.2 Hydro-electric power generation

Works associated with the enlargement of the storage to create Lake Eildon included a hydroelectric power station. The power station is currently operated by Southern Hydro Limited and has two 60 megawatt generators capable of generating a combined 120 megawatts. The power station mainly operates during summer-autumn when irrigation water is released, but there is provision for limited output in winter. Southern Hydro can draw an agreed amount of water (up to 50,000 ML annually) to generate electricity at any time of the year. Water released for hydro-power is usually captured in Waranga Basin.

In 1995 a small hydro-electric station (operated by Pacific Hydro) with 4.5 megawatt output was installed on the Eildon pondage. The low head power station was constructed after excavating a cut through the embankment at the northern end of the gate structure.

Releases for hydro power generation must be managed so that floods are not initiated or aggravated. Eildon pondage is managed so that river rise and fall rates of 0.15 m in any hour or 3,500 ML/d in any 24 hour period are not exceeded, while operating over a range of flows of between 1,500 ML/d and 6,000 ML/d.

Power generation is fully automatic with remote control and monitoring from a master station connected to a unit controller. Additionally, the unit controller is hard wired to a gate controller installed by Goulburn Murray Water (GMW). This relays signals by radio telemetry to a central control centre at the Eildon office of GMW. This controller monitors river flows, gate operations and turbine operation as part of a fully automatic and integrated water management system. In the event of a line outage, a stand-by diesel generator has been installed to operate pondage gates.

3.3 Water management

On average, 1,768,000 ML or 91% of water released from Lake Eildon is diverted for irrigation purposes. Water released from Lake Eildon flows down the Goulburn River to

Goulburn Weir, where over 50% of the annual inflows are diverted for irrigation (Nathan 1992). Outflows from Goulburn Weir are to the lower Goulburn River and to irrigation areas via the East Goulburn Main Channel to the north-east and via the Stuart Murray and Cattanagh Canals to the north-west, which transfer water to Waranga Basin. From Waranga Basin water is transferred further westwards via the Waranga Western Channel. This channel is capable of supplying water as far as Ouyen, some 600 km from Lake Eildon.

The Bulk Entitlement (BE) conversion process provides for a minimum flow of 120 ML/d from Eildon pondage weir between May and September (i.e. as the dam fills) (DCNR 1995). The minimum passing flow can be increased to 250 ML/d in any month when the volume of inflow to Lake Eildon during the previous 24 months exceeds the trigger flows (Vf) listed in Table A1.2. The trigger flows reflect the required inflows to allow a seasonal allocation of 200% of water right. An additional passing flow of up to 80 GL must then be released from Eildon pondage during November in order to replenish effluent lagoons (e.g. wetlands and billabongs) along the Goulburn River between the dam and Lake Nagambie. The 80 GL release is subject to:

- The maximum release from Eildon pondage not exceeding 16,000 ML/d, with maximum rates of rise and fall approved by the relevant Minister;
- Inflow to Lake Eildon for the 24 months ending in October of that year exceeding the flows indicated in Table A1.2;
- Inflow into Lake Eildon for the 12 months ending in October of that year exceeding 800 GL;
- The maximum release being reduced where tributary flows downstream of Eildon pondage contribute to the filling of wetlands;
- The sum of Eildon spill and releases under the target filling arrangements during September and October of that year not exceeding 100 GL; and
- The relevant government department confirming the requirement for the release in that year.

However, these conditions have yet to be met and the 80 GL provision has never been called on.

Table A1.2: 24-month trigger flows into Lake Eildon (DCNR 1995)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vf (GL)	2785	2786	2782	2785	2782	2796	2802	2801	2779	2780	2776	2788

The BE process also included provision for the release of 30 GL to address downstream water quality issues, for example to ameliorate the impact of nuisance algal blooms should they occur in the lower reaches of the Goulburn River. This provision has not yet been called on.

Goulburn Weir

Goulburn Weir was constructed on the Goulburn River near Nagambie between 1887 and 1891 (GMW 2003). It was the first major diversion structure built for irrigation development in Australia. The weir raises the level of the Goulburn River so that water can be diverted by gravity along the Stuart Murray Canal, Cattanagh Canal and East Goulburn Main Channel. Construction of the weir also resulted in the formation of Lake Nagambie.

The weir required upgrading after more than 90 years of continuous service, and stabilisation and rehabilitation works were carried out between 1983 and 1987. The new design (Table

A1.4) includes nine fabricated steel radial gates between new concrete piers which will rotate clear of the 100 year flood (170,000 ML/d) when fully raised. The piers are anchored to the weir and support the gates and operating deck. Goulburn Weir is operated remotely via a SCADA system, and all discharges are released through the three major channel outlets, or through the weir into the Goulburn River.

According to the Goulburn BE, GMW is permitted to divert all inflows to Goulburn Weir up to a limit of 9,890 ML/d (DCNR 1995). This includes maximum flows of 3,600 ML/d for the Stuart Murray Canal, 3,690 ML/d for Cattanagh Canal and 2,600 ML/d for the East Goulburn Main Channel. A minimum average weekly flow of 250 ML/d (daily rate no less than 200 ML/d) is released as a passing flow from the weir to the Goulburn River to meet the needs of downstream diverters and protect the condition of the river (DCNR 1995). A passing flow is also to be delivered at McCoys Bridge and must exceed a monthly average of 350 ML/d (daily minimum of 300 ML/d) from November to June, and exceed 400 ML/d (daily minimum of 350 ML/d) from July to October.

The impact of Lake Eildon and Goulburn Weir on the hydrology of the Goulburn River is discussed in more detail in the following section.

Table A1.3: Lake Eildon storage – facts and figures (from GMW 2003)

Embankment	
Height	79 m
Length	983 m
Spillway	
Height	46 m
Length	197 m
Gates x 3	20 m long x 6 m high
Outlet	
Tower height	72 m
Outlet tunnel diameter	7 m
Outlet tunnel length	392 m
Lake	
Volume in Lake at Full Supply Level	3,390,000 ML
Surface area at FSL	13,840 ha
Length of shoreline at FSL	483 km
Maximum depth	76 m
Catchment	3,900 sq km

Table A1.4: Goulburn Weir – facts and figures (from GMW 2003)

Location	Goulburn River
Nearest town	Nagambie
Embankment height	15 m
Weir length	127 m
Flood gates	radial x 9
	overshot x 2
Structure length	212 m
Construction materials	concrete & masonry
Catchment area	10,205 sq km
Volume in Lake at Full Supply Level	25,000 ML
Area at Full Supply Level	1,130 ha

3.4 Flood mitigation

Flooding is a natural feature of the Goulburn River system. Floods throughout the study area are controlled by numerous levees, along with the storage and release of floodwaters through the Loch Garry system and control structures on floodplain drainage channels. Levees exist throughout the study area but are more common along the lower Goulburn River. There are relatively few levees in the upper reaches of the Goulburn; those present are mainly associated with infrastructure and larger towns such as Seymour (SR&WSC 1984).

Loch Garry is a natural depression located approximately 16 km downstream from Shepparton and is a remnant of the ancestral form of the Goulburn River (see Section 5.1). Loch Garry receives floodwaters from the Goulburn River, which spill north into Bunbartha Creek when water levels exceed 10.36 m at the Shepparton gauge. Floodwaters released from Loch Garry to Bunbartha Creek are controlled by a series of gates set in a 10 km embankment that is 2-3 m high (SKM and Kinhill 1982a and b). Under natural conditions, winter-spring flood flows along the lower Goulburn River would have regularly over-topped the river channel and spread over the adjacent floodplain. The river channel downstream from Shepparton now contains 2-year flood events (approximately 41,000 ML/d). At this level, there is some overbank flow and the Wakiti Creek outlet is close to overflowing. There are also minor outflows to the Deep Creek distributary system, which flows into the Murray River upstream of the Bama sand hills. Extensive overbank flooding within the levied river floodway occurs with flows greater than the current 2-year event. Outflows to distributary systems (particularly releases from Loch Garry to Bunbartha Creek, outflows to the Deep Creek and Wakiti Creek systems, and outflow from Coomboona towards Wells Creek) become increasingly important at higher flows.

There are a number of distributary channels that break out through the natural levees downstream of Loch Garry, predominantly to the north of Goulburn River channel into the Deep Creek system (HydroTechnology, 1995). This network of distributary channels is bounded to the south by the Goulburn River’s natural levees and to the north by natural levees along Broken Creek (an ancestral channel of the Goulburn River).

Since European settlement of the region, there has been considerable effort to construct and maintain flood control works along the northern levees of this portion of the Goulburn River (HydroTechnology, 1995). The natural levees have been augmented by artificial levees to increase the capacity of the floodplain along the main Goulburn River channel and reduce the frequency of flooding into the Deep Creek system. A number of flood outlet structures (or regulators) are also incorporated into the levees to reduce the risk of levees being over-topped and damaged. Constructed in 1925, the regulator at Loch Garry on the Bunbartha Creek outlet is the most important structure and has been operated since this time to allow floods to be diverted into the Deep Creek system prior to breaching of the levees downstream of Loch Garry. Minor outlet structures were also constructed downstream from Loch Garry at Deep Creek, Wakiti Creek and Hancocks Creek outlets. The construction of levees and operation of regulators has caused the main channel of the Goulburn River, downstream of Loch Garry, to carry an increased portion of flood flows and reduced the frequency of flows through the Deep Creek system.

A1-4 HYDROLOGICAL IMPACTS OF STORAGE AND DIVERSION

Aspects of the downstream river system that can be affected by dams include (Finlayson *et al.* 1994):

- Volume of flow;
- Seasonal regime of the river;
- Daily pattern of flow;
- Extremes of flow (floods and low flows);
- Water quality, including temperature, dissolved oxygen, turbidity, pH, conductivity and colour;
- Sediment transport;
- Fish passage;
- Invertebrate drift.

Erskine (1996) used a scheme devised by Petts (1980) to describe three orders of downstream impact associated with the presence of large dams:

- First order impacts are changes to streamflow, water quality and sediment load downstream from the dam;
- Second order impacts are changes to channel form as a result of first order impacts; and
- Third order impacts include the feedback effects between changes to channel morphology and its impact on ecological processes.

Erskine (1996) concluded that Lake Eildon and its operation has:

- Caused a reversal of the season pattern of flow (e.g. maximum flow in summer and autumn, minimum flows in winter and spring);
- Altered flow duration by truncating the high flows (maximum flow reduced), increasing medium sized flows and decreasing low flows;
- Decreased the return frequency of flood events
- Decreased the flood magnitudes for a given return frequency; and
- Decreased downstream sediment loads.

A more detailed description of the hydrological impacts of Lake Eildon and the diversion of water for irrigation and consumptive use is presented below and in Appendix 3. The second and third order impacts that ensue from these changes are discussed in Chapter 5.

The 'seasonal flow inversion' that results from regulated releases from Lake Eildon is most pronounced immediately downstream of the dam (reach 1). The monthly flow pattern measured at Alexandra (Figure A1.3a) has shifted, with the highest monthly flows now occurring in February-March rather than August-September. The impact of Lake Eildon on flood frequency is pronounced at Alexandra (Figure A1.3c). For example, a flow event that has a 10-year average recurrence interval (ARI) under the current flow regime had a 1-year ARI under the natural flow regime. Floodwaters captured by the dam are then released as higher than natural mid and low-flows over the summer- autumn (Figure A1.3b).

The pattern of monthly flow downstream at Murchison in Reach 4 (Figure A1.4a and b) is similar to that of the natural flow regime but has been greatly dampened due to the diversion of water at Goulburn Weir. A flow event with a 10-year ARI under the current flow regime is equivalent to an event with a 2-year ARI under the natural flow regime (Figure A1.4c).

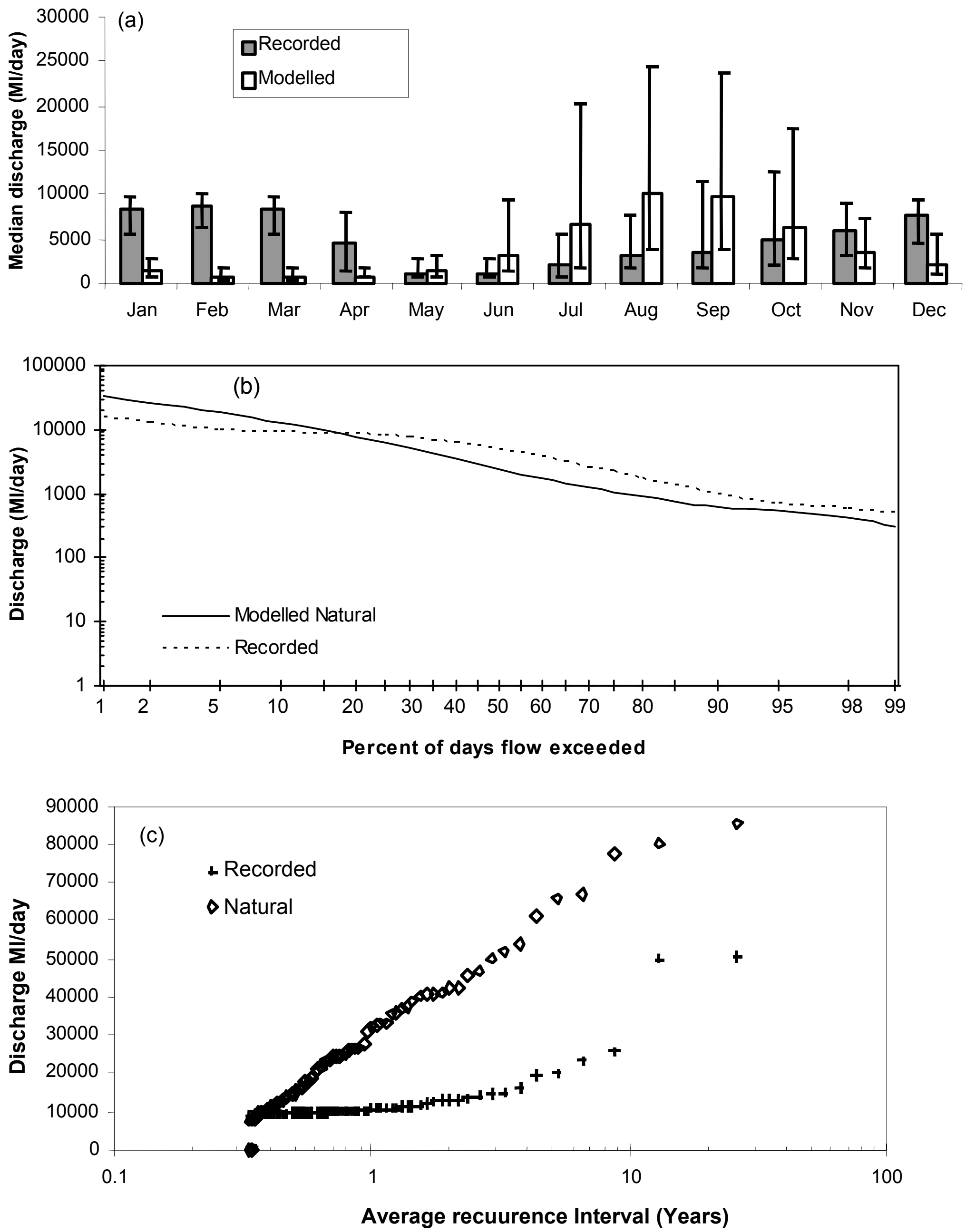

Figure A1.3: Impact of regulation on Goulburn River flows at Alexandra, (a) monthly flows (b) flow duration, and (c) annual recurrence intervals. Note that modelled flows represent current land use patterns but with storages and diversions removed.

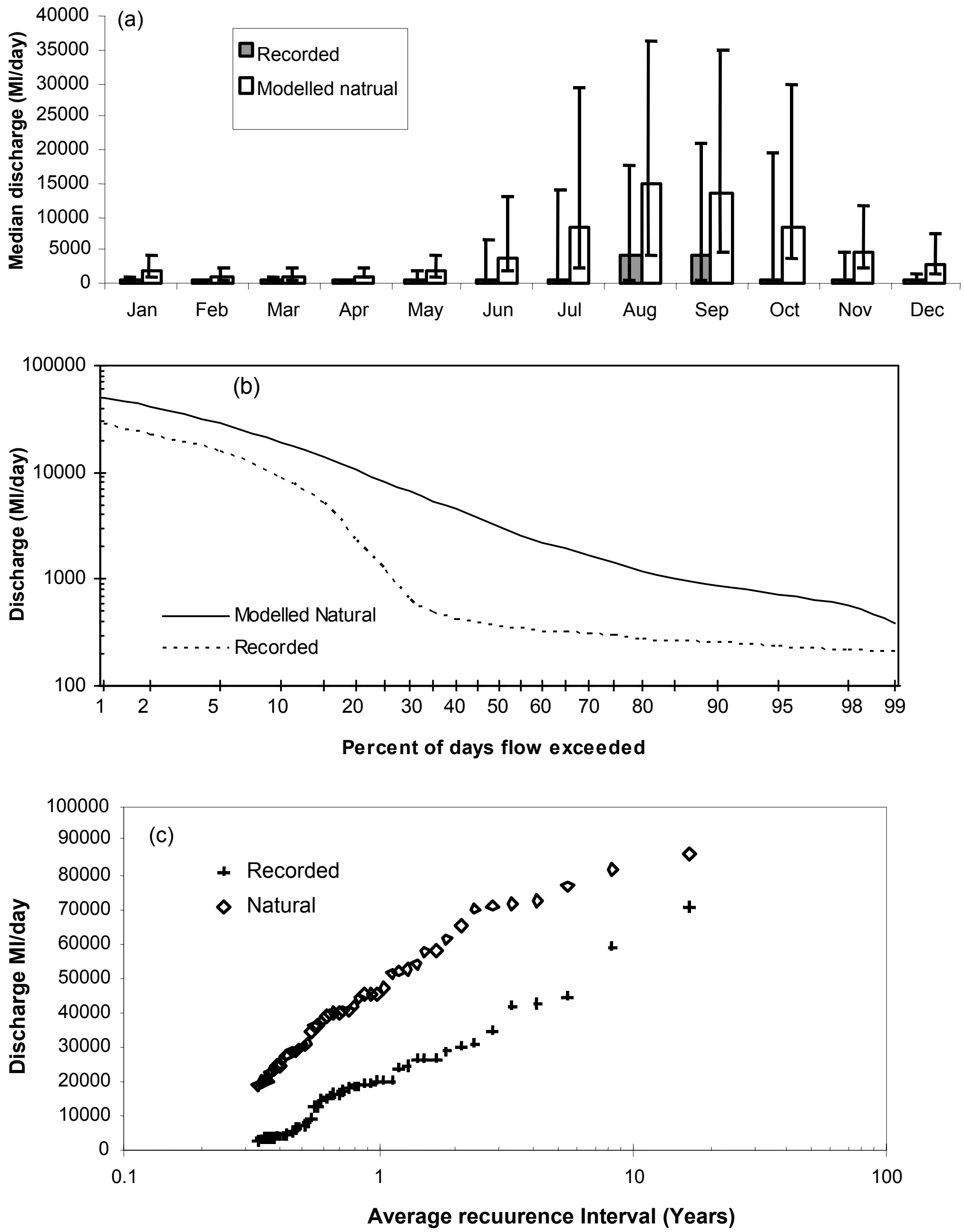

Figure A1.4 Impact of regulation on Goulburn River flows at Murchison, (a) monthly flows (b) flow duration, and (c) annual recurrence intervals. Note that modelled flows represent current land use patterns but with storages and diversions removed.

Preliminary estimates of the threshold flow for out of channel flows at Eildon and Murchison are available from anecdotal information and the Flood Warning Service (Table A1.5). Anecdotal reports suggest that out of channel flows commence at around 11,000 ML/day downstream of Lake Eildon and 24,000 ML/day at Murchison (equivalent to 30 feet at the Shepparton Gauge). The flood warning levels are higher than these discharges. The recurrence interval of flows above these thresholds downstream of Eildon and at Murchison are increased (i.e. the floods have become less frequent) as a result of regulation. Of particular note is the moderate flood level downstream of Eildon that would naturally occur every year is now occurring only one in six years. As well as a reduction in the frequency of flooding, the average duration of flood events above these thresholds have decreased. Anecdotal reports suggest that billabongs along the Goulburn River downstream of Murchison begin filling at 24,000 ML/day. The frequency of flows above this threshold has only decreased slightly as a result of regulation but the mean duration of these events is substantially reduced from twenty days to six days.

Table A1.5: Frequency and recurrence interval of flooding in Goulburn River downstream of Lake Eildon and at Murchison

		Recurrence Interval (years)		Average duration (days)	
	Discharge (ML/day)	*Natural*	*Recorded*	*Natural*	*Recorded*
Alexandra					
Anecdotal onset of out of channel flow	11000	0.7	1.6	34	19
Minor	14700	0.7	2.8	22	14
Moderate	26300	0.9	6.2	7	6
Murchison					
Anecdotal onset of out of channel flow (30' at Shepparton gauge)	24000	1.2	1.7	20	6
Minor	32700	1.2	3.6	10	6
Moderate	58700	3.6	8.3	4	3

4.1 Previous environmental flow recommendations

The need to provide environmental flows for the Goulburn River was first considered in the early 1990's. The Department of Conservation and Natural resources and the Rural Water Corporation undertook a 'Preliminary assessment of the environmental water requirements of the Goulburn River basin (Lake Eildon to Murray River)', presented as two draft reports (DCNR and RWC 1993, Lloyd and Hunter 1993).

The draft report prepared by DCNR and RWC (1993) considered the environmental, landscape, recreational and cultural values associated with the Goulburn River and how they had been affected by the presence of Lake Eildon and Goulburn Weir and the delivery or diversion of water for irrigation and consumptive use.

Lloyd and Hunter (1993) developed preliminary environmental flow recommendations aimed at maintaining or enhancing environmental values. The draft report only examined options thought viable by a Steering Committee for the project and acknowledged that the recommendations only provided a partial solution to issues associated with river regulation. The draft report considered the following tasks and options related the flow regime:

- Fill and drawn down rates of Lake Eildon and Eildon pondage to minimise large variations in water level fluctuations.
- Provision of a minor flood over 14 days (peak of 16,000 ML/d and total release from Lake Eildon of 80 GL) to provide a stimulus to aquatic plants and animals, ensure the integrity of the river channel dimensions, and create variability in aquatic habitat.

- Non- mitigation of minor flood peaks.
- Increased minimum flows released from Lake Eildon (from 120 ML/d to 250 ML/d measured at Thornton) to extend riffle habitat and reduce the ‘flashiness’ of the hydrograph. A minimum flow of 250 ML/d would also compensate for reduced flows between the fish farm diversion and release points.
- Variation in step releases in spring to minimise water level variations.
- Develop ecologically based operating procedures for Lake Nagambie and develop a proposal for longer-term study and trials
- Investigate the provision of fish passage past Goulburn Weir and associated benefits and costs
- Increase minimum flows below Goulburn Weir from 250 ML/d to 500 ML/d (in years when water right exceeds 130%) to increase the habitat available for fish and aquatic macroinvertebrates.
- Provide spring flushes below Goulburn Weir of 1000-2000 ML/d for 6-8 weeks in late spring (for years with water right in excess of 130%) to promote movement of juvenile fish.
- Determine rates of rise and fall in river height in the Goulburn River below Lake Nagambie
- Quantify downstream impacts associated with changes to Broken River flows.

The draft report indicated that the non-mitigation of flood peaks was not modelled and analysed, as this option was considered too costly to the water authority and landholders. Also, the potential to vary step releases in spring was not investigated. The reasons for this are not clear. It was not clear how the minimum flows of 250 ML/d and 500 ML/d for the upper and lower Goulburn River, respectively, were derived. Nor was it clear how the recommendation for 1000-2000 ML/d pulses was derived.

While the draft report was not finalised, it is interesting to note that a number of recommendations were acknowledged when the Bulk Entitlements for the Goulburn system were set. For example, the BE allows for a minimum flow release from Lake Eildon of 250 ML/d and a pulse of 80 GL recommended by Lloyd and Hunter (1993) for the inundation of wetlands between Lake Eildon and Seymour, subject to conditions outlined in section 3.3.

A1-5 ENVIRONMENTAL AND ECOLOGICAL FEATURES

Initiatives such as the Victorian River Health Strategy (DNRE 2002b), the Goulburn Broken Regional Catchment Strategy (O'Neill and McLennan 2002) and the draft management plans for the Heritage Rivers and Natural Catchments Areas (DNRE 1997) include important vision statements and objectives for the management of our waterways. These strategies have included a considerable amount of community input and consultation during their development. It may be expected that the Goulburn Broken Regional Strategy, in particular, would represent community aspirations for the condition of waterways in the region.

The environmental goal of the Goulburn Broken Regional Strategy is 'to protect and enhance natural assets and their supporting infrastructure in a way that provides benefits for: (i) native biodiversity and (ii) social and economic aspects.

The Victorian River Health Strategy supports the vision that our rivers will be ecologically healthy, managed within healthy catchments:

- Supporting a diverse array of indigenous plants and animals within their waters and across their floodplains;
- Flanked by a mostly continuous and broad band of native riparian vegetation;
- With flows that rise and fall with the seasons, inundating floodplains, filling billabongs and providing a flush of growth and return of essential nutrients back to the river;
- With water quality that sustains crucial ecological functions;
- With native fish and other species moving freely along the river and out to the floodplains and billabongs to feed and breed during inundation;
- Replenishing productive estuaries or terminal lakes.

Together, the aspirations of these two strategies provide guiding principles for the Goulburn Scientific Panel in terms of assessing river condition and making recommendations to improve river health within a water management context. These principles may also serve as broad rehabilitation objectives that serve as the basis of environmental flow recommendations. For example the Murray Scientific Panel (Thoms *et al*. 2000), used such principles to develop broad rehabilitation for the Murray River:

- To maintain or enhance the natural diversity of habitats and biota within the river channel, riparian zone and floodplain;
- To maintain or enhance the natural linkages between the river and the floodplain;
- To maintain the natural metabolic functioning of aquatic ecosystems in the study area.

The Goulburn Scientific Panel has developed the following vision for the Goulburn River as it develops environmental flow recommendations: 'a *healthy working river that supports a diversity of natural ecosystems and processes, thereby sustaining the community of the Goulburn-Broken catchment'*.

Some of the major problems being addressed by the Goulburn Broken Regional Catchment Strategy are listed in Table A1.6. Many of these threats have been known for a number of years and the region has in place a range of programs and strategies to address them.

The potential impacts most relevant to this study relate to a loss of connectivity between the river channel and its floodplain, a loss or simplification of riparian vegetation, decline in aquatic and terrestrial habitat, and a decline of water quality (e.g. lower than natural water temperature below Lake Eildon). In combination, these impacts pose a threat to or have resulted in a decline in the range or occurrence of flora and fauna, including threatened species, across the study area. These issues will be discussed in more detail in the following sections on the key environmental and ecological features of the Goulburn River below Lake Eildon.

Table A1.6: Major activities affecting riparian and instream conditions in the Goulburn Broken catchment (adapted from O'Neill and McLennan 2002).

Activities	Some key impacts	Existing programs to manage impacts
Management of riparian land		
Grazing banks and billabongs	• Changed vegetation structure and species composition, especially understorey • Reduced regeneration • Weed invasion • Bank instability hence erosion and sediment deposition in waterways	• Licensed grazing • Waterways management and implementation plan (private land)
Clearing banks	• Complete loss of vegetation structure & diversity, so loss of plant & animal species • Weed invasion • Reduced/no input of organic matter and snags to rivers • Reduced quality of bank habitat for aquatic animals	• Native vegetation retention controls
Promotion of exotics	• Doubtful to negligible habitat quality • Willows: changed channel morphology and hence habitat • Changed input of energy and snags • Decline in suitability of riparian habitat	• Extension programs
Levees and floodplain development	• Reduction or loss of linkages • Decline in quality and area of floodplain habitat, reduction in quality of riverine environment • Changed river and floodplain morphology	• Floodplain strategy implementation
Recreation: camping	• Loss of understorey, especially ground layer and wood debris, so impact on plants • and also animals (lizards, invertebrates, insectivorous birds) • Reduced snag input to rivers	• Recreation strategy • Parks and Forest Ranger service
Catchment Management		
Catchment clearing	• Changed stream flows: peakier, less base flow; more instream erosion & • sedimentation • Increased catchment erosion hence sedimentation of streambed, smothering biota • Poor quality runoff (including turbidity) causes deterioration in instream habitat • Increased salinity levels • Loss of wetland habitat	• Native vegetation retention controls

Activities	Some key impacts	Existing programs to manage impacts
Poor land management	• Increased input of contaminants such as sediment, salt or nutrients, depending on the land use • Rabbit infestation can damage riparian vegetation, increased erosion and hence increase sediment input • Loss of wetland habitat	• Salinity program • Water quality program • Rabbit action plan
Disposal of poor quality effluent	• Reduced habitat quality from poor water quality • Changed species composition • Algal blooms	• Water quality program
Management in the river channel		
Snag removal	• Loss of habitat and food source • Changed channel shape	• Waterways management and implementation plan
Culverts and regulators	• Disrupted longitudinal and lateral linkages, reduced fish movement • Reduced access to habitat	• Waterways management and implementation plan
On stream storages	• Disrupted and degraded longitudinal linkages, reduced fish movement, sediment and organic matter transport, recolonisation • Changed flow patterns change occurrence of ecological triggers	• Bulk Water entitlement process
Low level releases on storages	• Disrupted of life cycles from reduced temperature – reduction/prevention of • breeding, hatching, growth, germination • Reduced primary productivity	• Flow management
Recreation: boating	• Removal of "unsafe" snags • Bank erosion, sedimentation	• Various
Weed removal	• Loss of plant species, loss of animal habitat • Release of sediment	• Various

5.1 Geomorphology

The Goulburn River is an anabranching system that is reasonably typical of many streams of the Riverine Plains of the Murray Basin. The critical factors in the response of the river to regulation, and in planning environmental flows, are the bed and bank material, and the width of the floodplain.

Below Lake Eildon, the Goulburn River has two distinct zones (Erskine *et al*. 1993): (i) Lake Eildon to Murchison and (ii) between Murchison and the Murray River. Between Lake Eildon and Murchison, the river is confined by resistant bedrock and valley walls (Figure A1.5) and the bed material of the Goulburn changes progressively from gravel to sand to clay, changing from gravel to sand between Seymour and Nagambie. Most of floodplain (approximately 2–4 km wide) has ridge and swale features, billabongs and wetlands.

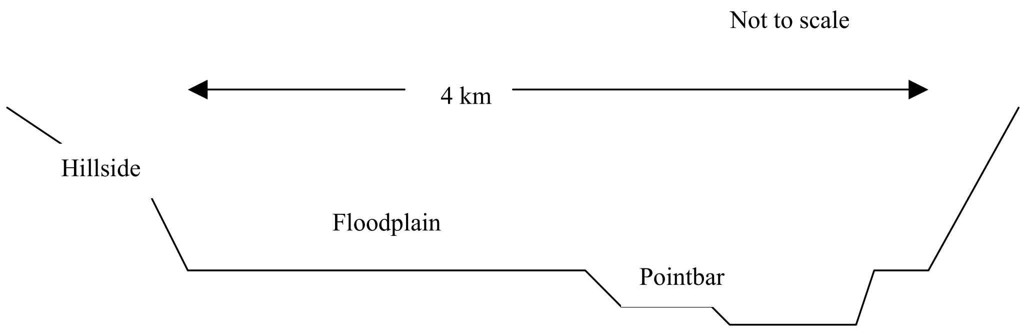

Figure A1.5: Schematic of a typical cross-section of the Goulburn River between Lake Eildon and Murchison

Below Murchison, the river enters the low gradient of the Riverine Plains and cuts into the resistant alluvial sediments of the Shepparton Formation, rather than bedrock. It has long been clear that the unusual variation in the width of the Goulburn's floodplain influences the distribution of floodwaters in the valley. Bowler (1978) described the general pattern of channel history. In simple terms, the Goulburn River below Murchison is incised into the gently undulating clay and sands of the Shepparton Formation. This is typically a mottled orange/red to white sandy clay, to grey plastic clay, overlying cemented sands. The size and bedload of the river has changed over the last 40,000 years, as climate has changed. At the same time, the course of the river has changed due to channel avulsion. The width and character of the floodplain is then explained by when an avulsion took place. It is possible to identify three distinct river reaches:

1. *Nagambie to Loch Garry*. A much larger stream than the present Goulburn cut a broad trench. An example of the large, sandy meanders of this 'Ancestral channel' is preserved at Loch Garry (Figure A1.6). About 10,000 years ago the climate changed, and the river became smaller, and the bedload changed from sand to mud and clays. The river became a smaller, more sinuous channel within the larger Ancestral channel.

Figure A1.6: Preserved meander of the 'Ancestral Channel' of the Goulburn River at Loch Garry

2. *Loch Garry to Wakiti Creek*: The Goulburn River avulsed (changed course) to the south, leaving the large Ancestral channel preserved as Broken Creek. The floodplain in this reach is narrower than upstream (Figure A1.7), presumably because it is younger and has had less time to cut a larger trench. The modern river still fits within the bends of the Ancestral channel.

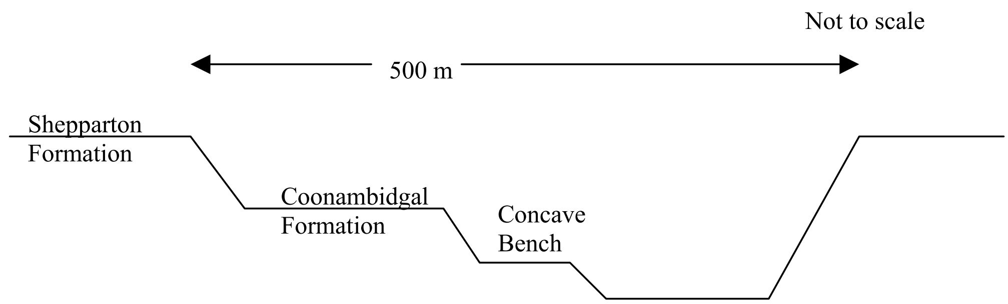

Figure A1.7: Schematic of a typical cross-section of the Goulburn River between Loch Garry and Wakiti Creek

3. *Wakiti Creek to the Murray Junction*. Over the last 5–10,000 years, the Goulburn River has again avulsed to the south, leaving what is now Wakiti Creek. This is the narrowest section of the Goulburn's floodplain (Figure A1.8), being only as wide as the meander belt. This is the case simply because the river has had less time to cut its trench by meandering.

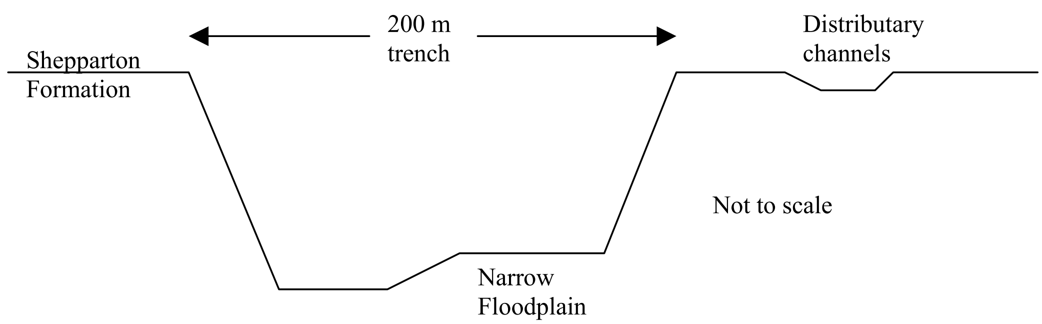

Figure A1.8: Schematic of a typical cross-section of the Goulburn River between Wakiti Creek and the Murray River

The capacity of the floodplain to carry floods decreases downstream of Loch Garry, as it occupies progressively younger and narrower trenches. Another contributing factor is that the modern floodplain (known as the Coonambidgal sediments) converges with the surface of the Shepparton Formation downstream. The result is an increase in the number and size of flood distributary channels downstream, particularly via the Deep Creek system. The Deep Creek system occupies the low point of the Shepparton Formation surface between the alluvial ridge of the present Goulburn, and the alluvial ridge of former channel, now Broken Creek. The most likely course for the next avulsion of the Goulburn River is along the path of You You

Creek, that is cutting headwards toward the Goulburn from the Murray, parallel with the Bama sand hills near the Yambuna Choke.

5.1.1 Pre-Eildon river processes in the Goulburn River

Between Eildon and Nagambie, the pre-regulation Goulburn River was a laterally-migrating channel with classical meandering features including: a gravel bed, sand-gravel point bars, ridge and swales sequences behind the point bars, and numerous cut-off bends and billabongs. These form some 400 wetlands along this section of river. Below Nagambie, the river narrows and deepens. Meander bends are often cutting into the resistant Shepparton formation, producing high outside banks. Point bars disappear as the bedload declines; at most there will be a small sand deposit at the point of the bend. The bends migrate by depositing a drape of fine sediment on the face of the bank during floods. Another type of deposit that begins to appear is concave benches. These are low benches formed on the upstream side of the outer bend, when the bend is eroding down-valley. There is less lateral migration in these reaches because of the resistant banks, but the active floodplain is still characterised by undulating ridges and swales.

The decreasing floodplain width with distance downstream has led to an increase in distributary channels flowing away from the main river. These channels become common on the lower floodplains, forming sinuous channels leaving the river, or long channels cutting across meander necks.

Above Nagambie, in the absence of flow regulation, we would expect to see slow meander migration (certainly less than 0.1m per year on average) and bends would ultimately cut off, creating billabongs. Mid-channel bars would be armoured, but bed sediments would move every few years. Below Nagambie, processes would be slow, with little observable change over years.

5.1.2 Impacts of water management

Erskine (1996) and Erskine *et al*. (1993) have described channel changes associated with Eildon dam. In summary, the dam has led to less bed material transport. Below Nagambie, constant low flows have led to cutting of a low-flow channel and steepening of the bank toe.

Lake Eildon traps approximately 99% of the sediment load carried by upstream tributaries (Erskine 1996). However, even before the dam reduced the sediment load, the modern Goulburn River carried a small and fine sediment load (Erskine *et al*. 1993, Erskine *et al*. 1996). Despite the large reduction in sediment load, there has been little bed degradation between Lake Eildon and Nagambie because regulated flows and dams spills generally do not have the 'competence' to move deposited sediments (Erskine 1996), and tributary inflows are an ongoing source of sediment. The bed of the river has become armoured by the concentration and sorting (imbrication) of coarse gravels that form a protective layer over finer sediments (Erskine *et al*. 1993). This armouring was evident when the Scientific Panel visited sites along the river in January 2003. The hyporheos (zone with subsurface flow through bed sediments) is almost certainly infilled with sediment due to protection by the armoured gravels.

There is also some evidence that the river channel in the upper Goulburn River has contracted since the construction of Lake Eildon. The Scientific Panel noted that low benches and bars of sand, gravel and mud, are discontinuous along the banks, and often vegetated by relatively young trees. Bank erosion rates are low due a combination of flood suppression and bank protection works.

Below Nagambie, the main flow change has been a large increase in the duration of low flows (300 – 500 ML/d), and possibly an increase in flood frequency downstream of Shepparton as distributary channels have been blocked, and the floodplain has been constrained by levees. As a result of the increased low flow duration, the river appears to have cut a narrower channel, evidenced by steep, actively eroding bank toes, and a low bench formed at the channel edge. This bench is often cut into the Shepparton Formation sediments, and is not depositional. The bench would be covered by flows between 1 – 2,000 ML/d. It is possible that the steepening of the bank toe is leading to slump failures in the banks. Local people suggest that bank slumping has become more common because of seepage from high local groundwater levels. This could certainly be a factor. The rate of recession of higher flows below Nagambie could also be a factor in slumping, and should be compared with natural rates.

In summary, no environmental flow recommendations are proposed to address geomorphic issues, such as armouring of the river channel immediately below Lake Eildon. The disruption of the armour layer is not something that should be undertaken routinely, as this will increase mean particle size and so require successively larger flows to disrupt the armour layer and move underlying fine sediment. Work by Erskine (1996) indicated that irrigation releases up to 10,000 ML/d are not competent to move sediments of the average particle size found in the river in Reach 1. Fine sediments deposited on the armour layer most likely can be moved, for example by 'out of channel' flows delivered to inundate wetlands.

5.2 Vegetation Associated with the Goulburn River

5.2.1 Vegetation Patterns

In terms of species occurrences, community composition, relative abundance of species and of communities and their characteristics such as structural diversity, the study area between Lake Eildon and the Murray River could be adequately described using just 3 longitudinal zones:

- Confined floodplain in the upper reaches (reaches 1 and 2);
- A relatively short, tightly confined zone ('gorge') leading into reach 3; and
- Unconfined floodplain area in the lower reaches (reaches 4 and 5).

The upper reaches of the study area fall within the Central Victorian Uplands bioregion while the lower reaches fall within the Victorian Riverina bioregion (Berwick 2001). However, the broad patterns of vegetation that might once have occurred across these regions have now been obscured by land management practices. The large-scale clearance of land, predominantly for agriculture, now means that the riparian zone along the Goulburn River is an important remnant of previous native vegetation. The floodplain riparian woodland that exists along the upper Goulburn reaches are dominated by an overstorey of River Red Gum *(Eucalyptus camaldulensis*), with a tall understorey of Silver Wattle (*Acacia dealbata*), Blackwood (*Acacia melanoxylon*) and River Bottlebrush (*Callistemon sieberi*) amongst others over sedges and flood-tolerant grasses. Vegetation along much of the lower Goulburn River is made up from riverine grassy woodland and riverine sedgy forest. Riverine grassy forest has an overstorey of River Red Gum and an understorey of tussock (e.g. *Poa labillardieri*) and wallaby grasses. Riverine sedgy forest has a River Red Gum and Silver

Wattle overstorey and an understorey that includes sedges and aquatic and semi-aquatic plants.

Previous reviews (Howell and McLennan, 2002, Lyon and Clunie 2002) have identified 188 species of native vascular plants variously dependent upon aquatic environments within the Goulburn-Broken Catchment, of which 39 species (21%) are considered threatened (Table A.7). This includes 7 species listed as threatened under the *Flora and Fauna Guarantee Act* 1988. Eight species (including four listed under the FFG) are also listed federally as threatened under the *Environment Protection and Biodiversity Conservation Act* 1999.

According to this classification, common aquatic plants include *Vallisneria, Azolla*, *Lemna*, *Triglochi*n and *Typh*a, none of which are threatened. Species such as giant rush (*Juncus ingen*s), the rare *Rorippa eustylis* and endangered *Panicum queenslandicum* are restricted to riparian wetlands, whereas *Carex chlorantha*a, *Cyperus bifa*x, *C. victoriensi*s, *Eulalia aurea* (all threatened) and *Cyperus difformi*s, *C. pygmaeu*s, *Myriophyllum papillosum* and *Schoenoplectus tabernaemontani.* occur in broader riparian habitats. Thirty-two species are found only in wetlands. Representative genera include *Eleochari*s, *Marsilea* and *Ranunculu*s. Twenty percent of amphibious species are threatened (Howell and McLennan 2002).

Of the threatened species only found in the riparian zone, half are trees and shrubs including *Callistemon sieberi, Leptospermum* spp., *Acacia pendula* (endangered), *Lomatia myricoides* and *Rapanea howittian*a. Three threatened species each had their own unique classification: *Melaleuca halmaturorum* ssp. *halmaturorum* (vulnerable) was restricted to lacustrine (lake) environments; *Hydrilla verticillata* (rare) was considered a riparian obligate aquatic, and *Brasenia schreberi* (nationally rare and endangered in Victoria) was designated as a riparian wetland obligate aquatic.

Caution is needed in relation to threatened plant species, as occurrence on a floodplain and wetlands is not a perfect indicator of flow dependency or adaptation to aquatic conditions. For example, probably only ten of the 62 Victorian Rare or Thretened (VROT) species listed for the Lindsay-Wallpolla floodplains have life-cycles linked to flow regime and possibly influenced by river regulation (SKM and Roberts 2003).

Table A1.7: List of threatened flora species (adapted from Lyon and Clunie 2002)

Habitat	Scientific name	Common name
OLAC	***Melaleuca halmaturorum ssp. halmaturorum (v)***	**Salt Paperbark**
ROA	***Hydrilla verticillata r***	**Hydrilla**
RWOA	***Brasenia schreberi R e***	**Water-shield**
RO	***Acacia pendula (e)***	**Weeping Myall**
RO	***Brachyscome muelleroides (V e)***	**Mueller Daisy**
RO	***Eucalyptus crenulata E e***	**Buxton Gum**
RO	***Euphrasia scabra (K e)***	**Rough Eyebright**
RO	***Juncus psammophilus r***	**Sand Rush**
RWAMPH	***Rorippa eustylis r***	**Dwarf Bitter-cress**
RWAMPH	***Panicum queenslandicum var. queenslandicum e***	**Coolibah Grass**
RAMPH	***Carex chlorantha (k)***	**Green-top Sedge**
RAMPH	***Cyperus bifax (v)***	**Downs Flat-sedge**
RAMPH	***Cyperus victoriensis (k)***	**Flat-sedge**
RAMPH	***Eulalia aurea r***	**Silky Browntop**
AMPH	***Amphibromus pithogastrus K e***	**Plump Swamp Wallaby-grass**
AMPH	***Baumea planifolia (k)***	**Rough Twig-sedge**
AMPH	***Callitriche cyclocarpa (Vv)***	**Western Water-starwort**
AMPH	***Callitriche sonderi (k)***	**Matted Water-starwort**
AMPH	***Callitriche umbonata (v)***	**Winged Water-starwort**
AMPH	***Cardamine moirensis (v)***	**Riverina Bitter-cress**
AMPH	***Craspedia paludicola (v)***	**Swamp Billy-buttons**
AMPH	***Eleocharis macbarronii (k)***	**Grey Spike-sedge**
AMPH	***Eleocharis plana (v)***	**Flat Spike-sedge**
AMPH	***Eragrostis australasica v***	**Cane Grass**
AMPH	***Eryngium paludosum (v)***	**Long Eryngium**
AMPH	***Gratiola pumilo K r***	**Dwarf Brooklime**
AMPH	***Hypsela tridens (k)***	**Hypsela**
AMPH	***Myriophyllum gracile var. lineare (e)***	**Slender Water-milfoil**
AMPH	***Myriophyllum porcatum (Vv)***	**Ridged Water-milfoil**
AMPH	***Myriophyllum striatum (v)***	**Striped Water-milfoil**
AMPH	***Panicum decompositum (k) B185***	**Australian Millet**
AMPH	***Triglochin dubium r***	**Slender Water-ribbons**
WAMPH	***Amphibromus fluitans V k***	**River Swamp Wallaby-grass**
WAMPH	***Eleocharis pallens v***	**Pale Spike-sedge**
WAMPH	***Ranunculus papulentus (k)***	**Large River Buttercup**

OLAC	Obligate Lacustrine (found primarily on lakes edge)
OA	Obligate Aquatic (totally aquatic)
ROA	Riparian Obligate Aquatic (subset of RO)
RWOA	Riparian Wetland Obligate Aquatic (subset of ROA and OA)
RO	Riparian Obligate (always in riparian zone)
RAMPH	Riparian Amphibious
RWAMPH	Riparian Wetland Amphibious (subset of RAMPH)
AMPH	Amphibious (both in and out of water)
WAMPH	Wetland Amphibious

Field Observations

Macrophytes were observed when the Scientific Panel visited sites along the Goulburn River in January 2003, but were relatively scarce. Ribbon weed (*Vallisneria americana*) was the main macrophyte observed, with floating pondweed (*Potamogeton tricarinatus*) also common in the upper reaches. Overall, the in-channel macrophytes were not very diverse and were patchy, although more abundant in local pockets and backwaters. The channel has a simple rather than complex morphology and microhabitats suitable for macrophytes, such as backwaters are not very abundant. Turbidity was noticeably higher in the lower reaches of the Goulburn River, and so the euphotic depth (depth in which photosynthesis can occur) was smaller. This, combined with factors such as substrate mobilisation and the foraging behaviour of carp, make it difficult for macrophytes to establish and persist.

River red gum dominates the upper storey of the riparian zone, along with silver wattle (*Acacia dealbata*). The upper reaches of the study are supported a diverse tree-shrub layer below river red gum. However, the width of the riparian zone was variable, being only one tree line wide in some areas. A positive feature is the relative lack of willows along the river along the lower reaches of the Goulburn River, although willows are still a problem in some upstream areas (e.g. upstream of Molesworth Bridge). Other alien species such as blackberry, date palms, and briar are present but are not dominant.

The condition of the understorey was often difficult to assess due to the current dry state of the riparian zone. The condition of river red gum forest and woodland along the lower reaches of the Goulburn River is poor in many places, as evidenced by sparse canopies, of few and brown leaves. In several places, the River Red Gum forest appeared to be relatively young re-growth, with stands of mainly young trees; there are very few old trees that provide important habitat for birds and mammals, and these were typically on the riverbank and in the channel.

Land management practices such as grazing and clearing are obvious threats to river health. Flow-related threats and the effects of levees were not so obvious due to the visual impact of drought and grazing by livestock.

Hydrological analysis and geomorphic descriptions of the two (upper and lower) floodplain zones will give a finer resolution on longitudinal differences in the two floodplain zones, and this is likely to determine:

- The relative importance and distribution of floodplain vegetation types; and
- The range of wetland types.

These differences were not readily detected during a rapid field overview.

5.2.2 Impact of water management

River regulation has the potential to affect plant communities in all the major habitats of the river channel and floodplain.

Reduced frequency of out-of-channel floods and shorter duration of flood events result in the floodplain becoming generally drier. Flood intolerant species, including terrestrial and opportunistic species, establish more readily and persist for longer. This results in changes to the pattern of vegetation that occurs over time. Drier conditions reduce the growth and vigour of long-lived species such as River Red Gums. Increasing time between flood events means that long-term persistence of wetland plant communities dependent on a wet phase to grow and set seed may become at risk. This is because seedbanks and propagule-banks are re-plenished less frequently, and because seeds remaining in the seedbank are vulnerable to seed mortality and seed predation.

Changes in the timing of floods, or in the timing of low-flow periods, affects those plant species with life cycle stages that are cued to particular seasons, such as germination, establishment, flowering. Species that grow over-winter are disfavoured, whilst summer-growing species are encouraged, leading to changes in species composition and dominance.

More constant water levels provide conditions that are less conducive to the survival of native species and favours invaders such as willows as well as potentially nuisance native species such as Typha spp.

Cold water releases from Lake Eildon can reduce the growth rate of in-channel macrophytes; this may apply to Reaches 1 and 2, and Reach 3 to a lesser extent. Armouring of the riverbed in Reach 1 and 2 reduces benthic habitat available for in-channel macrophytes and probably reduces natural dynamics of expansion and contraction. This in turn may limit the food and habitat available for biota such as macroinvertebrates and small fish.

In summary, flow-related issues that should be considered when developing environmental flow recommendations include:

- Reduced frequency, timing and duration of out of channel flows (all reaches);
- Reduced frequency and duration of summer freshes and less variable water levels due to the delivery of irrigation water in summer-autumn and the filling of Lake Eildon in winter and spring (all reaches);
- Loss of shallow, slow-moderate velocity habitat, especially in summer-autumn.

5.3 River-Floodplain Interactions

5.3.1 River-Floodplain Connection

Floodplains play an essential functional role in riverine ecosystems and contribute significantly to regional diversity. Floodplains present an array of habitats for species, of which many are aquatic organisms adapted to the non-flowing, but often temporary, billabongs and backwaters. Floodplain ecosystems are often present as a mosaic of habitats based largely on the frequency and duration of flooding. For example, work on the Barmah-Millewa forests has identified many sub-habitats and the threats posed to them by changes in water management (Anon. 2000). Each of these sub-units can be characterised by the specific plant communities they support, which can in turn be identified by other faunal groups. For example, Parkinson (1996) indicated that diversity of bush-bird species on the Ovens floodplain near Peechelba was strongly correlated to the proximity of ephemeral wetlands.

The exchange of carbon through food webs (e.g. via trophic processes such as primary production, consumption – grazing and predation - and respiration) determines the vigour, biodiversity, and robustness of an ecosystem. Sources of carbon in river ecosystems are many and include leaves and litter from upper catchments, in-channel production (aquatic plants, algae, and biofilm) in middle reaches, and the products of production on the floodplain (litter, other terrestrial sources, and floodplain wetlands) in the lowland reaches. In upland reaches, carbon is delivered either by direct input from riparian vegetation or by transport in surface runoff. In floodplain reaches, a delivery system is also required but, as rainfall runoff is much reduced in force and quantity, the process is dependant on connections between the river and floodplain wetlands (billabongs and temporary anabranches) and/or the sweeping of floodplain areas by over-bank flow. Resource management can affect this relationship in several ways:

- The reduction of floodplain productivity (in the ecological sense) by clearing, heavy grazing etc. in areas likely to be inundated.
- Degradation of floodplain wetlands (eg draining, blocking, abstraction, heavy stock use).
- Alienation of floodplain by levees
- Flow regulation/water use which changes the timing, frequency, or extent (space or time) of over-bank flows.

Floodplain systems also support microbial and zooplankton communities that are more diverse than in the associated river systems. Floodplain wetlands may serve to inoculate the parent system during high flow events, contributing to biodiversity and recolonisation processes.

The floodplains in the study area have been significantly modified for agricultural production, including dryland and irrigated areas. As floodplain areas are developed, increased land values support intensive 'river management' activities to resist bank erosion and avoid floodplain inundation (e.g. levees) even at flows well within the normal range. This severely curtails the ecological role of the floodplain. Of all land management actions on the floodplain, levees and grazing by livestosck are the most basin-wide in their effect. Prevention of a flood in one area must increase pressures elsewhere and (like dryland salinity) cause and effect are often separated by some distance.

The movement of floodwater on the floodplain between Lake Eildon and Goulburn Weir has a longitudinal pattern, i.e. through channels and flood runners that flow parallel to the main channel, as well as laterally across the floodplain. While there are fewer levees along this section of the river than is the case along the lower Goulburn, flood runners often have block banks that halt the flow of water between the floodplain and the channel.

Along the lower Goulburn, the river channel is perched, with both natural and constructed levees. The topography of the floodplain varies in height and arrangement. There are different types of wetlands present (ephemeral, perennial, deep, shallow etc.) and this is likely to contribute to very different flora and fauna assemblages and biodiversity values. The river red gum of the riverine grassy woodland and riverine sedgy forest is a good source of organic matter that is food for macroinvertebrates when transported back to the river channel and to wetlands.

Field Observations
The field trip coincided with drought conditions that are likely to have influenced what the Scientific Panel was able to observe. For example, water allocations have been approximately 50% and this can be reflected in lower river flows. Also, there was a substantial quantity of eucalypt litter on the floodplain and blown into the river. At least in part, this reflects the response of river red gum to drought.

Horseshoe Lagoon near Trawool provided a good example of the importance of periodic drying of wetlands. When visited, thousands of river red gum seedlings were evident, having emerged as the wetland dried. A large number of dead carp were also noted. This demonstrated the important 'resetting' role played by drying in the hydrologic cycle of wetlands along the Goulburn River.

Discussion with local stakeholders (see Appendix 6) provided anecdotal evidence that floods represented by 30-35 feet (9.15 - 10.68 m) on the Shepparton gauge used to occur in spring-summer with a frequency of approximately 1 in 3 years. Such floods were usually followed by a dramatic increase in activity by fauna such as birds and frog numbers within 1 week of a flood. These observations are in accord with the early opinion of the Scientific Panel that regulation had reduced the frequency of these ecologically important flood flows below Goulburn Weir. Flow-related issues to be considered when developing environmental flow recommendations will be the same as that required for wetlands (section 5.3.2).

5.3.2 Wetlands

Nearly all the wetland classification systems currently in use through Australia are descriptive, including the Corrick classification system used in Victoria. This system classifies freshwater wetlands into five types based on their dominant vegetation and assumed contemporary water regime. A classification system adopted as part of the Ramsar convention is also in use, as it is used by the Federal government in its international dealings and in its negotiations with the States. The Ramsar classification system uses hydrology, geomorphic form, water quality (saline v fresh) and size, applied in a non-systematic way. The descriptive systems currently in use were not designed to provide a predictive capacity, for example to predict response to change or expected ecological condition.

Attributes used in the Corrick wetland classification include wetland size, tenure, type of wetland, and change (if any) since European settlement. This data base, when interrogated, provides useful information on wetland sizes and types, and trends since European settlement. Within the whole GBCMA area, wetlands are mostly freshwater meadows and freshwater marshes (whether measured by number or area), and typically small, < 9 ha (Clunie and Lyon 2002, Lyon *et al*. 2002). Of the four types of freshwater wetland present, Freshwater Meadows have most decreased in area, making these a priority for conservation.

Interrogation of this data will allow identification of Reach specific characteristics in sizes, change and dominant vegetation types. However, there was insufficient time available to undertake a full reach-based analysis prior to the submission of this issues paper. Points to note from preliminary analysis (Table A1.8, Appendix 5) are:

- In all reaches, most of the wetlands are small (1-9 ha); wetlands larger than 50 ha are much more common in the unconfined floodplain, i.e. in Reaches 4 and 5.
- All four freshwater wetland types occur in all reaches, but in different proportions.
- The frequency of Freshwater Meadows progressively increases downstream and is highest in Reach 5.
- Wetlands with Herb and River Red Gum as main vegetation types occur in all reaches, and at similar levels.
- Wetland diversity, in terms of vegetation types present, is greater in Reaches 4 and 5, the unconfined floodplain. These Reaches are in the Riverina bio-region, and hence include species typical of this bioregion: Black Box *Eucalyptus largiflorens*, Tangled Lignum *Muehlenbeckia florulenta*, Canegrass *Eragrostis australasica* / *Eragrostis infeocunda*.
- There is evidence of a trend for wetlands to become 'wetter'. The Corrick classification is centred on depth and duration of inundation, with FW Meadows having the shallowest and shortest flooding, and Open Permanent FW the most persistent. More detail is provided in in Appendix 5.
- Only a few wetlands have increased in area; it is 15 times more common for wetland to have decreased.
- Wetland change has been greatest in Reaches 4 and 5.

Table A1.8: Preliminary summary of reach-specific characteristics of wetlands

	Reach 1 and 2 Confined floodplain	Reach 3 Gorge	Reach 4 Unconfined floodplain (upper)	Reach 5 Unconfined floodplain (lower)
Census	372 wetlands. Mostly small (86% = 1-9 ha), and very few > 25 ha.	21 wetlands. Mostly small (86% = 1-9 ha), none > 25 ha	536 wetlands. Mostly small (60% = 1-9 ha) but also some medium and large wetlands (8% being larger than 50 ha)	768 wetlands Mostly small (53% = 1-9 ha), but nearly a quarter are medium to large area (24% are >> 26 ha).
Wetland Category (frequency)	Mostly FW Marsh (58%), with Deep FW Marsh and Permanent Open FW less common (approx 15%) and Freshwater Meadows least common (9%).	Mostly FW Marsh (38%) with FW Meadows, Deep FW Marsh and Permanent Open FW equally important.	Mostly FW Meadows and FW Marsh (45% and 31%). Deep FW Marsh is least common type (7%)	Mostly FW Meadows (50%); Deep FW marsh is least common type (11%).
WETLANDS DOMINATED BY HERB (H), RIVER RED GUM (RRG) OR COMBINED	H = 35% RRG = 37% H + RRG = 16% Total = 88%of wetlands	H = 33% RRG = 14% H + RRG = 19% Total = 66% of wetlands	H = 37% RRG = 24% H + RRG = 12% Total = 73% of wetlands	H = 36% RRG = 24% H + RRG = 12% Total = 72% of wetlands
Vegetation types with restricted range (not exclusive)			Canegrass mix (12) Lignum mix (1) Reed (6) Reed mix (11) Saline (2)	Black Box (3) Canegrass (14) Canegrass mix (1) Lignum mix (2) Reed (23) Reed mix (8)
Modified & constructed wetlands	Impoundments 16% Sewage ponds 1%	Impoundments 14% Sewage ponds 14%	Impoundments 15% Sewage ponds 1.5%	Impoundments 14% Sewage ponds 2%
Number of Wetland Types: Change since European settlement	Gain = 12 (was FW Marsh) Loss = 24 (9 to FW Marshes, 7 to Deep FW Marsh and 8 to Open Permanent FW).	Gain = 9 (was FW meadows) Loss = 26 (12 to FW Marsh, 8 to Deep FW Marsh, 6 to Open Permanent FW)	Gain = 15 (were FW meadows or FW Marsh) Loss = 4 (4 to Open Permanent FW)	Gain = 18 (were FW meadows, FW Marsh, Deep FW Marsh) Loss = 0

Additional points arising from analysis of existing data include:

- Analysis of floodplains is also needed, in their own right and because floodplains are the matrix within which riverine wetlands are located and functionally connected.
- This exploration of changes to wetlands in the Goulburn River downstream of Lake Eildon relates to time of field survey, 1995-1996 (Lyon, pers. comm. 2003) and to a limited range of indicators. Other changes have occurred that impact on wetland condition and function, making this a conservative analysis.

Previous investigations (Howell and McLennan 2002) have identified over 1800 wetlands greater than 1 hectare in area across the Goulburn Broken catchment, covering a total of approximately 82,000 hectares (this includes natural and man-made wetlands). The following are examples of high value wetlands in the study area that have been identified from the Directory of Important Wetlands and other local initiatives, such as wetlands for which specific management plans have been prepared:

- Molesworth (DCE 1990a and b);
- Homewood (DCE 1990c);
- Horseshoe Lagoon;
- Tabilk Lagoon;
- Gemmill Swamp;
- Reedy Swamp (DPI 2002);
- Kanyapella Basin (DSE 2002);
- Lower Goulburn River Floodplain.

These wetlands are considered important due to values associated with their representativeness, rarity or naturalness (Lyon and Clunie 2002). Each of the individual wetlands has particular values (e.g. provision of habitat for waterbird breeding, presence of threatened species) and many have specific management plans. Examples of environmental values associated with the important wetlands identified above include:

- Representative of wetland type (e.g. deep freshwater marsh) that has been greatly reduced since European settlement;
- Provision of breeding and rearing habitat for waterbirds, especially those recognised by international agreements (e.g. Ramsar convention, JAMBA and CAMBA);
- Provision of habitat for native flora and fauna;
- Presence of threatened flora and fauna;
- Provision of ecosystem services such as the maintenance of riverine water quality.

However, all the important wetlands of the study area are part of larger riparian/floodplain/wetland mosaics, where management often requires large-scale (catchment/floodplain) consideration. Many threatening processes have been formally recognised through State *(Flora and Fauna Guarantee Act* 1988) and Federal legislation *(Environment Protection and Biodiversity Conservation Act* 1999). The FFG Act lists the following potentially threatening processes for riparian and instream flora and fauna that are relevant to the waterways of the Goulburn Broken catchment (adapted from Howell and McLennan 2002):

1. Alteration to the natural flow regimes of rivers and streams;
2. Alteration to the natural temperature regimes of rivers and streams;
3. Degradation of native riparian vegetation along rivers and streams;
4. Habitat fragmentation as a threatening process for fauna;

5. Increase in sediment input into rivers and streams due to human activities;
6. Input of toxic substances into rivers and streams;
7. Introduction of live fish into waters outside their natural range;
8. Loss of hollow-bearing trees;
9. Predation of native wildlife by the cat *Felix catus;*
10. Predation of native wildlife by the introduced Red Fox *(Vulpes vulpe*s);
11. Prevention of passage of aquatic biota as a result of the presence of instream structures;
12. Removal of wood debris from streams;
13. The invasion of native vegetation by environmental weeds;
14. The use of lead shot for the hunting of waterfowl.

Howell and McLennan (2002) have linked these threatening processes with activities that occur within the Goulburn-Broken catchment (Table A1.9). Most of the threatening activities listed in Table 8 are relevant to the riparian/ wetland/floodplain complexes that exist along the Goulburn River.

Table A1.9: Major threatening activities that affect riparian and instream flora and fauna (from Howell and McLennan 2002):

Threatening Activities	Link to FFG Threatening Process	Likelihood	Consequence	Key Impacts or Consequence
Grazing banks and wetlands	3. 4. 5.	H	H	• Reduced habitat value • Fragmentation of habitat • Reduced regeneration of flora • Competition from weed invasion
Landforming, agricultural development, cultivation.	1. 4. 5.	H	H	• Fragmentation of habitat • Reduction in vegetation cover and reduced • regeneration • Weed invasion • Poor water quality – habitat alteration
Poor land management	3. 5. 6.	M	H	• Salinisation of water environment • Algal blooms leading to death • Poor water quality altering habitat
Removal of woody debris.	12	M	H	• Removal of habitat (snag removal) • Loss of natural flow patterns (eg. scouring)
Recreation	14	M	L/M	• Loss of vegetation quality and quantity • Impact on breeding species • Removal of habitat (snag removal)
Timber harvesting	8.	M	M	• Loss of habitat (hollow bearing trees) • Altered flows changes available habitat
Water regulation .	1. 2. 11.	H	H	• Altered flow changes available habitat • Altered temperature (thermal pollution) • Barriers to species migration • Altered habitat
Introduced flora & fauna	7. 9. 10.	H	H	• Loss of native species (predation and competition) • Proliferation of carp

Threatening Activities	Link to FFG Threatening Process	Likelihood	Consequence	Key Impacts or Consequence
	13.			• Reduced regeneration of flora • Reduction in available habitat • Spread of disease

H = high, M = medium, L = low

In summary, flow-related issues to be considered when developing environmental flow recommendations include:

- The timing, frequency and duration of wetlands inundation;
- The duration of connection and flow through wetlands on the floodplain.

5.4 Fish

5.4.1 Distribution and ecological requirements

A total of 19 native fish species have been recorded from the study area (Tables A1.10 and 11), nine of which have been identified as having a significant conservation status. Ten introduced species have also been recorded in the study area. The fish species present in the Goulburn River exhibit a variety of life history strategies and, as a result, a number of different ecological requirements need to be considered. For the purposes of the current study, the categories used in the Murray Flows Assessment Tool (MFAT) - part of the MDBC's Living Murray Initiative - will be used to classify the flow related ecological requirements of native fish in the Goulburn River. Under this system, native fish are divided into seven groups based upon current knowledge of their spawning and recruitment strategies (from unpublished MFAT summary notes):

1) **Flood spawners:** spawn and recruit following flow rises. Major spawning occurs during periods of floodplain inundation.
2) **Macquarie perch:** requires clean gravel substrate for spawning. Floodplain inundation not required, but spawning probably enhanced by rising flows.
3) **Wetland specialists:** spawn and recruit in floodplain wetlands (lakes, anabranches and billabongs) during in-channel flows.
4) **Freshwater catfish:** spawn in coarse sediment beds (usually sand or gravel) during any flow conditions.
5) **Main channel generalists:** spawn and recruit in high or low flow in the main channel.
6) **Main channel specialists:** spawn and recruit under high or low flow in the main channel. Woody debris is an important habitat attribute.
7) **Low flow specialists:** Only spawn and recruit during low flow (in-channel or floodplain habitats).

The Goulburn River between Eildon and Alexandra contains more pool-riffle structure than downstream reaches of the river and is strongly affected by cold water releases from Lake Eildon (Ryan *et al.* 2001). This helps to support a popular recreational trout fishery as well as a number of commercial aquaculture ventures based on trout, both of which have social and economic values within the region (DNRE 2002a). Prior to construction of Goulburn Weir and the successive dams at Eildon, a relatively diverse native fish fauna occurred in the Goulburn River between Eildon and Alexandra. Species historically present included Murray cod, Trout cod and Macquarie perch - these species have not been recorded in the reach below Lake Eildon for more than 30 years (DSE fish database, MAFRI unpublished data). This reach is also within the known range of River blackfish and Two spined blackfish (Koehn and O'Connor 1990; DSE fish database), although these species are mainly restricted to the tributaries of the Goulburn.

The Acheron and Rubicon rivers discharge into the Goulburn downstream of Alexandra and, with the increase in flow, habitat structure within the channel tends to become more uniform. Although there has been extensive de-snagging above Lake Nagambie (DNRE 2002a), large woody debris comprises an important component of in-channel habitat diversity in this region. Habitat and water temperature conditions between Alexandra and Goulburn Weir gradually become more favourable for native species like Murray cod, Trout cod and Macquarie perch, although temperatures are still depressed downstream at least to Lake Nagambie (Ryan *et al.* 2001). Trout can usually tolerate the increase in stream temperatures in the reaches above Lake Nagambie, although the reduction in physical habitat diversity appears to result in a less productive trout fishery in this region (DNRE 2002a). Carp are present in relatively large numbers in this reach and several other introduced species, including Tench, goldfish, Gambusia and Redfin, are also common (DSE fish database, DNRE 2002a). Anabranches and billabongs between Alexandra and Goulburn Weir provide a considerable amount of potential habitat for wetland fish species such as Flat-headed galaxias, Western carp gudgeon and Freshwater catfish. Of particular note is a large floodplain wetland near Tabilk that currently supports a significant population of the threatened Freshwater catfish (DNRE 2002a) and Murray hardyhead.

In the downstream region between Goulburn Weir and the Murray River, habitat conditions become more favourable for native species and the impact of cold water releases is minimal (Tom Ryan, Arthur Rylah Institute, pers. comm.). There is an increase in fish diversity in this reach, with 13 native species recorded (Table A1.11). The fish community of the lower Goulburn River is significant in terms of its conservation value, with five of the recorded species (Freshwater catfish, Silver perch, Macquarie perch, Trout cod, Murray cod) listed as threatened in the Victorian Flora and Fauna Guarantee Act (1988). Trout are uncommon in the lower reaches of the Goulburn River but several other introduced species are abundant, particularly Carp, Goldfish and Gambusia. Redfin were previously abundant in this region, although the numbers of this species have declined dramatically in recent years. The reason for this decline is not clear.

Table A1.10: Native and introduced fish species in Goulburn-Broken catchment (adapted from Lyon and Clunie 2002). MFAT classifications (see above) and conservation status are shown for native species (Vic Status – NRE (2002), FFG – State *Flora and Fauna Guarantee Act* (1988), EPBC – Federal *Environment Protection and Biodiversity Conservation Act* (1999)).

Scientific Name	Common Name	MFAT category	Vic Status	FFG	EPBC
Bidyanus bidyanus	Silver Perch	1	CEn	L	
Craterocephalus fluviatilis	Murray Hardyhead	3	End	L	Vul
Gadopsis bispinosus	Two-spined Blackfish	6			
Gadopsis marmoratus	River Blackfish	6			
Galaxias brevipinnis	Broad-finned Galaxias	5			
Galaxias fuscus	Barred Galaxias	5	CEn	L	End
Galaxias olidus	Mountain Galaxias	5			
Galaxias rostratus	Flat-headed Galaxias	3			
Hypseleotris klunzingeri	Western Carp Gudgeon	3, 7			
Maccullochella macquariensis	Trout Cod	6	CEn	L#	End
Maccullochella peelii peelii	Murray Cod	6	Vul	L	
Macquaria ambigua	Golden Perch	1	Vul		
Macquaria australasica	Macquarie Perch	2	End	L	End
Melanotaenia fluviatilis	Murray Rainbowfish	7	DD	L	
Nannoperca australis	Southern Pygmy Perch	3			
Nematalosa erebi	Bony Bream	3, 5			
Philypnodon grandiceps	Flat-headed Gudgeon	5			
Retropinna semoni	Australian Smelt	3, 5			
Tandanus tandanus	Freshwater Catfish	4	Vul	L	
Introduced species		-			
Carassius auratus	Goldfish	-			
Cyprinus carpio	Carp	-			
Gambusia holbrooki	Gambusia	-			
Misgurnus anguillicaudatus	Oriental Weatherloach	-			
Oncorhynchus mykiss	Rainbow Trout	-			
Oncorhynchus tshawytscha	Chinook Salmon	-			
Perca fluviatilis	Redfin	-			
Rutilus rutilus	Roach	-			
Salmo trutta	Brown Trout	-			
Tinca tinca	Tench	-			

Vic Status NRE threatened classification, CEn=Critically Endangered, Vul=Vulnerable, End=Endangered, Ins=Insufficiently known, LR=Lower risk near threatened, DD=Data Deficient

FFG L=listed under the *Flora and Fauna Guarantee Act* 1988, #=Action Statement completed.

EPBC Listed under the *Environment Protection and Biodiversity Conservation Act* 1999

Table A1.11: Distribution of recorded fish species within the study area (Source: DSE fish database, ARI unpublished data, MAFRI unpublished data)

Scientific Name	Common Name	MFAT category	Records
Lake Eildon to Molesworth			
Native			
Galaxias rostratus	Flat-headed Galaxias	3	Last record 1969
Maccullochella macquariensis	Trout Cod	6	Last record 1970
Maccullochella peelii peelii	Murray Cod	6	Last record 1970
Macquaria australasica	Macquarie Perch	2	Last record 1970
Philypnodon grandiceps	Flat-headed Gudgeon	5	Recent
Retropinna semoni	Australian Smelt	3, 5	Recent
Introduced			
Carassius auratus	Goldfish	-	Recent
Cyprinus carpio	Carp	-	Recent
Gambusia holbrooki	Gambusia	-	Recent
Oncorhynchus mykiss	Rainbow Trout	-	Recent
Perca fluviatilis	Redfin	-	Recent
Salmo trutta	Brown Trout	-	Recent
Tinca tinca	Tench	-	Recent
		-	
Molesworth to Seymour			
Native			
Gadopsis bispinosus	Two-spined Blackfish	6	Recent
Hypseleotris klunzingeri	Western Carp Gudgeon	3, 7	Recent
Maccullochella peelii peelii	Murray Cod	6	Last record 1970
Macquaria australasica	Macquarie Perch	2	Last record 1970
Nannoperca australis	Southern Pygmy Perch	3	Recent
Philypnodon grandiceps	Flat-headed Gudgeon	5	Recent
Retropinna semoni	Australian Smelt	3, 5	Recent
Introduced			
Carassius auratus	Goldfish	-	Recent
Cyprinus carpio	Carp	-	Recent
Gambusia holbrooki	Gambusia	-	Recent
Oncorhynchus mykiss	Rainbow Trout	-	Recent
Perca fluviatilis	Redfin	-	Recent
Salmo trutta	Brown Trout	-	Recent
Tinca tinca	Tench	-	Recent
Seymour to Nagambie			
Native			
Bidyanus bidyanus	Silver Perch	1	Recent
Craterocephalus fluviatilis	Murray hardyhead	3	Recent
Gadopsis marmoratus	River Blackfish	6	Recent
Galaxias rostratus	Flat-headed Galaxias	3	Recent
Maccullochella peelii peelii	Murray Cod	6	Recent
Macquaria ambigua	Golden Perch	1	Recent
Macquaria australasica	Macquarie Perch	2	Last record 1970
Melanotaenia fluviatilis	Murray Rainbowfish	7	Last record 1977
Nematalosa erebi	Bony Bream	3, 5	Last record 1981
Retropinna semoni	Australian Smelt	3, 5	Recent
Tandanus tandanus	Freshwater Catfish	4	Recent
Introduced			
Carassius auratus	Goldfish	-	Recent
Cyprinus carpio	Carp	-	Recent

Scientific Name	Common Name	MFAT category	Records
Gambusia holbrooki	Gambusia	-	Recent
Perca fluviatilis	Redfin	-	Recent
Salmo trutta	Brown Trout	-	Recent
Tinca tinca	Tench	-	Recent
Nagambie to Loch Garry			
Native			
Bidyanus bidyanus	Silver Perch	1	Recent
Gadopsis marmoratus	River Blackfish	6	Recent
Galaxias rostratus	Flat-headed Galaxias	3	Recent
Hypseleotris klunzingeri	Western Carp Gudgeon	3, 7	Recent
Maccullochella macquariensis	Trout Cod	6	Recent
Maccullochella peelii peelii	Murray Cod	6	Recent
Macquaria ambigua	Golden Perch	1	Recent
Macquaria australasica	Macquarie Perch	2	Recent
Nematalosa erebi	Bony Bream	3, 5	Last record 1982
Melanotaenia fluviatilis	Murray Rainbowfish	7	Recent
Philypnodon grandiceps	Flat-headed Gudgeon	5	Recent
Retropinna semoni	Australian Smelt	3, 5	Recent
Tandanus tandanus	Freshwater Catfish	4	Recent
Mordacia mordax	Short headed lamprey	na	Last record 1913
Introduced			
Carassius auratus	Goldfish	-	Recent
Cyprinus carpio	Carp	-	Recent
Gambusia holbrooki	Gambusia	-	Recent
Oncorhynchus mykiss	Rainbow Trout	-	Recent
Perca fluviatilis	Redfin	-	Recent
Salmo trutta	Brown Trout	-	Recent
Tinca tinca	Tench	-	Recent
Loch Garry to the River Murray			
Native			
Bidyanus bidyanus	Silver Perch	1	Recent
Gadopsis marmoratus	River Blackfish	6	Last record 1950
Galaxias rostratus	Flat-headed Galaxias	3	Recent
Hypseleotris klunzingeri	Western Carp Gudgeon	3, 7	Recent
Maccullochella macquariensis	Trout Cod	6	Last record 1970
Maccullochella peelii peelii	Murray Cod	6	Recent
Macquaria ambigua	Golden Perch	1	Recent
Melanotaenia fluviatilis	Murray Rainbowfish	7	Recent
Philypnodon grandiceps	Flat-headed Gudgeon	5	Recent
Retropinna semoni	Australian Smelt	3, 5	Recent
Tandanus tandanus	Freshwater Catfish	4	Last record 1981
Introduced species			
Carassius auratus	Goldfish	-	Recent
Cyprinus carpio	Carp	-	Recent
Gambusia holbrooki	Gambusia	-	Recent
Perca fluviatilis	Redfin	-	Recent

5.4.2 Impacts of water management

Several factors related to water management currently impact upon native fish populations in the Goulburn River. Among these is the impact of cold water releases from Lake Eildon. Lake Eildon has been identified as a maximum priority dam for research on the effects of cold water releases due to it influence on the thermal regime of the Goulburn River (Ryan *et al.*

2001). Gippel and Finlayson (1993) and Ryan *et al.* (2001) found that summer temperatures in the river below Lake Eildon are typically 5-7ºC lower and that winter temperatures are 2-3ºC higher due to releases from the dam. Further downstream, the effects of cold water releases are less pronounced, although summer water temperatures can remain low as far downstream to Goulburn Weir (Ryan *et al.* 2001).

As many of the native fish originally present in the Goulburn River were adapted to relatively warm water environments (Lake 1967; Rowland 1983), the impact of cold water releases can be dramatic. Cold water release has been implicated as a primary reason for the loss of breeding populations of native species including Murray cod, Trout cod, Silver perch, Golden perch and Macquarie perch in a number of rivers in southern Australia (Koehn *et al.* 1995; Lugg 1999; Ryan *et al.* 2001). The effects of cold water releases on native fish include reductions in metabolic and physiological rates, loss of cues for gonad maturation and spawning, and reduced river productivity. These effects result in reduced growth rates of fish, higher rates of mortality due to disease and predation, lack of breeding, recruitment failure and reductions in food resources (Ryan *et al.* 2001).

Given its dramatic effect on native fish communities, any proposed changes to the flow regime of the Goulburn River for environmental purposes must take into account the potential impacts of cold water on achieving environmental objectives. Under the Victorian River Health Strategy (DNRE 2002), the definition of a healthy river is one in which "the majority of plant and animal species are native and the presence of exotic species is not a significant threat to the ecological integrity of the system". However, it has also been suggested that the upper Goulburn River should be managed as a cold water trout fishery (Gippel and Finlayson 1993; DNRE 2002) due to the popularity of the trout fishery and the costs of ameliorating cold water releases. The decision on whether cold water releases should be ameliorated in the future, therefore, is an issue that will require consideration of social and economic factors as well as environmental issues (e.g. the restoration of native fish populations).

The presence and operation of Lake Eildon has changed the timing and magnitude of flows in the Goulburn River. This can affect the native fish communities of the Goulburn River in a number of ways. Flow regulation has resulted in a reversal of the seasonality of flows in the river, with higher irrigation flows in summer and autumn and lower winter and spring flows (Figure 3a). As several native fish species require low summer flows for successful spawning and recruitment (Humphries *et al.* 1999) and high flows, such as those occurring between Lake Eildon and Goulburn Weir throughout summer and autumn, are likely to reduce breeding success and recruitment for these species. A reduction in the frequency and magnitude of overbank flows in the upper and lower reaches of the Goulburn River has reduced the connectivity between the river and its floodplain. This is likely to reduce spawning opportunities for species that may require floods for successful spawning and/or recruitment (eg. golden perch and silver perch) and may also result in the drying out of habitat for species that utilise floodplain wetlands (eg. Flat-headed galaxias, Freshwater catfish). There has also been a reduction of within-channel flushes in the Goulburn River, particularly below Goulburn Weir. Flushes within the 30-80th % exceedance flow have been shown to be important in initiating migration by golden perch and silver perch (Mallen-Cooper *et al.* 1995) and are also important for the input of organic matter that forms the basis of the food-chain on which fish rely (Robertson *et al.* 1999).

Barriers to fish movement and migration are another important issue in the Goulburn River. Both Eildon Dam and Goulburn Weir act as complete barriers to fish movement, effectively separating fish populations in the upper reaches of the Goulburn River from those in the wider Murray-Darling Basin. Whilst it is technically feasible to install a fishway at Goulburn Weir, this is considered a low priority unless the impacts of cold water releases in the upper reaches are mitigated to suit native species (McGuckin and Bennett 1999, DNRE 1997). Apart from Eildon Dam and Goulburn Weir, fish passage through most of the main stem of the Goulburn River is generally not impeded, although several smaller structures within the river channel have been identified (McGuckin and Bennett 1999) that may potentially act as barriers under low flow conditions.

Instream habitat conditions have been altered by flow related management practices in the Goulburn River. Extensive desnagging was undertaken in the river between Eildon and Lake Nagambie (DNRE 2002) and in the river immediately upstream of the Murray River junction. Woody debris in the reach below Goulburn Weir has remained relatively intact however. Armouring of the riverbed substrate has occurred in the upper reaches and is likely to have reduced habitat complexity for small species and/or the larvae and juveniles of larger species that use interstitial spaces between rocks as shelter. Construction of block banks and levees has also occurred along the length of the river. These structures reduce connectivity between the channel and its floodplain, thereby reducing access to the floodplain for fish and preventing refilling of wetland habitats.

Introduced species have an important impact upon fish populations in the Goulburn River. In the upper reaches, large populations of brown and rainbow trout are present and are favoured by current water management practices. Whilst trout are often considered beneficial in terms of their angling and aquaculture values, they have significant impacts upon native species. Trout are well known to compete with and/or prey upon native fishes and several instances of localised extinctions of small native fishes, particularly galaxiids, have been documented in Australia (Cadwallader 1978; Raadik 1995; Crook and Sanger 1998). Carp are also present throughout the Goulburn River system and may impact directly upon native fishes and indirectly upon habitat quality (Koehn *et al.* 2000). Gambusia, Tench, Goldfish and Redfin are also present in the system and are likely to have negative impacts on native fish. Whilst the presence or absence of introduced species is not determined directly by flow management practices, introduced species may be favoured by particular flow conditions. As a consequence, the potential ecological responses of introduced species must be taken into account when considering changes to flow regimes for environmental purposes.

In summary, the flow-related issues that should be explored when developing environmental flow recommendations for fish in the Goulburn River include:

- The implication of reduced frequency and duration of out of channel flows that inundate wetlands and the floodplain and provide key life-cycle cues (all reaches);
- The implications of reduced frequency and duration of summer freshes that provide life-cycle cues and maintain water quality along the river, particularly in pools (all reaches);
- The potential loss of both shallow (reaches 1-3) and deep water habitat (reaches 4 and 5);
- The implications of low flows on fish movement along the river (all reaches).

The release of cold water from Lake Eildon, while an important factor in terms of fish community structure, will be considered in terms of its potential as a ‘confounding factor’ that could negate the benefits expected when environmental flow recommendations are implemented.

5.5 Macroinvertebrates

Macroinvertebrates are a widely used indicator of river condition in Australia. For example, macroinvertebrates are collected from river and stream sites across Victoria as part of the programs such as EPA Victoria's biological monitoring program, which includes monitoring sites in the Goulburn River catchment (EPA 1999, Figure A1.9).

Streams across the Goulburn catchment supports a rich and diverse macroinvertebrate fauna. Recent monitoring EPA Victoria (unpublished data) identified 283 separate taxa from sites across the catchment, and many of these were agglomerations of similar species. However, macroinvertebrate communities in the main channel of the Goulburn River below Lake Eildon generally had fewer (and often less abundant) taxa than in nearby tributaries and rivers upstream of Lake Eildon (Figures A1.10 and 11). Disturbance-sensitive species also decreased in abundance downstream of Lake Eildon (Figure A1.12).

Except in fast-flowing upland streams and ephemeral systems, macroinvertebrates are generally less likely to respond directly to flow modifications than to other environmental factors such as the availability of physical habitat and food and the level of predation, which themselves are likely to reflect flow modifications. In the regulated part of the Goulburn these factors are likely to be expressed differently at different points along its length.

Macroinvertebrate communities immediately downstream of Lake Eildon are likely to have declined due to factors such as changes to the condition and availability of physical habitat, decreased summer water temperatures and consequent changes in food supply and predation. The metabolic rate of all invertebrates is directly related to ambient temperature and, within an individual's tolerance range, can halve with a drop of 10 degrees. Cold water released from Lake Eildon is likely to slow the growth rate of aquatic macroinvertebrates and, by increasing the length of time spent as larvae, increase their exposure to predation and disease. This not only reduces the larva's probability of survival but may also mean that the adult emerges out of synchrony with those from warmer waters, with significant implications for important for reproduction success in some species.

Aquatic plants, edge vegetation and gravel bars (including riffles) are important macroinvertebrate habitat in the upper reaches of the study area, supporting food production and providing shelter. Shallow gravel beds provide sun-lit hard surfaces for the growth of algae (food for grazers), cracks and crevices which trap course organic material (food for shredders), fast flowing water from which filter-feeders can collect food, and hiding places to avoid predation. Flow-related factors that disrupt this process include high flows that preclude light penetration and bed armouring, which is a process where larger stones become 'grouted' into position by finer particles. These factors combine to reduce the shelter and organic material available to macroinvertebrates. It should be noted that the presence of Lake Eildon (acting as a large 'settling pond') also changes the nature and quantity of macroinvertebrate food resources downstream.

The nature of the river changes downstream of Goulburn Weir, and as a consequence the macroinvertebrate community that one might expect to find there also changes. Increased turbidity reduces the opportunity for growth of attached algae on emergent plants, deposition bars (at some flows) and snags. This situation highlights the value of short-term variations in flow which maximise exposure to light. Slow flow velocity and the nature of the channel mean that typical riffle fauna, macroinvertebrates that depend on rapid flow over course substrates, are absent. Course organic material, now supplied mainly from the floodplain, is present and tends to accumulate in deposition zones and especially against snags. Biofilm layers (complex communities typically containing cyanobacteria, algae, bacteria, sponges, and fungus as well as associated microinvertebrates) are also present, particularly on the surfaces of plants and snags. This changed river environment thus determines the macroinvertebrate community that could be expected.

Management-related changes that might be expected to cause the macroinvertebrate community to differ from expected include increased turbidity and constant flows, both of which decrease the zone in which photosynthesis can take place. Increased deposition of fine sediment and suppression of aquatic plant growth, removal of snags and interference with the natural supply of organic material from the floodplain can all increase the risk that biofilm layers will be smothered and that respiration of some macroinvertebrate taxa will be curtailed. The natural supply of organic matter to a river can also be affected by reducing floodplain productivity (removing trees, undercover, or introducing alien species), alienating the floodplain by block banks and levees, or reducing the frequency of flow events which result in significant connectivity between floodplain and channel.

Macroinvertebrate communities generally respond to these environmental changes in two ways, (i) by the loss of species no longer supported by the modified environment or, (ii) by a general reduction in the numbers of individuals in many or most taxa. The first represents a loss of diversity (though of course lost species might be replaced by other species either more tolerant or not previously supported). The second is a loss of biomass, which can also result in a general loss of system productivity that is likely to be expressed as a reduction in the higher trophic levels (such as fish and birds). In reality environmental degradation is likely to produce both diversity and biomass responses in various combinations.

Sampling Site	Location
Above Lake Eildon	
EFM	Goulburn River downstream of Woods Point
EDA	Goulburn River upstream of Kevington
EEV	Goulburn River at Burns Bridge
Gol	Goulburn River upstream of Lake Eildon
Jam	Jamieson River upstream of Lake Eildon
Lake Eildon to Nagambie	
EDB	Goulburn at FieldingsvaleFish Farm
EGK	Goulburn at Leakes Fish Farm
EFW	Goulburn River at main bridge, Alexandra
EGA	Goulburn at main bridge east of Molesworth
Nagambie to the Murray River	
EGM	Goulburn river downstream of Goulburn Weir
EEF	Goulburn River upstream of Toolamba
EDT	Goulburn River at Toolamba
EEG	Goulburn River downstream of Seven Creek
EEE	Goulburn River upstream of Shepparton
EEJ	Goulburn river downstream of Shepparton
EFF	Goulburn River at Dalby Rd
EFT	Goulburn River at McCrackens Rd
EFG	Goulburn River at Medland Rd
EEC	Goulburn River at Undera North
EDE	Goulburn River at McCoys Bridge
EFR	Goulburn River at Yambuna Bridge
EED	Goulburn River at Stewarts Bridge

Figure A1.9: Location of EPA Victoria macroinvertebrate sampling sites

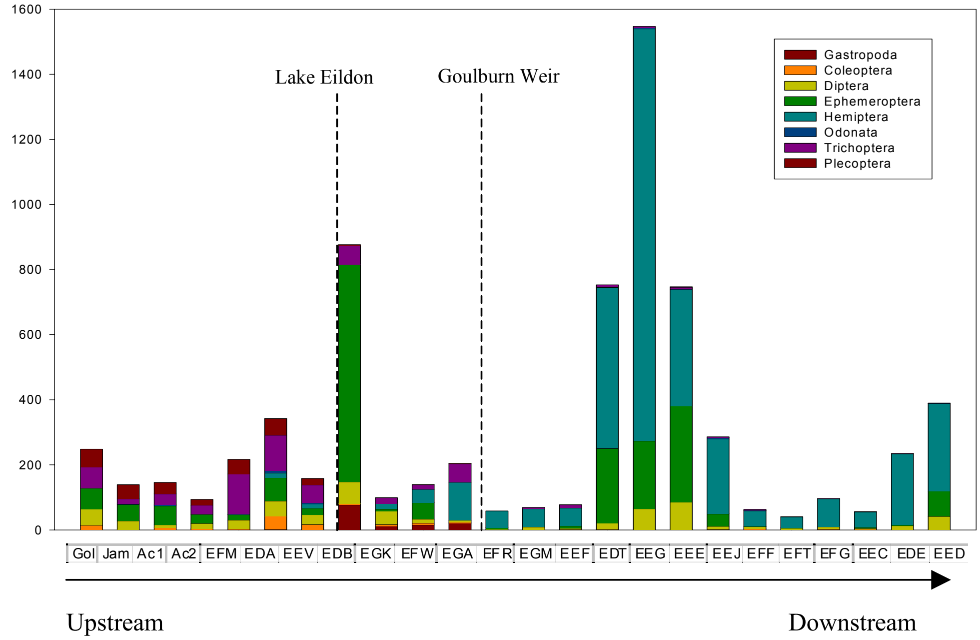

Figure A1.10: Macroinvertebrate taxa and abundance at Goulburn River and tributary sites (based on EPA Victoria, unpublished data)

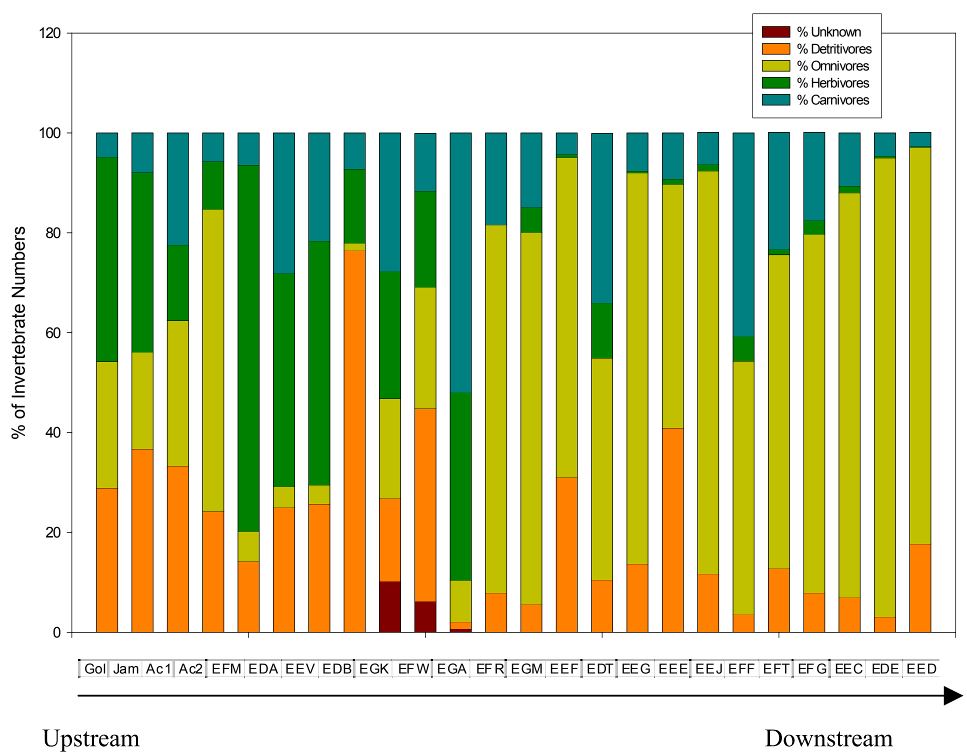

Figure A1.11: Proportion of macroinvertebrates associated with different feeding groups (based on EPA Victoria, unpublished data)

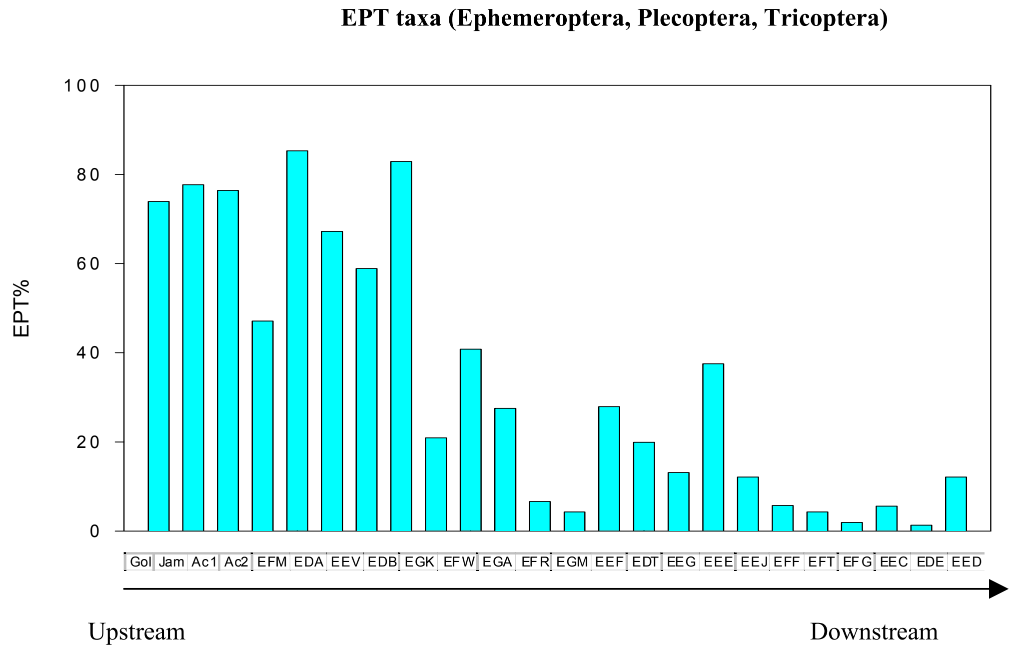

Figure A1.12: Proportion of disturbance-sensitive taxa at sites on the Goulburn River and tributaries (based on EPA Victoria, unpublished data)

5.5.1 Impacts of water management

Management-related changes that may cause the macroinvertebrate community to differ from expected include:

- Increased turbidity and constant flows (both decrease the zone in which photosynthesis, and therefore food production, can take place);
- Increased fine sediment load and lack of 'freshes' (both increasing the risk that biofilm layers will be smothered and that respiration of some macroinvertebrate taxa will be curtailed);
- Removal of snags and suppression of aquatic plant growth; and
- Interference with the natural supply of organic material from the floodplain. This latter might result by reducing floodplain productivity (removing trees and understorey, or introducing alien species), alienating the floodplain by block banks and levees, or reducing the frequency of flow events which result in significant connectivity between floodplain and channel.

The flow-related issues that should be explored when developing environmental flow recommendations for macroinvertebrates in the Goulburn River include:

- The implication of reduced frequency and duration of out of channel flows that inundate and connect wetlands and floodplain habitats with the river channel (all reaches);
- The implications of reduced frequency and duration of summer freshes that inundate channel benches (provision of organic material), mobilise fine sediments and maintain water quality along the river, (all reaches);

- The potential loss of shallow, slow water velocity conditions that are favourable to aquatic macrophytes that provide additional habitat and organic matter for macroinvertebrates (reaches 1-3);
- The potential loss of riffle habitat due to high flows associated with summer irrigation releases (reaches 1-3).

As is the case for fish, cold water releases from Lake Eildon will be considered in terms of its potential as a 'confounding factor' that could negate the benefits expected when environmental flow recommendations are implemented.

5.6 Water Quality

There has been a long history of managing water quality issues, such as eutrophication and algal blooms, in the Goulburn Broken catchment (e.g. Cottingham *et al*. 1995a and b, Cottingham 1994, GBCMA 2002a and b and others). The Goulburn Broken Regional Catchment Strategy (O'Neill and McLennan 2002) provides a good summary of water quality issues and their priority for management, such as eutrophication and algal blooms, salinity, thermal pollution, turbidity and suspended solids.

5.6.1 Eutrophication and algal blooms

The problems associated with toxic blue green algae blooms in surface waters have been widely recognised by resource managers and the general public.

Algal growth and the formation of blooms require a combination of factors, including sufficient light (good water clarity), warm water temperature, available nutrients such as nitrogen and phosphorus, and still conditions. Of these factors, nutrient availability has long been considered the most amenable to management and reducing nutrient transport to waterways has been the basis of the Goulburn Broken water quality strategy (Cottingham 1994). The major sources of nitrogen and phosphorus are recognised as being runoff from forest, agriculture and urban areas, and point sources such as discharges from irrigation drains, sewage treatment plants and fish farms.

Nutrient concentration is relatively low in the upper reaches of the Goulburn River, particularly for phosphorus, and increases with distance downstream (Appendix 4). While higher nutrient concentrations increase the risk of algal blooms, the regular events in Lake Eildon emphasises that algal blooms can occur even in relatively low nutrient environments if conditions are suitable.

The Goulburn Broken Water Quality Strategy has been in place for 5 years. Recent evaluation of water quality data failed to detect any trend in phosphorus concentration at water quality monitoring sites in the study area (Smith and Nathan n.d.). However, a decreasing trend for total nitrogen has been recorded in the Goulburn River at Murchison and Shepparton, presumably due to improved control of point source discharges resulting from the recent implementation of strategy initiatives (e.g. reduced nutrient loads in discharges from sewage treatment plants and fish farms). This is a promising result given that these are the early years of a 20-year strategy and that detecting trends in water quality often takes a long time because of the variability often associated with water quality data.

5.6.2 Salinity

The Goulburn Broken Dryland Salinity Management Plan (GBDSMP) was first prepared in 1989 as part of a coordinated State response to the salinity problem. After 12 years of implementation, dryland salinity remains a major concern for the catchment community. Recent projections (MDBC, 1999) indicate that a significant proportion of the catchment, particularly on the Broken and Goulburn floodplains, is likely to become affected by high watertables and salinity over the next 50 years. Revised estimates from the Murray Darling Basin Commission indicate that an additional 165,000 tonnes of salt per year will be generated from dryland salinity in the Goulburn Broken catchment within a 100 year timeframe. This additional salt threatens the condition of the Murray River downstream, and important assets within the Goulburn Broken catchment including water quality, productive land, urban infrastructure, heritage sites and biodiversity.

Salinity levels measured at water quality monitoring stations along the Goulburn River (Appendix 4) is well below that which poses a threat to flora and fauna, and is representative of the good quality water released from Lake Eildon. However, the discharge of increasing salt loads from tributaries and groundwater represent a long term risk to salinity levels in the Goulburn River and should be monitored in the future. McGuckin (1991) investigated water quality in pools along the Goulburn River between Shepparton and the Murray River and found no evidence of salinity or thermal stratification and associated water quality effects (e.g. high salinity, low dissolved oxygen) when irrigation season flows were above 500 ML/d. Further monitoring of pool water quality was recommended to assess any changes to water quality during low flow periods (e.g. drought or flows below 250 - 400 ML/d).

5.6.3 Turbidity and suspended solids

High water turbidity can reduce the penetration of light into the water column and so reduce photosynthesis and primary production. Suspended solids also attenuate light penetration in the water column and deposition can smother productive habitats, such as riffle habitat used by macroinvertebrates and fish.

Turbidity levels in the Goulburn River are generally low (median less than 10 NTU) between Lake Eildon and Murchison (Appendix 4). Turbidity in the upper reaches of the Goulburn River was higher than normal when visited by the Scientific Panel, presumably as a result of increased suspended sediment in water released from the low storage levels of Lake Eildon (E. Meggitt, pers. comm.). Turbidity in the Goulburn River below Shepparton increases significantly (median greater than 20 NTU). However, there is no information available with which to assess the ecological impact of higher turbidity levels (e.g reduced primary productivity). Increased turbidity is likely to be due to a combination of inflow from the Broken River, urban runoff and irrigation drainage, the activity of carp and livestock. Carp are often implicated in increased river turbidity and are the most abundant fish in the Goulburn River. Damage to river banks from direct livestock access (e.g. destruction of vegetation and pugging of soils) is also a potential source of localised turbidity, along with tributary and localised inputs of organic matter, nutrients and pathogens.

Suspended solids concentration is generally low (median less than 20 mg/L) in the Goulburn River between Lake Eildon and Murchison (Appendix 4). The Goulburn River has a naturally low suspended load and Lake Eildon and Lake Nagambie both serve as sediment traps. Suspended solids concentration increases below Shepparton (median = 36 mg/L), due to inputs from tributaries such as the Granite Creeks and the Broken River. The Goulburn River is recognised as a significant source of suspended sediment to the Murray River. The

Scientific Panel noted higher concentrations and the deposition of sediments on important in-channel habitat in the lower reaches of the Goulburn River during its visit.

5.6.4 Index of Stream Condition Scores

The Index of Stream Condition (ISC) was developed as a tool to assist water managers assess condition, set management objectives and measure the effectiveness of long term programs for the rivers in their catchment (Ladson *et al.* 1999). The ISC integrates information on the major components (sub-indices) of river systems: the current river flow regime, water quality, condition of the channel and riparian zone and the macroinvertebrate communities living in the stream. The ISC has recently been applied to:

- Benchmark the condition/health of streams across Victoria; and
- Assist Catchment Management Authorities (CMAs) to set management objectives for rivers.

ISC and sub-index scores indicates that the sites assessed along the Goulburn River below Lake Eildon are in poor to very poor condition, predominantly due to the altered hydrology of the river (Figure A1.13) (DNRE n.d.). Results indicate that the physical form and condition of the riparian zone are generally good (although conditions in the vicinity of Seymour are poor), as is the general condition of water quality.

5.6.5 Impact of water management

Water management impacts both directly and indirectly on water quality conditions in the Goulburn River. Direct relationships between flow and water quality parameters such as nutrients and turbidity are often hard to establish due to the presence and operation of Lake Eildon and Goulburn Weir. For example, Cottingham *et al*. (1995b) found there was rarely a significant relationship between flow and nutrients nitrogen and phosphorus concentration in the Goulburn River, and most of relationships that were detected were weak. Similarly, Olive and Fredricks (1997) found that while turbidity levels were highest during high flood events, there was no simple relationship between flow and turbidity in the Goulburn River at Shepparton.

Direct effects include:

- Lake Eildon and Lake Nagambie act as sediment traps, capturing a high proportion of the suspended load carried by the river. However, a combination of a naturally low sediment yield, armouring of the river bed in the upper reaches and a generally stable river channel (Erskine *et al.* 1993, Chapter 5) means that the sediment trapping efficiency of Lake Eildon and Lake Nagambie is not currently a big risk to water quality (e.g. as a result of increased incision into the riverbed).
- Cold water releases from Lake Eildon have been noted in previous sections as a potential impediment to the establishment of native flora and fauna in the upper reaches of the study area.

Potential risks associated with higher nutrient, suspended solids and turbidity in the lower reaches of the Goulburn River are greatly influenced by catchment scale factors, such as gully erosion and land use (e.g. DeRose *et al.* 2003, GBCMA 2002a and b). Water management indirectly affects water quality conditions due to the discharge of nutrients in irrigation drainage and from water returned from intensive animal industries such as fish farms.

Increased salt loads exported from irrigation areas and, increasingly, from dryland areas also contribute to water quality conditions. While salt concentration in the Goulburn River is low, irrigation drainage and groundwater discharges are sources of salt that are predicted to increase in the future.

In summary, water quality in the Goulburn River is generally good, although nutrient, salinity and turbidity levels are higher in the lower reaches. However, these issues are best addressed via the catchment-scale programs that are currently being refined and implemented, especially as strong flow-water quality relationships are difficult to define.

Reach	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	Total	Condition
1	0	8	8	6		22	Poor
2	0	7	8	7	6	22	Poor
3	0	6	8		8	2	Poor
4	0	6	8	9		22	Poor
5	0	6	7	8		20	Poor
6	0	7	8		6	20	Poor
7	0	7	8	10		24	Poor
8	0	8	7	9	4	21	Poor
9	0					N/A	N/A
10	0	9	7			19	Very Poor
11	0	5	2				Very Poor
12	0	8	6			18	Very Poor
13	0	8	5	9		21	Poor
14	0	8	4	9	8	22	Poor

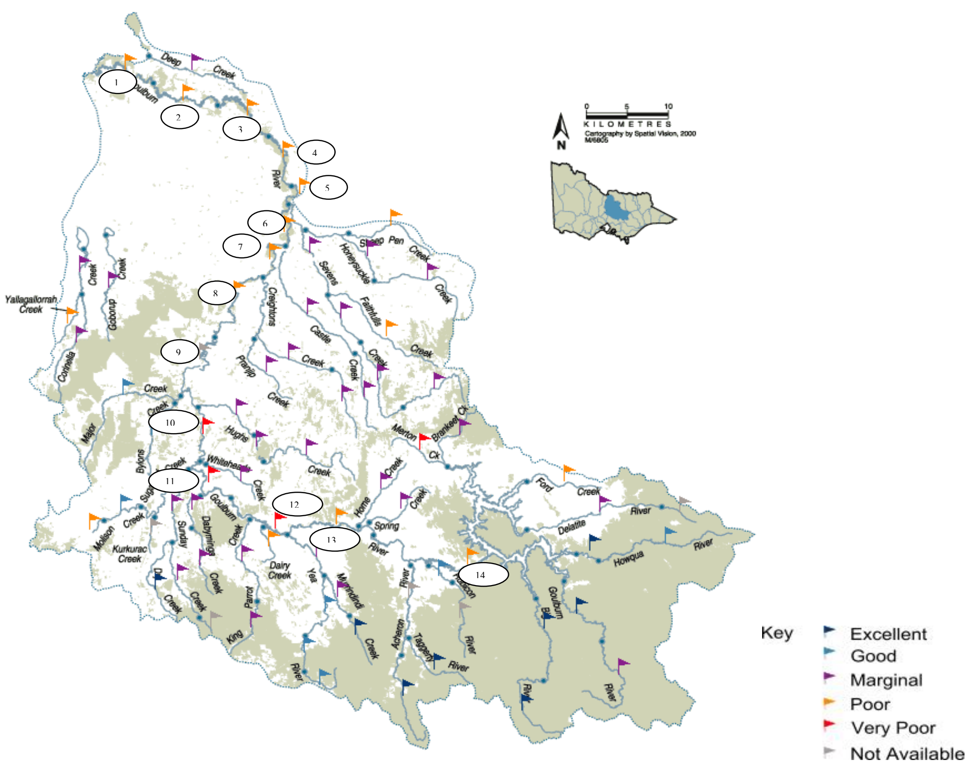

Figure A1.13: ISC scores for sites along the Goulburn River (from http://www.vicwaterdata.net)

A1-6 ENVIRONMENTAL VALUES AND FLOW-RELATED ECOLOGICAL OBJECTIVES

In the previous section, the Scientific Panel outlined important ecological and environmental features and attributes (assets) of the Goulburn River and their values. This approach is consistent with a system developed for assessing of Australian rivers (Dunn 2000), which assigns ecological value according to five categories:

- **Naturalness** – the extent to which attributes of a river are undisturbed or unmodified (e.g. unregulated flow, absence of alien flora and fauna, natural water chemistry);
- **Representativeness** – the extent to attributes of the river are ‘typical’ of natural systems (e.g. representative flora or fauna populations, representative physical features);
- **Diversity and richness** – both of physical features such as sediments and habitats, and of in-channel, wetland and floodplain flora and fauna;
- **Rarity** – the presence of threatened physical features, flora and fauna;
- **Special features** – such as ephemeral floodplain wetlands, dryland rivers with no opening to ocean, cave systems.

The risks posed by the current flow regime (and its management) to the attributes and values associated the Goulburn River can then be used as the basis for developing flow-related ecological objectives. Environmental flow recommendations can then be set to achieve the flow-related objectives. As outlined in the FLOWS method (DNRE 2002), recommendations have two features: (i) they define the component of the flow regime to be modified (e.g. low flow, bankfull flow) and (ii) they identify the timing (e.g. seasonality) and nature of releases (e.g. to provide 10 cm depth of riffle habitat). Recommendations should also relate to a quantified, predicted ecological outcome.

6.1 Summary of issues and objectives

The information presented in Chapter 5 has been summarised into the following tables, which outline:

- The attribute of the river system (e.g. macroinvertebrate or fish communities);
- Features that have an ecological value;
- Ecological objectives and the flow-related threats;
- Components of the flow regime that will be considered when developing environmental flow recommendations; and
- Other complimentary management issues that will help maximise the ecological outcomes of an environmental flow regime.

It should be noted that the flow components and objectives listed in Tables A1.12-17 are preliminary. The Scientific Panel has yet to fully consider and quantify the nature of the threats posed by aspects of the current flow and management regime for the Goulburn River, particularly on a reach-by-reach basis. The development of more detailed flow-related objectives and specific flow recommendations is part of Stage 2 of the FLOWS method (see Chapter 7).

Table A1.12: Ecological features and flow components to be assessed for aquatic, riparian and wetland vegetation of the Goulburn River

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
Vegetation	In-channel	• Macrophyte stands that provide habitat for fauna such as fish and invertebrates and contribute to river productivity	Fair	• Enhance the extent and diversity of aquatic vegetation	✓✓✓	• Armouring of the stream bed (Reach 1) • Cold water (Reaches 1-3) • Loss of shallow water areas (Reaches 1-3)	• Flushes that initiate the movement of fine sediments	• Amelioration of cold water released from Lake Eildon
	River bank	• Longitudinally continuos riparian vegetation, dominated by native species	Good	• Maintain diversity • Reduce impact of weeds	✓	• Constant flows	• Variability of low flow • Variability of high flow	• Riparian rehabilitation and management • Weed control program • Management of livestock access
	Wetland	• Representative and natural vegetation communities	Variable - poor to good	• Enhance the extent and diversity of aquatic vegetation	✓✓	• Reduced frequency, seasonality and duration of flood events	• Timing, frequency and duration of out of channel flows	• As above
	Floodplain matrix	• Variability and connection between vegetation communities	Poor to good	• Enhance the extent and diversity of aquatic vegetation	✓✓	• Reduced frequency, seasonality and duration of flood events	• Timing, variability and duration of flood flows	• Best practice land management
Floodplain	Connectivity with channel	• Heterogeneous floodplain hydraulic characteristics	Poor - moderate	• Flood regime has all the elements of a natural floodplain, including ➢ Seasonality ➢ Frequency ➢ duration	 ✓✓✓ ✓✓✓ ✓✓✓	• Reduced frequency, seasonality and duration of flood events	• Variability of out of channel flows	• Best practice land management • Review of levees and blockbanks

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
	Floodplain matrix	Heterogeneous floodplain mosaic	Poor - moderate	• Connection of floodplain ecotypes, including grasslands, woodlands, permanent and temporary wetlands	✓✓	• Reduced frequency, seasonality and duration of flood events	• Variability and seasonal pattern of out of channel flows	• Best practice land management • Review of levees and blockbanks

Table A1.13: Ecological features and flow components to be assessed for macroinvertebrates in Reach 1 of the Goulburn River (Lake Eildon to Molesworth)

Ecological Attribute	Feature	Environmental /ecological value	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management to consider
Invertebrates: In-channel	Functional trophic relationships	• Processing of organic matter and nutrients • Source of food for fish	• Moderate Very variable. May reflect local influence of tributaries, backwaters & other inputs of organic matter	• Trophic structures more closely resembling local tributaries	✓✓✓	• Seasonal flow inversion • Bed armouring • Cold water • Less abundant aquatic and riparian vegetation • Reduced C inputs due to reduced flood frequency and extent • Changed nature of carbon from CPOM to algal-based POM plus dissolved?	• Seasonality of low flows and flushes • Frequency of flushes that initiate sediment movement • Seasonality and frequency of flooding	• Amelioration of cold water releases from Eildon • Control of introduced fish species
	Biodiversity	• Diversity of community structure	• Poor-moderate	• Ausrivas O/E scores = Band A	✓✓			
	Biomass	• Natural rates of river productivity • Source of food for fish	• Probably poor /unbalanced	• Biomass equivalent to nearby tributaries	✓✓	• As above Note also loss of carbon through settling in Lake Eildon	• As above	• As above

Ecological Attribute	Feature	Environmental /ecological value	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management to consider
Invertebrates: Wetlands (No data available)	Functional trophic relationships	• Processing of organic matter & nutrients. Diverse food for fish and terrestrial vertebrates (birds, bats)	• Probably poor. Likely to be concentrated in a few groups eg midges, mosquitos, microinvertebrates	• Dynamic, diverse food webs	✓✓✓	• Disrupted wetting/drying cycle	• Seasonality and frequency of Out-of-channel flows	• Control of introduced fishes
	Biomass	• Production of food for fish & terrestrial vertebrates	• No information	• Biomass expressed in diverse organisms supporting diverse floodplain system	✓✓✓	• as above	• Seasonality and frequency of Out-of-channel flows	• Modify levees and block banks • Control stock access (pugging and grazing) • Aquatic, emergent, bank vegetation restored.

Table A1.14: Ecological features and flow components to be assessed for macroinvertebrates in Reach 2 and 3 of the Goulburn River (Molesworth to Nagambie)

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
Invertebrates: In-channel	Functional trophic relationships	• Processing of organic matter, nutrients and microbiota • Source of food for fish	• Reduced diversity. Few herbivores, increased omnivores (reflecting turbidity, reduced plants)	• Trophic structure and diversity more closely resembling upstream sites	✓✓✓	• Seasonal flow inversion • Cold water • Less abundant aquatic and riparian vegetation • Reduced C inputs due to reduced flood frequency and extent	• Seasonality of low flows and flushes • Short-term fluctuations to counteract turbidity & encourage plant growth • Seasonality and frequency of flooding	• Amelioration of cold water releases from Eildon • Control of introduced fish species • Aquatic, emergent and riparian vegetation and snags protected or restored • Modify levees and block banks • Control stock access (pugging and grazing)
	Biodiversity	• Diversity of community structure	• Reduced (see above)	• Ausrivas O/E scores = Band A	✓✓	• As above	• As above	
	Biomass	• Natural rates of river productivity • Source of food for fish	• Poor/ unbalanced	• Biomass equivalent to similar streams elsewhere e.g. Ovens	✓✓	• As above • reduced productivity relating to: - altered wetting/drying cycle - interaction between turbidity and flow variation	• Seasonality and frequency of Out-of-channel flows • Short-term variability	• As above

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
In Wetlands (No data seen)	Functional trophic relationships	• Processing Org. Matter & Nutrients. • Diverse Food for fish and terrestrial vertebrates (birds, bats)	• Highly variable – depending on land use	• Dynamic food webs maintaining wetland diversity and productivity	✓✓✓	• Reduced frequency and changed seasonality of over-bank flows	• Seasonality and frequency of Out-of-channel flows	• As above
	Biodiversity	• Provide resilience and trophic support sustainability.	• As above	• Diverse, resilient communities through full range of physical conditions	✓✓✓	• As above	• As above	• As above
	Biomass	• Productivity Food for fish & terrestrials	• As above	• Biomass expressed in diverse organisms supporting diverse floodplain system	✓✓✓	• As above	• As above	• As above

Table A1.15: Ecological features and flow components to be assessed for macroinvertebrates in Reach 4 and 5 of the Goulburn River (Nagambie to the Murray River)

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
Invertebrates: In-channel	Functional trophic relationships	• Processing of organic matter , nutrients and microbiota • Source of food for fish	• Reduced diversity. Few herbivores, increased omnivores (reflecting turbidity, reduced plants?) and detritivores	• Trophic structure and diversity with a more balanced representation of all functional groups	✓✓✓	• Reduced winter flows • Constant summer flows • Smothering by settling material • Less abundant aquatic and riparian vegetation • Reduced C inputs due to reduced flood frequency and extent	• Seasonality of low flows and flushes • Short-term fluctuations to shift fine sediment, counteract turbidity & encourage plant growth • Frequency of flooding	• Protection of riparian vegetation • Limit stock access on banks
	Biodiversity	• Diversity of community structure	• Depressed (see above)	• Ausrivas O/E scores = Band A	✓✓	• As above	• As above	• As above
	Biomass	• Natural rates of river productivity • Source of food for fish	• Moderate to very poor/ unbalanced	• Biomass equivalent to similar streams elsewhere e.g. Ovens	✓✓	• As above • reduced productivity relating to: - altered wetting/drying cycle - low velocity/ settling sediment - interaction between turbidity and flow variation	• Seasonality and frequency of Out-of-channel flows • Short-term variability	• Modify levees and block banks • Control stock access (pugging and grazing) • Aquatic, emergent, bank vegetation restored

Ecological Attribute	Feature	Environmental/ecological asset	Condition	Ecological objectives	Extent that objectives are flow related	Flow related threats	Flow components to be addressed	Complementary management required
In Wetlands (No data seen)	Biomass	• Processing Org. Matter & Nutrients. • Diverse Food for fish and terrestrial Verts. (birds, bats)	• Some good. Highly variable – depending on land use	• Dynamic food webs maintaining wetland diversity and productivity.	✓✓✓	• Reduced frequency and changed seasonality of over-bank flows	• Seasonality and frequency of Out-of-channel flows	• As above • Protect natural vegetation
	Functional trophic relationships	• Provide resilience and trophic support sustainability.	• As above	• Diverse, resilient communities through full range of physical conditions	✓✓	• As above	• As above	• As above
	Biodiversity	• Productivity - food for fish & terrestrials	• Often poor but sometimes high	• Biomass expressed in diverse organisms supporting diverse floodplain system	✓	• As above	• As above	• As above

Table A1.16: Ecological features and flow components to be assessed for native fish populations in Reaches 1-3 (Lake Eildon to Nagambie).

Ecological Attribute	Environmental/ ecological asset	Ecological objectives	Feature/group	Condition	Extent that objectives are flow related	Flow components to be addressed	Complementary management required
Fish	• Diversity of native fish • Naturally reproducing and self sustaining populations of native fish • Populations of threatened and icon species	• Suitable thermal regime for spawning, growth and survival of all life stages	Flood spawners Macquarie perch Main channel generalists Main channel specialists Low flow specialists	• Poor • Poor • Poor • Poor • Poor	✓	• Not addressed by flow change	• Mitigation of cold water releases
		• Suitable in-channel habitat for all life stages	Flood spawners Macquarie perch Main channel generalists Main channel specialists Low flow specialists	• Poor • Poor • Poor • Poor • Poor	✓✓✓	• Baseflow (all year)	• Protection of existing habitat and habitat restoration • Management of introduced fish
		• Suitable off-channel habitat for all life stages	Wetland specialists	• Fair	✓✓	• Overbank flows (natural timing and duration)	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks • Management of introduced fish

Ecological Attribute	Environmental/ ecological asset	Ecological objectives	Feature/group	Condition	Extent that objectives are flow related	Flow components to be addressed	Complementary management required
		• Passage for all life stages	Flood spawners Macquarie perch Main channel generalists Main channel specialists Low flow specialists	• Poor • Poor • Poor • Poor • Poor	✓✓	• Baseflow (all year)	• Removal of instream barriers and/or installation of fish ladders
		• Cues for adult migration during spawning season	Flood spawners Macquarie perch Main channel specialists	• Poor • Poor • Poor	✓✓✓	• Freshes (Oct-Feb)*	• Mitigation of cold water releases • Removal of instream barriers
		1. Access to floodplain and off-channel habitats for spawning and/or larval rearing	Flood spawners	• Poor	✓✓✓	• Overbank flows (Oct-Feb)*	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks
		2. Low flows for spawning and recruitment	Low flow specialists	• Poor	✓✓✓	• Low flow periods (Sep-Feb)*	• Protection of existing habitat and habitat restoration • Management of introduced fish

Ecological Attribute	Environmental/ ecological asset	Ecological objectives	Feature/group	Condition	Extent that objectives are flow related	Flow components to be addressed	Complementary management required
		3. Floodplain and bench inundation for exchange of food and organic material between floodplain and channel	Flood spawners Macquarie perch Wetland specialists Main channel generalists Main channel specialists Low flow specialists	• Poor • Poor • Fair • Poor • Poor • Poor	✓✓✓	• Freshes (natural timing and duration) • Overbank flows (natural timing and duration)	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks

* Flow components considered low priority unless cold water releases are mitigated, as temperatures are currently too low to achieve the ecological objective.

Table A1.17: Ecological objectives for native fish populations in Reach 4 (Nagambie to Loch Garry) and Reach 5 (Loch Garry to the River Murray).

Ecological Attribute	Environmental/ ecological asset	Ecological objectives	Feature/group	Condition	Extent that objectives are flow related	Flow components to be addressed	Complementary management required
Fish	• Diversity of native fish • Naturally reproducing and self sustaining populations of native fish • Populations of threatened and icon species	• Suitable in-channel habitat for all life stages	• Flood spawners • Macquarie perch • Freshwater catfish • Main channel generalists • Main channel specialists • Low flow specialists	• Poor • Poor • Poor • Fair • Fair-Poor • Fair	✓✓✓	Baseflow (all year)	• Protection of existing habitat and habitat restoration • Introduced fish management
		• Suitable off-channel habitat for all life stages	• Wetland specialists • Freshwater catfish	• Fair • Poor	✓✓	Overbank flows (natural timing and duration)	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks • Introduced fish management
		• Passage for all life stages	• Flood spawners • Macquarie perch • Freshwater catfish • Main channel generalists • Main channel specialists • Low flow specialists	• Poor • Poor • Poor • Fair • Fair-Poor • Fair	✓✓	Baseflow (all year)	• Removal of instream barriers

Ecological Attribute	Environmental/ ecological asset	Ecological objectives	Feature/group	Condition	Extent that objectives are flow related	Flow components to be addressed	Complementary management required
		• Cues for adult migration during spawning season	• Flood spawners • Macquarie perch • Main channel specialists	• Poor • Poor • Fair-Poor	✓✓✓	Freshes (Oct-Feb)	• Mitigation of cold water releases • Removal of instream barriers
		• Access to floodplain and off-channel habitats for spawning and/or larval rearing	• Flood spawners	• Poor	✓✓✓	Overbank flows (Oct-Feb)	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks
		• Low flows for spawning and recruitment	• Low flow specialists	• Fair	✓✓✓	Low flow periods (Sep-Feb)	• Protection of existing habitat and habitat restoration • Introduced fish management
		• Floodplain and bench inundation for exchange of food and organic material between floodplain and channel	• Flood spawners • Macquarie perch • Wetland specialists • Freshwater catfish • Main channel generalists • Main channel specialists • Low flow specialists	• Poor • Poor • Fair • Poor • Fair • Fair-Poor • Fair	✓✓✓	Freshes (natural timing and duration) Overbank flows (natural timing and duration)	• Riparian and floodplain wetland management • Removal of unnecessary levees and block banks

A1-7 DEVELOPMENT OF ENVIRONMENTAL FLOW RECOMMENDATIONS

Environmental flow recommendations will be developed using the process outlined in the FLOWS methodology (DNRE 2002). The steps involved in the FLOWS method include:

Stage 1:

- Project inception;
- Data collation;
- Documentation of representative sites/reaches (site paper).
- Field assessment by Panel members;
- Development of an issues paper - highlight environmental assets and key threats, and flow-related ecological objectives that serve as the basis for environmental flow recommendations.

Stage 2:

- Hydraulic and hydrological analysis to develop environmental flow recommendations that address flow-related ecological objectives
- Reporting to key stakeholders (final report).

A key feature of the FLOWS method is the consideration of different (generic) components of a flow regime (Figure A1.14) that are likely to be ecologically important:

- Cease to flow – periods where no flow is recorded in the river channel, which can lead to partial or complete drying of the river bed. During these periods, the river can contract to a series of pools that act as a refuge for in-stream biota.
- Low flows – the low flow that generally provides a continuous flow through the channel. The flow may be limited to a narrow area of the channel in the high points of the stream, but will provide flow connectivity between habitats within the channel.
- Freshes – are small and short duration flow events that exceed the baseflow of the previous few days (e.g. following summer rainfall events). These are important to refresh water quality in pools after periods of low flow or cease to flow and to move silt from productive substrates.
- High Flows (in channel) – persistent increase in baseflow that occurs with the onset of the wet season. These are flows that cover the bed and some low in-channel benches. This allows full connection between all habitats in the river, important for fish passage during migration.
- Bankfull flows – flows that fill the channel, but do not spill onto the floodplain. The have mainly geomorphological functions, maintaining the channel shape and form (preventing in-filling of pools for example). The impact of river regulation is mainly to reduce the frequency of these flows when water is stored over the high flow season.
- Overbank flows – exceed the bankfull flow and spill out of the channel onto the floodplain. These are ecologically important for wetlands, and for bringing food (either carbon dissolved for the floodplain floor, or in the form of leaves and twigs) to the stream channel. The rising limb of an overbank flow represents the ‘commence to flow’ for floodplain features such as wetlands. On the receding limb, the bankfull level represent a ‘cease to flow’ for floodplain features.

While the FLOWS method provides important direction on the ecologically significant components of the flow regime that should be considered when developing environmental flow recommendations, there is little guidance on how to assess the past and current impacts of regulation, or the likely impacts of environmental flows. Therefore, the Flow Events Method (FEM) developed by the CRC for Catchment Hydrology (Stewardson 2001) will be used to supplement the FLOWS method. FEM is a framework that facilitates the analyses of key flow events by comparing the current flow regime to natural. It complements the FLOWS method in developing environmental flow recommendations and was used successfully the Bulk Water Entitlement (BE) process in the Broken River in North East Victoria (Stewardson and Cottingham 2002) and on the Loddon River. As applied to the Broken River system, the FEM was used to:

- Identify the habitat potentially affected by flow variation, particularly for native fish, macroinvertebrates and in-stream and riparian vegetation;
- Characterise flow events to be considered;
- Assess changes to ecologically important aspects of the flow regime, based on changes to flow event recurrence interval;
- Set flow targets to achieve ecological outcomes to be achieved with the delivery of environmental flows in the future.

This process is aided by the construction of daily flow models and data sets, and hydraulic modelling of representative sites within reaches of the study river. A hydraulic model has been constructed to assist with the application of the FEM to the Goulburn River.

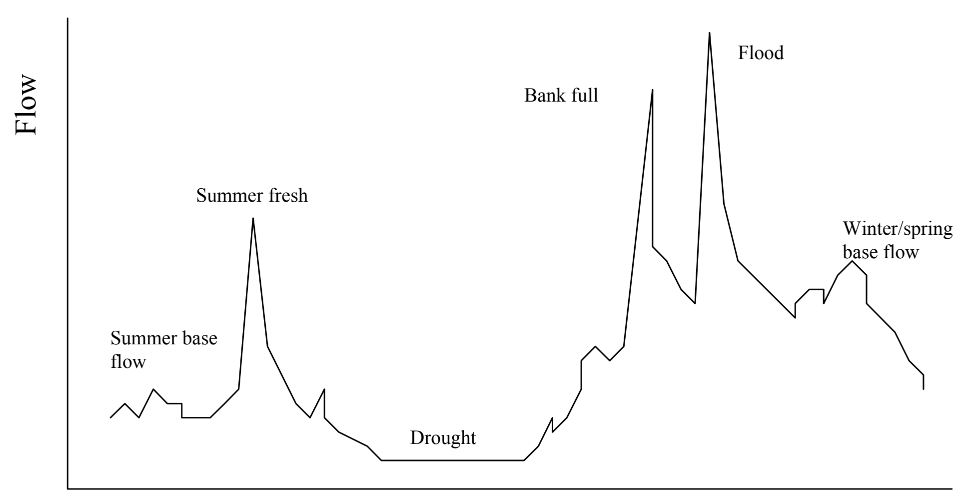

Figure A1.14: Time series showing different components of a natural flow regime

A1-8 CONSTRAINTS ON ENVIRONMENTAL FLOW RECOMMENDATIONS AND COMPLEMENTARY RIVER MANAGEMENT ACTIONS

The Scientific Panel will consider a number of operational and environmental constraints as it develops detailed environmental flow recommendations. The ecological condition of the Goulburn River is the result of many factors operating at different spatial and temporal scales. Many of these factors may not be directly related to the flow regime of the river but can certainly reduce or confound the potential effects of environmental flows when they are delivered. For example, factors such as Goulburn Weir being a barrier to fish movement and colder than natural summer water temperatures below Lake Eildon, in isolation or together, can reduce the effectiveness of environmental flows recommended to re-establish or enhance native fish populations between Lake Eildon and Lake Nagambie.

8.1 Constraints on environmental flow recommendations

The Scientific Panel will consider the following constraints as it develops environmental flow recommendations. Where final recommendations have the potential for adverse social or economic impacts, the Panel will acknowledge these.

- The capacity to release large volumes of water from Lake Eildon (release capacity 17,500 ML/d) and the potential for minor flooding, with potential bed and bank erosion and damage to infrastructure and assets;
- The potential that the ecological outcomes expected with additional releases may be negated if the water temperature is too cold. It is recognised that ameliorating cold water releases poses some risk to trout fisheries and trout farms;
- The Panel does not have sufficient resources to model the salinity implications of any recommendations. The MDBC may be approached to undertake salinity modelling at a future date;
- Lack of flexibility in operations due to level of commitments and extensive rules for operating Lake Eildon and unpredictable short-term demands associated with hydroelectricity power generation;
- High demands for Goulburn water from outside of the catchment and potential future demands, for example in providing more water for the Murray River;
- Balancing differences in the volumes required to inundate floodplain areas in middle reaches with that of downstream reaches;
- Unknown but extensive changes to surface and connections (e.g. small block banks, excavated channels into out of wetlands)
- Land management practices
- The maintenance of Lake Nagambie as an important recreation and social amenity.

8.2 Complementary River Management Actions

Complementary (non flow-related) management actions required to increase the likelihood of successful ecological outcomes to be considered by the Scientific Panel will include:

- Amelioration of cold water releases from Lake Eildon;
- Retention of the ban on gravel extraction from the river;
- Review and removal of unnecessary levees and block banks;
- Exclusion of livestock from the riparian zone;
- Continuation of rabbit control measures;

- Provision of fish passage past Goulburn Weir;
- Continuation of carp control strategies;
- Continued implementation of the Goulburn Broken water quality and revegetation strategies.

A1-9 LEVELS OF SCIENTIFIC EVIDENCE

A lack of transparency related to the quality of information used to develop environmental flows is a common limitation to the Scientific Panel process (Cottingham *et al*. 2002). To overcome this issue, a scheme consistent with that developed for the Living Murray process has been adopted to assign a qualitative ranking to the **information** that is available for the Goulburn River system:

- **High** - expert judgement supported by data and consensus knowledge related directly to the study area from published papers and technical reports;
- **Moderate** - expert judgement supported by unpublished data and knowledge, which can be made available for public consideration (e.g. via websites and technical reports);
- **Low** - expert judgement based on general scientific experience or anecdotal information.

A summary of the quality of information available to this study is presented in Table A1.18.

Table A1.18: Levels of scientific evidence used in this report

Discipline	Ranking	Comments
Hydrology impacts	High	Good information directly relevant to the study area. Consensus on large hydrological impacts from peer reviewed scientific reports and high quality technical reports
Geomorphology	High	Good information from peer reviewed scientific reports and high quality technical reports
Floodplain interactions	Moderate	No peer reviewed scientific papers but high quality technical reports and excellent mapping of the floodplain
Fish ecology	Moderate	Some useful peer reviewed papers, technical reports and data from extensive databases, but little published information on the ecology of native fish species in the study area
Vegetation	Moderate to low	Good information on species present and some aspects of condition (numerous technical reports and management plans) but information on ecological responses to changed flow regimes is poor and it is hard to separate flow responses from that of other influences such as catchment effects and drought
Invertebrates	Moderate to low	Moderate information on condition from existing monitoring programs and extensive databases but information on ecological responses to changes to the flow regime is poor. The is no information on wetland inverterbates.
Water quality	Moderate to high	Some peer reviewed reports directly relevant to the study area and extensive databases with good quality data. However, separation of flow-related changes to water quality from wider catchment influences is difficult.

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APPENDIX 2 JUSTIFICATION FOR SELECTION OF SURVEY REACHES

Goulburn River Environmental Flow Study

Justification for selection of survey reaches

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Michael Stewardson

Peter Cottingham

Terry Hillman

November 2002

Introduction

Standard approaches to defining environmental flows for streams often involve the identification of representative river reaches. Cross-sections surveyed in these reaches are used in 1 or 2D hydraulic models to relate flow regime to habitats. The location and character of these reaches is critical to the success of the project because these reaches are used to define the environmental flow regime.

The following is a rationale for selecting survey sites for the Goulburn River between Lake Eildon and the River Murray. In this case, a site refers to a section of river within a representative reach that contains examples of the major geomorphic and ecological features typical of that reach. The survey data collected will be used to construct a hydraulic model of the Goulburn River, which will be an important tool when considering the environmental water requirements of the river.

Representatives from the CRC for Catchment Hydrology and CRC for Freshwater Ecology (the selection panel) visited sections of the Goulburn River in August and October 2002 to locate sites for cross section surveys. Potential sites were selected after examining topographic maps, aerial photographs, previous surveys of the river and its floodplain, and consultation with Goulburn-Broken CMA staff. The potential sites were then visited and those deemed suitable for survey confirmed.

Representative reaches

Reaches are selected on the premise that they are representative of the stream between the reaches. Selection methods normally divide the river into reaches based on planform, confinement, major tributaries or significant points of system operation (e.g. major weirs or offtakes). It is possible to identify several reaches on the Goulburn River in this way. For example, Erskine *et al.* (1993) defined nine reaches between Eildon and Nagambie based on sinuosity of the channel. The survey of three long reaches (3 km each) between Lake Eildon and Nagambie and two below Nagambie was considered appropriate to this study. The reaches were selected to represent both straight and sinuous sections of the river, such as those defined by Erskine *et al*. (1993).

The characteristics used to identify reaches and select sites were consistent with those recommended in the FLOWS manual (DNRE 2002):

- Location of major tributaries,
- Channel morphology and structure,
- Floodplain morphology and structure,
- Presence of key habitats of value,
- System operation, and
- Flora and fauna structure and function.

Where possible, these characteristics were assessed using a recent colour aerial photographic series held by the Goulburn Broken CMA, survey plans, local information and the selection panel's knowledge of the river. Once candidate sites were identified, site inspections were carried out to finalise selection. It should be noted that the preliminary examination of aerial photographs and plans, combined with discussions with CMA staff, were a useful addition to the procedure recommended in the FLOWS manual. The meeting with the CMA provided a more complete, if less detailed, picture of variations in the character of the Goulburn River.

This complemented the site visits undertaken by the selection panel, which was constrained due to access and available time.

Summary of sites selected
Five sites were selected for cross section survey (Table A2.1).

Table A2.1: Goulburn River cross section sites between Lake Eildon and Murchison

Site Number	Name	Location	Description
G1	Alexandra	E 379 723 N 5 881 356	Downstream of Alexandra at the end of Binns McRaes Rd
G2	Ghin Ghin	E 351 328 N 5 884 356	Homewood at the end of Bryant's Lane
G3	Northwood	E 334 879 N 5 910 669	Northwood at the end of Gerard's Road
G4	Murchison	E 340 444 N 5 946 333	Picnic area at downstream end of Murchison
G5	Wyuna	E 322 125 N 5 996 393	End of Murrumbidgee Road

The Acheron River is the first major tributary of the Goulburn River downstream of Lake Eildon. The selection panel discussed the merit of locating a site upstream of Acheron River to assess environmental flow requirements in this section of the river. On balance, it was decided that there was more merit in surveying the lower section with more detail than adding an additional site between Lake Eildon and Acheron River. This section of the river is subject to cold-water releases from Lake Eildon, and the negative effects of low water temperature on stream communities (e.g. native fish) are likely to confound the effects of environmental flow releases.

There is no clear break in the channel's physical character between the Acheron River confluence and the constriction of the floodplain near Kerrisdale. However, there is considerable variation in channel planform and floodplain width. The two major tributaries in this section of the Goulburn River are Home Creek and the Yea River. Two reaches were chosen to represent hydraulic variability in the reach of the river, both including straight and sinuous sections. The upper reach is upstream of both tributaries and located close to Alexandra (site G1). The second reach (G2) is downstream of both tributaries and located mid-way between the Yea River confluence and Kerrisdale. It was considered unnecessary to include a third reach between Home Creek and Yea River as this section of river is similar in character to the other two reaches and Home Creek is a relatively small tributary. Both sites were located close to survey benchmarks.

No reach was selected for the confined section of river between the floodplain constriction near Kerrisdale and Seymour. This reach is relatively short and highly variable (in planform). It was considered unrealistic to select a representative reach for this short section of the Goulburn River.

A site was chosen in a typical section of the river downstream of Seymour near Northwood (site G3). A single site was considered adequate to represent conditions between Seymour and

Lake Nagambie; this was confirmed during the site visits. The selected site was chosen because of the proximity of a survey benchmark.

The river channel below Lake Nagambie is relatively uniform, being deeply incised with clay bed and banks. The main variation in the channel is associated with the presence of benches and small point bars. These benches and point bars are likely to be the main features to be affected by flow regulation, along with the frequency and duration of flood flows into floodplain distributary channels. The site chosen at Murchison (G4) was considered representative of the Goulburn River between Lake Nagambie and Loch Garry. An additional site at Wyuna (G5) was chosen to represent the Goulburn River downstream of Loch Garry.

An additional survey site downstream of Yambuna was also considered. However, confounding factors such as large variability in channel dimensions and, particularly, the influence of backflows from the Murray River meant that any one survey site was unlikely to be representative. The development of environmental flow recommendations based on hydraulic modelling at a single site was considered unrealistic. This does not imply that the Goulburn River below Yambuna will not be considered when developing environmental flow recommendations. This section of the river clearly has environmental values that should be considered (e.g. good instream and riparian habitat, presence of threatened species etc.).

The following are other considerations that influenced reach selection and survey design.

Floodplains
Floodplain wetlands are clearly an important form of habitat associated with the Goulburn River. One of the major impacts of flow regulation on the Goulburn River has been to alter the frequency and duration of regular flooding. This is likely to have changed the pattern of filling and drying of floodplain billabongs and anabranches. Ideally, detailed surveys of the broad floodplain and floodplain-channels would allow us to model the effect of flow regulation on flooding. This modelling has been undertaken for the lower Goulburn floodplain but not for the upper Goulburn floodplain. Detailed surveys are an expensive exercise, beyond the resources available for this project. Also, the survey of only three kilometres of floodplain that would result from extending the channel cross-section surveys would be of little use for floodplain modelling. The 1935 survey of the floodplain and river does provide some good information on floodplain distributary channels between Eildon and Molesworth. It was considered that these data, possibly supplemented by a longitudinal survey of the effluent points, would provide useful information to the project team.

Benchmarks
River cross sections had to be surveyed to Australian Height Datum to allow comparison with other survey information. Benchmarks had to be reasonably close to the survey site to reduce costs for the surveys.

Access
Good access to the site is important, both for surveyors and for the Scientific Panel that will visit the river at a later date.

Gauges
The surveyed cross-sections will be used to construct a hydraulic model that will use flows derived from stream gauges. Therefore, the sites were located close enough to a gauge, or

group of gauges, that the accuracy of flow data would not be unduly influenced by tributary inputs to the river.

Compliance points

Once an environmental flow regime has been agreed, it will be necessary to evaluate compliance. Compliance is usually defined in terms of flows at specific points in the river. Implementing the environmental flow regime would be most efficient and accurate if the survey sites, located close to gauges, were also used as the compliance points.

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APPENDIX 3 SUMMARY OF HYDROLOGICAL IMPACTS

Hydrological Impact of River Regulation on the Flow Regime of the Goulburn River

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February, 2003

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School of Anthropology, Geography and Environmental Studies
The University of Melbourne

Introduction

This Appendix describes the impact of flow regulation on the flow regime of the Goulburn River. This hydrological study was conducted as part of the Environmental Flow assessment of the Goulburn River by CRC for Freshwater Ecology and CRC for Catchment Hydrology. The Assessment is based on a comparison of recorded mean daily streamflow for the period July 1975 to June 2000 and modelled natural streamflows for the same period. The data and method used to model natural flows is described in a separate appendix. These data were collated for five sites along the Goulburn River at which detailed habitat assessments have been carried out (site locations and characteristics are described elsewhere in this report). Catchment areas at these five sites and streamflow gauges along the Goulburn River are shown in Figure A3.1.

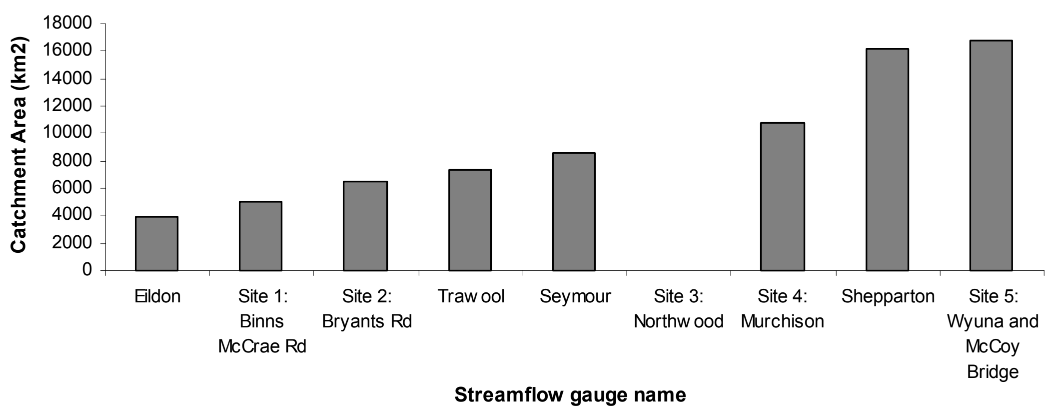


Figure A3.1: Catchment areas at channel survey sites and streamflow gauges along the Goulburn River.

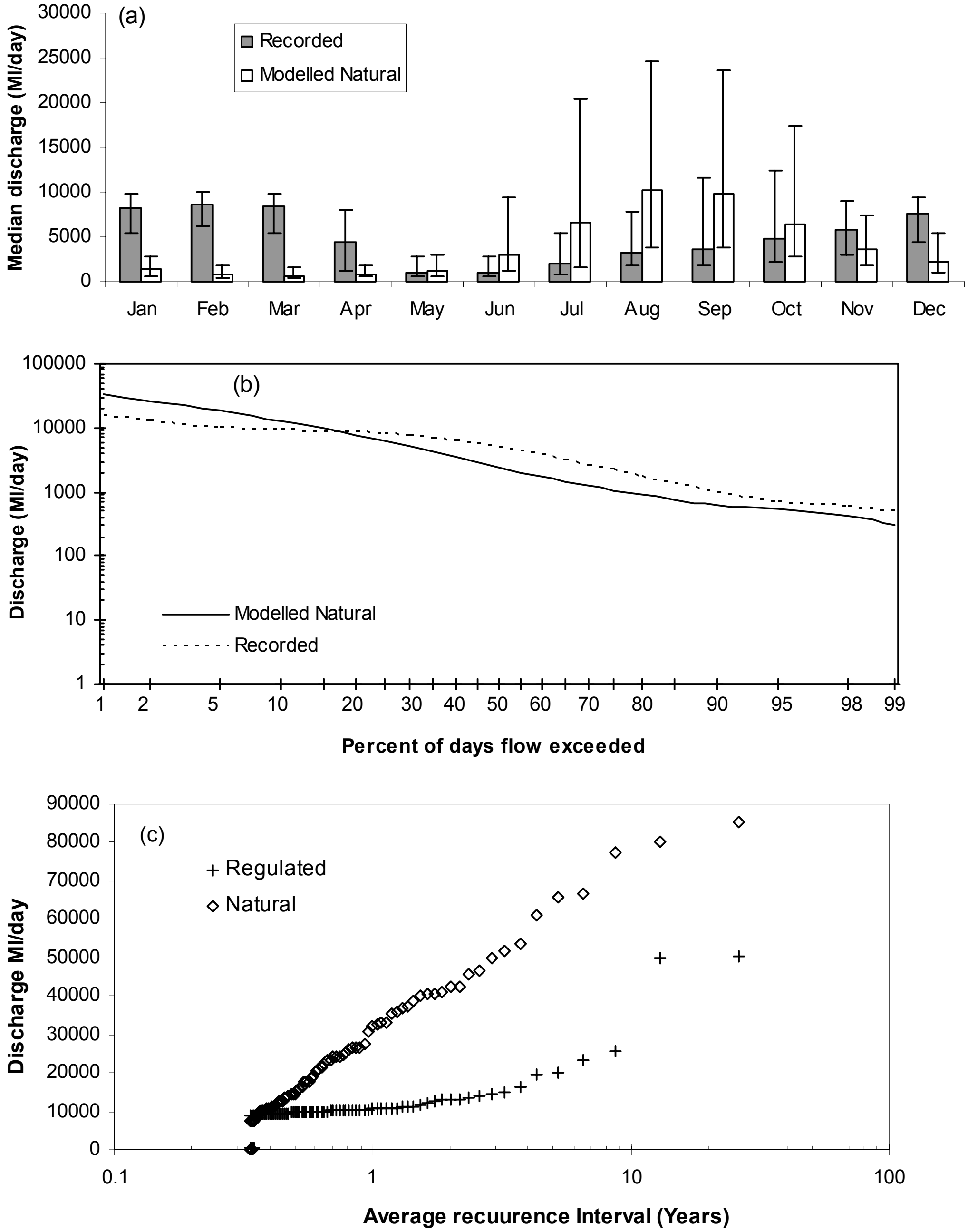
In addition to private diversions throughout the Goulburn River catchment, The Goulburn River is regulated through operation of:

- Lake Eildon and the associated Eildon Weir,
- Goulburn Weir including two channel off-takes to the west (Cattanach Channel and Stuart Murray Channel) and one to the east (East Goulburn Main Channel),
- Regulating structures within the Broken River catchment (i.e. Lake Nillahcootie, diversions to and releases from Lake Mokoan, diversions into Broken Cr at Casey's Weir)

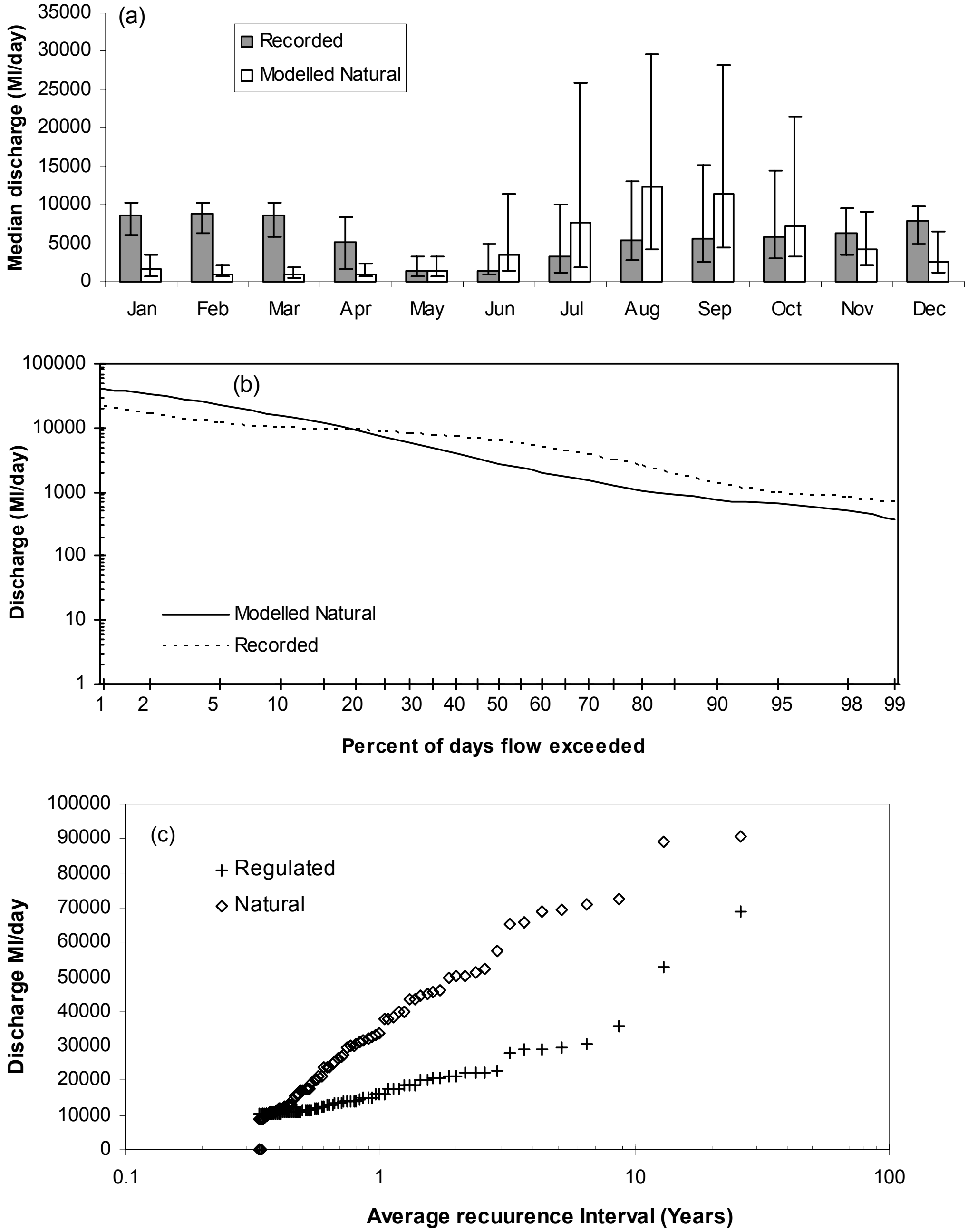
Operation of these regulating structures is described in section 3 of this report. The Goulburn River flow regime is further affected by diffuse activities within the catchment including alterations to vegetation, construction of small dams and drainage schemes, and obstructions to flood flows throughout the lowland portion of the catchment. These catchment influences on the flow regime are not considered in this assessment. However, there are extensive flood control works in the lower Goulburn River that restrict movement of floodwaters over the floodplain. The significant influence of these flood control works is described in section 3.

Previous assessments of the impact of regulation on the flow regime of the Goulburn River have been described by Gippel and Finlayson (1993) and Nathan (1992).

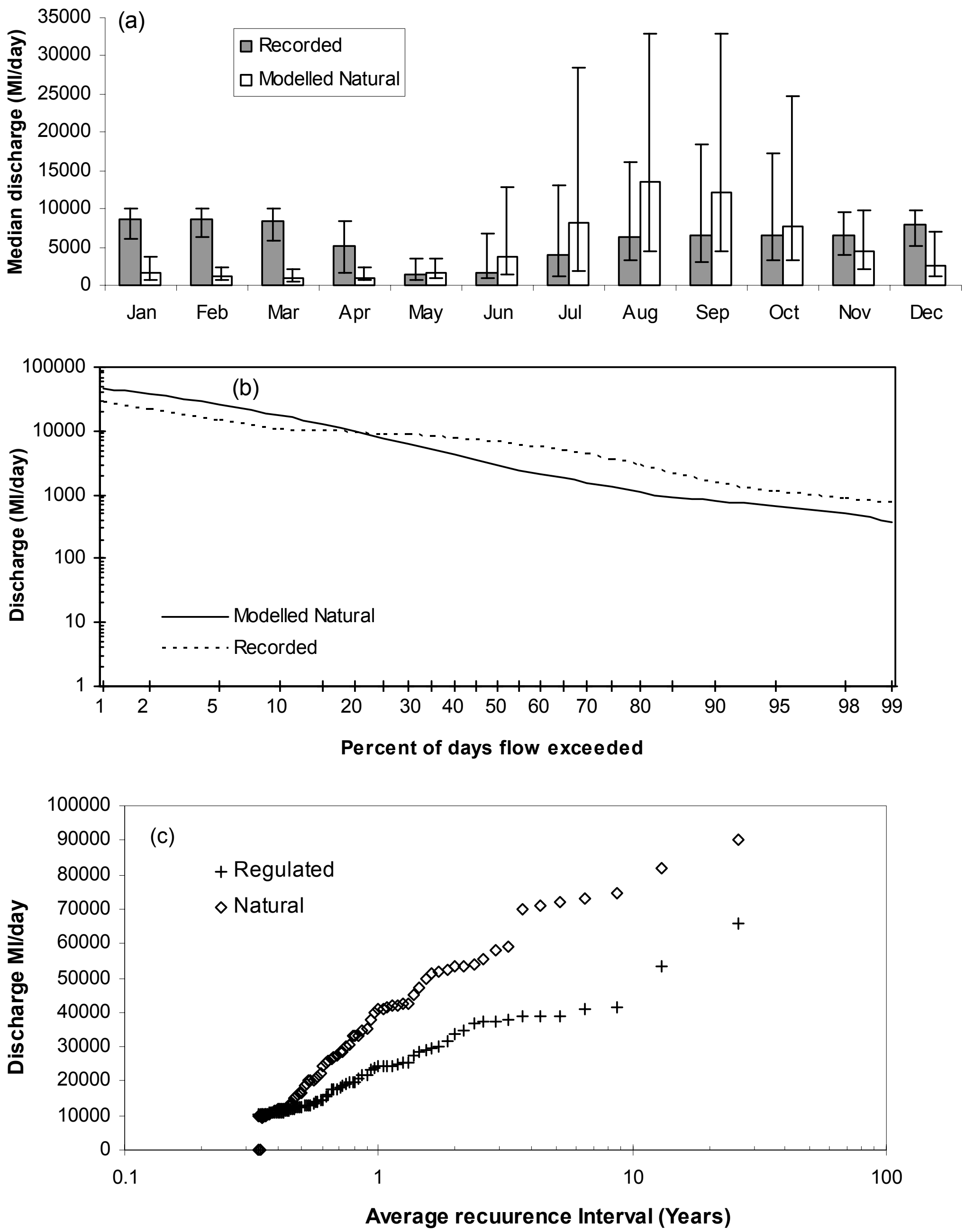
Site 1, Alexandra



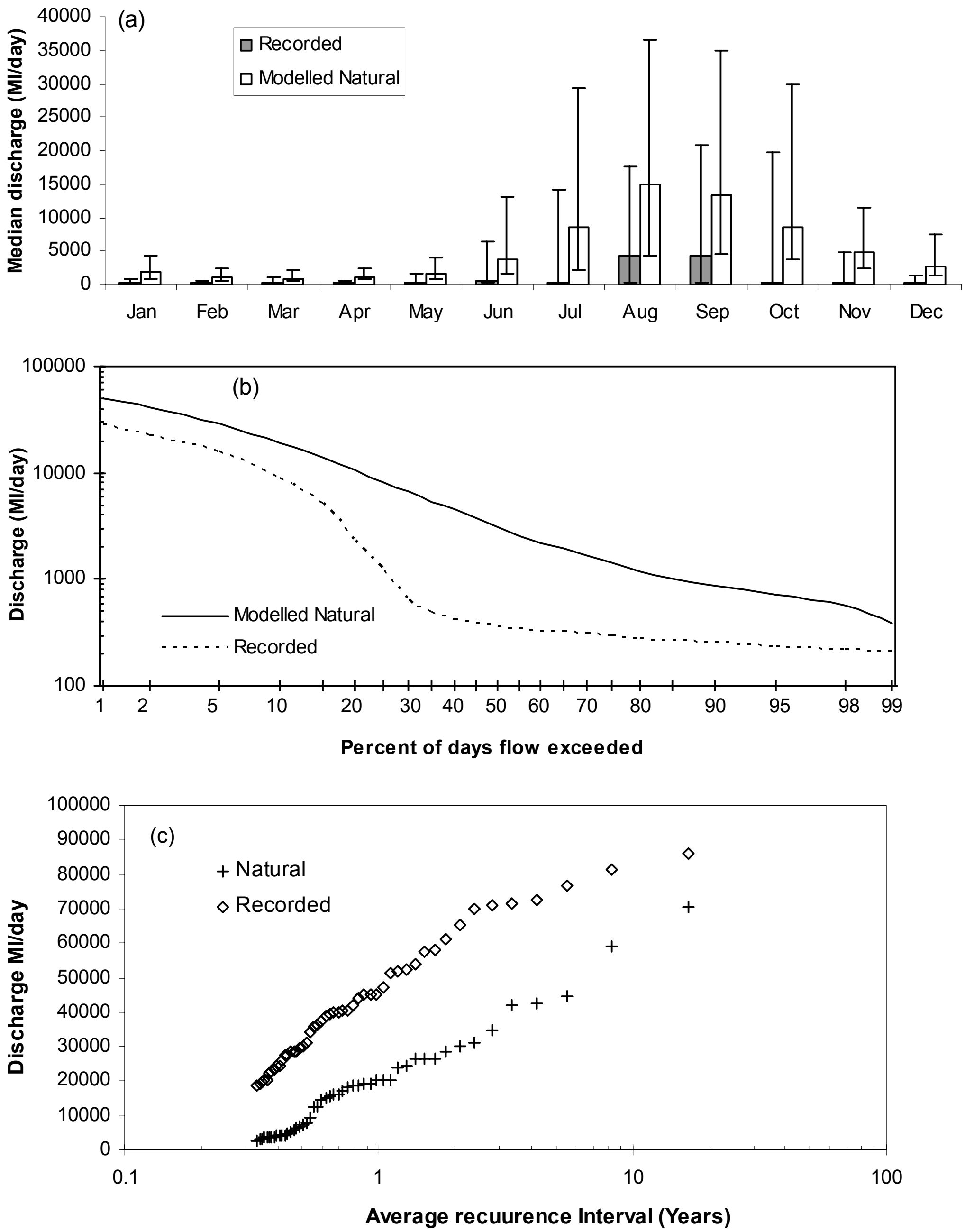
Site 2 Ghin Ghin



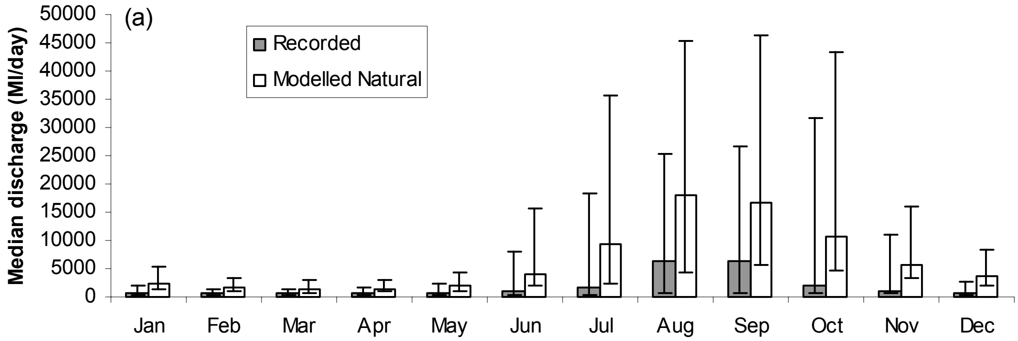
Site 3, Northwood



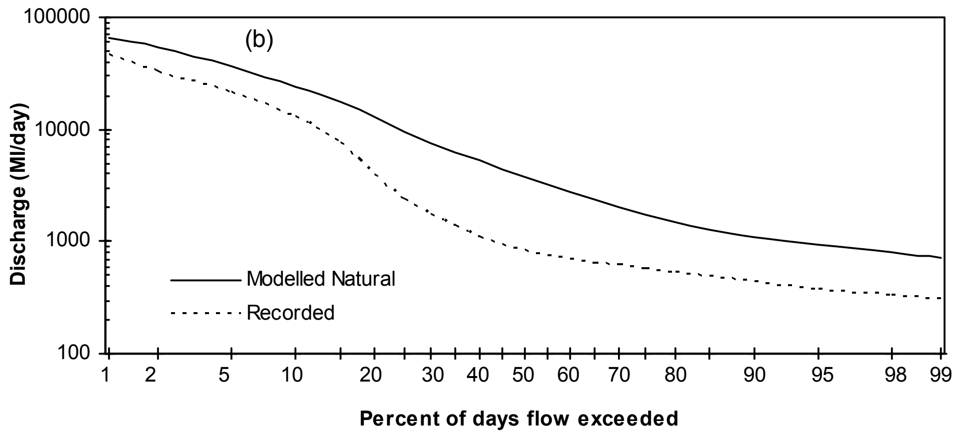
Site 4, Murchison



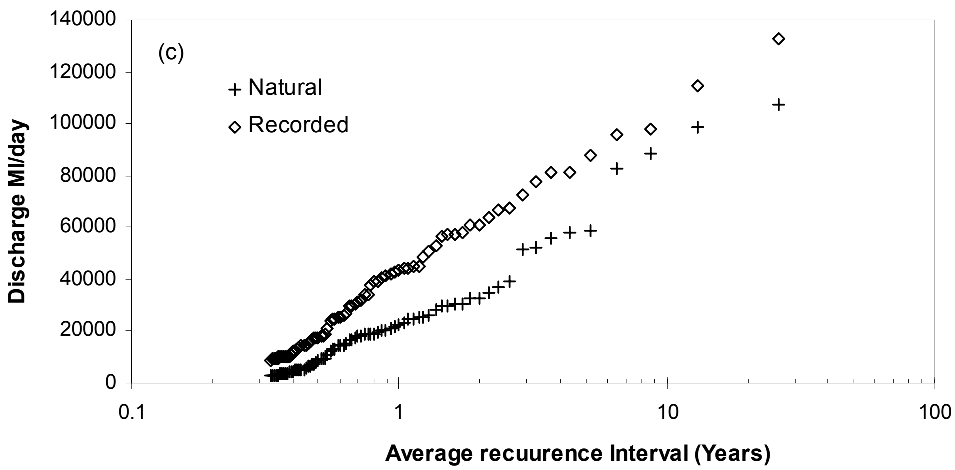
Site 5, Wyuna



(a)
Recorded
Modelled Natural
Median discharge (Ml/day)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



(b)
Discharge (Ml/day)
100000
10000
1000
100
Modelled Natural
Recorded
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent of days flow exceeded



(c)
Natural
Recorded
Discharge Ml/day
140000
120000
100000
80000
60000
40000
20000
0
0.1
1
10
100
Average recuurence Interval (Years)

APPENDIX 4 WATER QUALITY DATA

GOULBURN RIVER @ EILDON (405 203) July 1975 – October 2002

	No. of Data	Minimum	Mean	Maximum	Standard deviation.	Percentiles				
						10	25	**50**	75	90
ALKALINITY (mg/l CaCO3)	70	12.00	16.01	20.00	1.71	14.00	15.00	**16.00**	17.00	18.00
CADMIUM (mg/l)	5	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00
CHROMIUM (mg/l)	5	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00
COPPER (mg/L)	5	0.001	0.002	0.003	0.001	0.001	0.001	**0.001**	0.002	0.003
CALCIUM (mg/l)	70	1.80	2.43	3.20	0.29	2.05	2.20	**2.40**	2.60	2.75
CHLORIDE (mg/l)	70	3.00	4.72	6.00	0.74	4.00	4.00	**5.00**	5.00	6.00
COLOUR (FILT.) (Pt/Co Units)	145	5.00	13.62	80.00	9.40	5.00	9.00	**12.00**	15.00	20.00
DISSOLVED OXYGEN (mg/L)	312	5.40	9.91	15.50	1.29	8.10	9.40	**10.10**	10.60	11.20
DISCHARGE (ML/day)	320	84.0	3767.9	17192.0	3518.3	125.0	149.0	**3047.0**	7053.0	8990.5
EC (LAB) (uS/cm)	70	38.00	53.63	78.00	6.66	45.00	50.00	**54.00**	57.00	61.00
EC (FIELD) (uS/cm)	320	20.00	60.91	810.00	57.51	46.00	50.00	**54.00**	60.00	67.00
POTASSIUM (mg/l)	70	0.50	0.78	2.30	0.26	0.55	0.60	**0.71**	0.80	1.00
MAGNESIUM (mg/L)	70	1.5	2.0	3.0	0.3	1.6	1.8	**2.0**	2.2	2.3
NICKEL (mg/l)	5	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00
NITRATES AND NITRITES (mg/l)	145	0.0260	0.1080	0.2800	0.0427	0.0530	0.0780	**0.1000**	0.1300	0.1600
SODIUM (mg/l)	70	3.30	4.23	5.10	0.45	3.55	3.90	**4.30**	4.50	4.85
LEAD (mg/l)	5	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00
REACT. PHOSPHORUS (FILT) (mg/l)	144	0.0030	0.0033	0.0110	0.0009	0.0030	0.0030	**0.0030**	0.0030	0.0040
SULPHATE (mg/l)	70	1.00	2.30	7.30	0.95	1.45	2.00	**2.00**	3.00	3.00
SUSPENDED SOLIDS (mg/l)	145	1.00	3.99	56.00	6.99	2.00	2.00	**2.00**	4.00	7.00
TEMPERATURE (°C)	320	7.50	12.12	19.70	2.09	9.75	10.50	**12.00**	13.00	15.00
TOTAL KJELDAHL NITROGEN (mg/l)	144	0.070	0.172	0.600	0.072	0.100	0.120	**0.160**	0.200	0.220
TOTAL PHOSPHORUS (mg/l)	145	0.0050	0.0117	0.0560	0.0076	0.0050	0.0070	**0.0100**	0.0140	0.0200
TURBIDITY (LAB) (NTU)	1	1.6	1.6	1.6		1.6	1.6	**1.6**	1.6	1.6
TURBIDITY (FIELD) (NTU)	315	0.30	5.02	65.00	8.84	0.90	1.30	**2.00**	3.70	13.00
ZINC (mg/l)	5	0.00	0.01	0.02	0.01	0.00	0.00	**0.00**	0.01	0.02
PH (LAB) (pH)	70	4.60	6.97	7.50	0.41	6.60	6.70	**7.00**	7.30	7.40
PH (FIELD) (PH)	313	4.90	6.72	7.80	0.47	6.20	6.40	**6.70**	7.10	7.30

GOULBURN RIVER @ SEYMOUR (405202) Oct 1976 - Jul 1990

	No. of Data	**Minimum**	**Mean**	**Maximum**	**Standard deviation**	**Percentiles**				
						10	25	**50**	75	90
ALKALINITY (mg/l CaCO3)	49	13.00	17.41	24.00	2.81	14.00	16.00	**17.00**	18.00	23.00
CALCIUM (mg/l)	49	2.20	3.07	7.50	1.00	2.30	2.40	**2.70**	3.40	4.00
CHLORIDE (mg/l)	49	3.00	15.21	62.00	11.07	5.00	6.00	**15.00**	20.00	27.00
DISSOLVED OXYGEN (mg/L)	159	4.30	8.98	13.00	1.35	7.40	8.20	**9.10**	9.80	10.50
DISCHARGE (ML/day)	174	615.0	6464.4	41159.0	4539.8	1176.0	3708.0	**6553.5**	8227.0	9418.0
EC (FIELD) (uS/cm)	168	45.00	103.91	670.00	72.87	54.00	60.00	**82.00**	120.00	160.00
IRON (mg/L)	46	0.12	1.46	14.00	2.31	0.24	0.40	**0.69**	1.40	3.60
HARDNESS (mg/L)	49	10.00	21.92	63.00	8.76	13.00	17.00	**20.00**	25.00	30.00
POTASSIUM (mg/l)	48	0.10	1.04	4.60	0.73	0.40	0.70	**0.90**	1.15	2.00
MAGNESIUM (mg/L)	49	1.7	3.2	12.0	1.7	1.9	2.0	**2.7**	3.9	4.9
MANGANESE (mg/L)	46	0.01	0.02	0.12	0.02	0.01	0.02	**0.02**	0.03	0.04
NITRATES AND NITRITES (mg/l)	47	0.0300	0.1851	0.7400	0.1541	0.0670	0.0920	**0.1470**	0.2200	0.3800
SODIUM (mg/l)	49	3.10	9.79	32.00	5.67	4.30	4.90	**10.00**	13.00	17.00
SULPHATE (mg/l)	49	1.00	2.92	9.00	1.46	1.60	2.00	**2.60**	3.30	5.30
SUSPENDED SOLIDS (mg/l)	49	2.00	19.14	240.00	36.66	4.00	5.00	**8.00**	13.00	55.00
SILICA (mg/L)	47	2.9	6.6	9.1	1.2	5.1	5.9	**6.6**	7.4	7.8
TEMPERATURE (°C)	169	6.50	13.45	22.00	3.54	8.50	10.00	**14.00**	16.00	18.00
TOTAL DISSOLVED SOLIDS (mg/L)	48	0.00	68.40	200.00	37.81	33.00	40.00	**58.50**	90.50	120.00
TOTAL KJELDAHL NITROGEN (mg/l)	48	0.100	0.436	1.900	0.350	0.200	0.225	**0.300**	0.500	0.950
TOTAL ORGANIC CARBON (mg/L)	45	1.0	4.8	22.0	3.8	2.0	2.0	**4.0**	6.0	10.0
TOTAL PHOSPHORUS (mg/l)	47	0.0080	0.0316	0.1700	0.0300	0.0110	0.0150	**0.0200**	0.0350	0.0660
TURBIDITY (FIELD) (NTU)	163	0.30	12.29	160.00	20.70	0.70	1.40	**3.60**	16.00	32.00
COLOUR (Pt/Co)	49	5.00	55.10	300.00	57.10	15.00	20.00	**30.00**	60.00	120.00
pH (FIELD) (PH)	162	5.10	7.09	10.20	0.64	6.30	6.70	**7.10**	7.50	7.80

GOULBURN RIVER @ MURCHISON (405200) Aug 1975 – Oct 2002

	No. of Data	Minimum	Mean	Maximum	Standard deviation.	Percentiles				
						10	25	**50**	75	90
SURFACTANTS ( )	10	0.01	0.02	0.03	0.01	0.01	0.01	**0.02**	0.02	0.03
ALKALINITY (mg/l CaCO3)	97	12.00	25.45	43.00	6.48	18.00	20.00	**25.00**	31.00	34.00
BORON (mg/L)	11	0.02	0.07	0.14	0.04	0.02	0.03	**0.07**	0.09	0.11
CALCIUM (mg/l)	97	1.70	4.26	7.80	1.10	3.00	3.30	**4.40**	4.90	5.50
CHLORIDE (mg/l)	97	14.00	29.63	89.00	10.73	21.00	23.00	**27.00**	33.00	44.00
COLOUR (FILT.) (Pt/Co Units)	147	5.00	38.26	180.00	32.38	14.00	20.00	**25.00**	45.00	80.00
DISSOLVED OXYGEN (mg/L)	489	2.30	8.40	14.70	1.66	6.30	7.20	**8.40**	9.80	10.40
DISCHARGE (ML/day)	508	0.1	1633.0	39914.3	4641.8	3.3	7.8	**255.5**	363.5	4940.0
EC (FIELD) (uS/cm)	499	42.00	162.56	810.00	64.59	110.00	130.00	**150.00**	180.00	220.00
FLUORIDE (mg/L)	12	0.02	0.05	0.19	0.05	0.02	0.03	**0.04**	0.06	0.06
IRON (mg/L)	93	0.30	1.44	7.10	1.06	0.70	0.82	**1.06**	1.50	3.00
HARDNESS (mg/L)	96	18.00	33.21	67.00	8.07	23.00	28.00	**33.50**	38.00	40.00
MERCURY (mg/L)	8	0.00005	0.00018	0.00030	0.00008	0.00005	0.00015	**0.00020**	0.00020	0.00030
POTASSIUM (mg/l)	96	0.10	1.19	3.00	0.52	0.80	0.90	**1.00**	1.30	1.90
MAGNESIUM (mg/L)	97	3.1	5.3	11.0	1.3	3.9	4.4	**5.4**	5.9	6.4
MANGANESE (mg/L)	93	0.01	0.03	0.14	0.02	0.01	0.02	**0.03**	0.04	0.06
NITRATES AND NITRITES (mg/l)	243	0.0030	0.2204	3.0000	0.2516	0.0540	0.1040	**0.1500**	0.2700	0.4000
SODIUM (mg/l)	97	9.90	18.63	50.00	5.68	14.00	15.00	**17.00**	20.00	25.00
REACT. PHOSPHORUS (FILT) (mg/l)	147	0.0030	0.0045	0.0410	0.0040	0.0030	0.0030	**0.0030**	0.0040	0.0070
SULPHATE (mg/l)	97	1.70	4.06	13.00	2.00	2.00	2.40	**3.60**	5.20	6.00
SUSPENDED SOLIDS (mg/l)	243	1.00	15.29	130.00	14.25	4.00	8.00	**12.00**	18.00	29.00
SILICA (mg/L)	93	3.2	6.4	10.0	1.2	5.0	5.5	**6.3**	7.2	7.8
TEMPERATURE (°C)	502	4.00	14.53	26.50	4.91	8.30	10.00	**14.50**	18.40	21.00
TOTAL DISSOLVED SOLIDS (mg/L)	94	0.00	107.17	250.00	32.18	80.00	92.00	**99.50**	120.00	140.00
TOTAL KJELDAHL NITROGEN (mg/l)	243	0.090	0.419	1.400	0.235	0.200	0.250	**0.310**	0.500	0.700
TOTAL ORGANIC CARBON (mg/L)	87	2.0	6.0	12.0	2.6	2.0	4.0	**6.0**	8.0	10.0
TOTAL PHOSPHORUS (mg/l)	242	0.0100	0.0309	0.1400	0.0178	0.0160	0.0190	**0.0260**	0.0360	0.0570
TURBIDITY (FIELD) (NTU)	491	0.20	12.37	140.00	15.80	2.70	4.40	**7.40**	13.00	27.50
COLOUR (Pt/Co)	97	10.00	55.67	200.00	32.78	20.00	30.00	**50.00**	70.00	100.00
pH (FIELD) (pH)	493	5.50	6.94	8.40	0.48	6.40	6.60	**6.90**	7.20	7.60

GOULBURN RIVER @ SHEPPARTON (405204) Oct 1976 – Oct 2002

	No. of Data	Minimum	Mean	Maximum	Standard deviation.	Percentiles				
						10	25	**50**	75	90
ALKALINITY (mg/l CaCO3)	49	17.00	29.55	76.00	8.86	21.00	25.00	**30.00**	33.00	36.00
CALCIUM (mg/l)	48	3.00	5.21	16.00	2.22	3.50	3.90	**4.80**	5.40	7.40
CHLORIDE (mg/l)	49	12.00	38.43	79.00	14.56	21.00	27.00	**39.00**	50.00	55.00
COLOUR (FILT.) (Pt/Co Units)	146	10.00	66.57	220.00	40.75	25.00	40.00	**55.00**	90.00	120.00
DISSOLVED OXYGEN (mg/L)	307	3.60	8.19	12.00	1.52	6.40	7.00	**8.10**	9.40	10.20
DISCHARGE (ML/day)	320	177.0	3790.2	57438.1	8040.1	316.5	405.5	**631.0**	1797.5	10904.0
EC (FIELD) (uS/cm)	316	70.00	197.54	460.00	60.13	120.00	150.00	**200.00**	240.00	270.00
IRON (mg/L)	46	0.43	3.38	10.00	1.79	1.60	2.10	**2.90**	4.30	4.90
HARDNESS (mg/L)	49	18.00	37.33	71.00	12.03	22.00	28.00	**36.00**	44.00	55.00
POTASSIUM (mg/l)	48	0.50	2.20	4.90	0.79	1.50	1.70	**2.05**	2.55	3.30
MAGNESIUM (mg/L)	49	2.9	5.6	9.7	1.6	3.3	4.3	**5.7**	6.5	7.7
MANGANESE (mg/L)	46	0.02	0.08	0.35	0.07	0.04	0.05	**0.07**	0.09	0.11
NITRATES AND NITRITES (mg/l)	195	0.0030	0.1721	1.6000	0.1910	0.0070	0.0390	**0.1400**	0.2300	0.3500
SODIUM (mg/l)	49	9.50	25.49	47.00	8.20	15.00	19.00	**27.00**	31.00	33.00
REACT. PHOSPHORUS (FILT) (mg/l)	146	0.0030	0.0078	0.0540	0.0081	0.0030	0.0030	**0.0050**	0.0090	0.0150
SULPHATE (mg/l)	49	2.00	6.11	12.00	2.26	3.30	4.00	**6.00**	7.50	9.00
SUSPENDED SOLIDS (mg/l)	195	9.00	40.63	180.00	24.86	19.00	25.00	**36.00**	47.00	70.00
SILICA (mg/L)	47	0.1	7.9	13.0	2.3	5.3	6.5	**8.1**	9.5	11.0
TEMPERATURE (°C)	317	5.50	16.56	30.00	5.78	9.50	11.00	**16.50**	21.50	24.60
TOTAL DISSOLVED SOLIDS (mg/L)	48	0.00	143.08	250.00	42.33	100.00	121.50	**140.00**	160.00	200.00
TOTAL KJELDAHL NITROGEN (mg/l)	195	0.200	0.623	1.800	0.318	0.300	0.400	**0.500**	0.790	1.100
TOTAL ORGANIC CARBON (mg/L)	41	3.0	8.6	19.0	3.9	5.0	6.0	**7.0**	11.0	14.0
TOTAL PHOSPHORUS (mg/l)	194	0.0210	0.0734	0.2200	0.0343	0.0380	0.0490	**0.0670**	0.0910	0.1100
TURBIDITY (FIELD) (NTU)	310	0.30	28.60	135.00	22.27	5.50	14.00	**23.25**	39.00	58.00
COLOUR (Pt/Co)	49	20.00	92.24	280.00	53.94	40.00	60.00	**80.00**	120.00	160.00
pH (FIELD) (pH)	313	5.70	6.96	9.40	0.45	6.40	6.70	**6.90**	7.20	7.50

GOULBURN RIVER @ MCCOY'S BRIDGE (405232) Dec 1976 – Feb 2003

	No. of Data	Minimum	Mean	Maximum	Standard deviation.	Percentiles				
						10	25	**50**	75	90
SURFACTANTS ( )	1	0.01	0.01	0.01		0.01	0.01	**0.01**	0.01	0.01
ALKALINITY (mg/l CaCO3)	258	15.00	32.14	84.00	9.78	20.00	25.00	**31.00**	37.00	44.00
BORON (mg/L)	1	0.02	0.02	0.02		0.02	0.02	**0.02**	0.02	0.02
CADMIUM (mg/l)	50	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00
CHROMIUM (mg/l)	50	0.00	0.01	0.01	0.00	0.00	0.00	**0.01**	0.01	0.01
COPPER (mg/L)	50	0.001	0.005	0.012	0.002	0.003	0.003	**0.004**	0.005	0.007
CALCIUM (mg/l)	258	2.50	5.27	15.00	1.90	3.50	4.00	**5.00**	6.00	6.90
CHLOROPHYLL-A (ug/L)	25	4.3	27.7	104.0	29.5	4.9	8.6	**15.0**	31.0	83.0
CHLORIDE (mg/l)	307	13.00	38.03	99.00	14.84	21.00	27.00	**36.00**	45.00	58.00
COLOUR (FILT.) (Pt/Co Units)	226	15.00	74.16	250.00	42.89	30.00	40.00	**60.00**	100.00	140.00
DISSOLVED OXYGEN (mg/L)	572	4.20	9.03	12.80	1.39	7.20	8.00	**9.00**	10.10	10.80
DISSOLVED ORGANIC CARBON (mg/L)	228	1.0	7.2	23.0	3.5	4.0	4.5	**6.0**	9.0	12.0
DISCHARGE (ML/day)	1283	31.5	3673.4	57190.0	7212.9	406.0	519.0	**785.0**	2270.0	11930.0
EC (LAB) (uS/cm)	272	86.00	218.00	1400.00	100.82	130.00	160.00	**210.00**	259.00	310.00
EC (FIELD) (uS/cm)	1280	57.00	227.40	16000.00	448.90	140.00	160.00	**210.00**	250.00	310.00
FLUORIDE (mg/L)	1	0.05	0.05	0.05		0.05	0.05	**0.05**	0.05	0.05
IRON (mg/L)	30	1.90	3.69	7.40	1.49	2.30	2.40	**3.23**	4.68	5.81
HARDNESS (mg/L)	31	24.00	41.29	74.00	14.69	25.00	31.00	**36.00**	56.00	62.00
MERCURY (mg/L)	1	0.00001	0.00001	0.00001		0.00001	0.00001	**0.00001**	0.00001	0.00001
POTASSIUM (mg/l)	258	1.10	2.98	7.60	0.93	1.90	2.30	**2.90**	3.50	4.10
MAGNESIUM (mg/L)	258	2.8	5.5	11.0	1.4	3.8	4.5	**5.5**	6.2	7.2
MANGANESE (mg/L)	30	0.02	0.07	0.16	0.03	0.03	0.05	**0.07**	0.08	0.11
NICKEL (mg/l)	50	0.00	0.00	0.01	0.00	0.00	0.00	**0.00**	0.00	0.01
NITRATES AND NITRITES (mg/l)	744	0.0030	0.2091	1.9000	0.2370	0.0040	0.0150	**0.1500**	0.3200	0.5100
SODIUM (mg/l)	258	10.00	26.15	64.00	9.78	15.00	19.00	**24.00**	31.00	40.00
LEAD (mg/l)	50	0.00	0.00	0.01	0.00	0.00	0.00	**0.00**	0.00	0.00
REACT. PHOSPHORUS (FILT) (mg/l)	709	0.0000	0.0186	0.2200	0.0220	0.0050	0.0080	**0.0130**	0.0200	0.0330
PHAEOPHYTIN (ug/L)	25	0.1	2.2	9.5	3.0	0.1	0.1	**1.1**	2.6	8.2
SILICA TOTAL (mg/L)	50	4.7	16.8	65.0	11.5	6.1	9.1	**14.5**	20.0	32.0
SULPHATE (mg/l)	255	2.00	7.16	34.00	3.55	4.00	5.00	**6.90**	8.10	11.00
SUSPENDED SOLIDS (mg/l)	81	1.00	43.90	180.00	22.16	22.00	31.00	**42.00**	52.00	61.00
SILICA REACTIVE (mg/L)	739	0.0	5.7	13.0	3.9	0.2	1.2	**6.8**	8.8	10.0
TEMPERATURE (°C)	1283	5.50	16.75	30.00	5.78	9.50	11.10	**16.50**	22.00	24.50

	No. of Data	Minimum	Mean	Maximum	Standard deviation.	Percentiles				
						10	25	**50**	75	90
TOTAL DISSOLVED SOLIDS (mg/L)	29	82.00	158.62	280.00	47.39	99.00	120.00	**150.00**	180.00	220.00
TOTAL KJELDAHL NITROGEN (mg/l)	742	0.100	0.788	2.600	0.318	0.460	0.560	**0.700**	0.950	1.200
TOTAL ORGANIC CARBON (mg/L)	28	4.0	8.5	19.0	3.6	5.0	6.0	**8.0**	11.0	13.0
TOTAL PHOSPHORUS (mg/l)	742	0.0190	0.1185	0.8400	0.0648	0.0660	0.0820	**0.1100**	0.1400	0.1720
TURBIDITY (LAB) (NTU)	233	1.6	44.3	130.0	20.3	22.0	29.0	**40.0**	56.0	70.0
TURBIDITY (FIELD) (NTU)	1266	0.00	42.74	270.00	22.00	22.00	28.00	**37.50**	52.00	71.00
ZINC (mg/l)	50	0.00	0.01	0.03	0.00	0.01	0.01	**0.01**	0.01	0.02
COLOUR (Pt/Co)	31	30.00	88.87	240.00	48.78	50.00	50.00	**80.00**	120.00	140.00
PH (FIELD) (PH)	1270	5.90	7.07	8.50	0.39	6.60	6.80	**7.10**	7.30	7.50
ARSENIC (mg/L)	44	0.001	0.0017	0.004	0.0008	0.001	0.001	**0.002**	0.002	0.003

APPENDIX 5 SUPPLEMENTARY RIPARIAN AND WETLAND INFORMATION

Riparian Zone

The condition of the immediate riparian zone throughout the whole study area, as given in the sub-index 'streamside' in the Index of Stream Condition (ISC), increases downstream from Eildon. Continuity and width rate consistently higher in study Reaches 4 and 5 than in study Reaches 1, 2 and 3. (Figure A5.1 and 5.2).

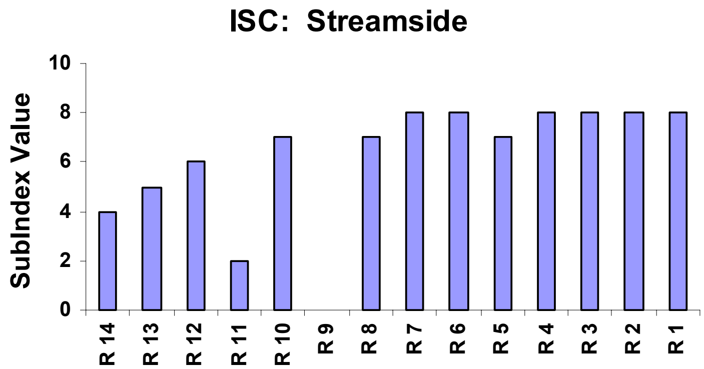


Figure A5.1: Longitudinal plot of the Streamside sub-index in ISC (max = 10). Reach 14 (R14) is downstream of Eildon, and Reach 1 (R1) closest to the junction with the River Murray. See Figure 5 for location of R1 to R14.

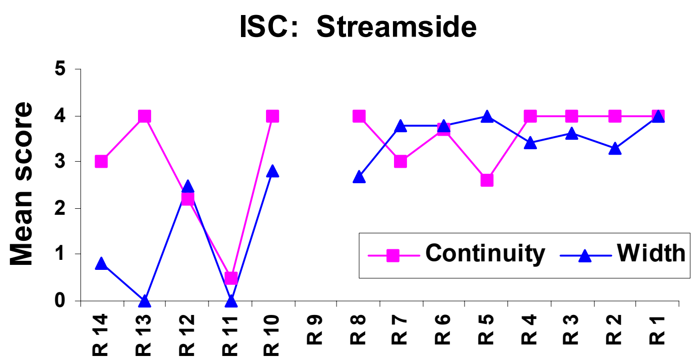


Figure A5.2: Mean score for riparian vegetation continuity and width (max = 5).

Wetland type and abundance

Reach	Wetland Type	Wetland Size Class 1- 9	10-25	26-50	> 50	Reach TOTAL	% of REACH TOTAL
1 and 2	FW Meadows	29	5	1	0	35	*9.4*
	Shallow FW Marsh	192	21	4	0	217	*58.3*
	Deep FW Marsh	38	15	2	0	55	*14.8*
	Permanent Open FW	57	2	0	1	60	*16.1*
	Other	0	0	0	0	0	*0*
	Sewage Pond	4	1	0	0	5	*1.3*
	Total =	**320**	**44**	**7**	**1**	**372**	
	As % of Total =	*86*	*12*	*1.9*	*<<1*		
3	FW Meadows	2	2	0	0	4	*19*
	Shallow FW Marsh	7	1	0	0	8	*38.1*
	Deep FW Marsh	3	0	0	0	3	*14.3*
	Permanent Open FW	3	0	0	0	3	*14.3*
	Other	0	0	0	0	0	*0*
	Sewage Pond	3	0	0	0	3	*14.3*
	Total =	**18**	**3**	**0**	**0**	**21**	
	As % of Total =	*85.7*	*14*	*0*	*0*		
4	FW Meadows	147	60	22	13	242	*45.1*
	Shallow FW Marsh	83	44	20	18	165	*30.8*
	Deep FW Marsh	17	13	4	5	39	*7.3*
	Permanent Open FW	73	5	2	8	88	*16.4*
	Other	1	0	1	0	2	*0.4*
	Sewage Pond	6	1	0	1	8	*1.5*
	Total =	**321**	**122**	**49**	**44**	**536**	
	As % of Total =	*59.9*	*23*	*9.1*	*8*		
5	FW Meadows	161	109	63	50	383	*49.9*
	Shallow FW Marsh	72	47	19	26	164	*21.4*
	Deep FW Marsh	60	13	4	8	85	*11.1*
	Permanent Open FW	105	8	5	1	119	*15.5*
	Other	0	0	0	0	0	*0*
	Sewage Pond	5	6	1	5	17	*2.2*
	Total =	**403**	**183**	**92**	**90**	**768**	
	As % of Total =	*52.5*	*24*	*12*	*12*		
	GRAND Total =	**1068**	**353**	**148**	**136**	**1705**	
	As % of Total =	*62.6*	*21*	*8.7*	*8*		

COMPILATION ERROR: the total of 1705 wetlands does not include 8 ‘unclassified’ wetlands in Reach 4, giving an overall estimated total of 1713, an error of 2 wetlands.

Wetland vegetation types

Dominant Vegetation in a Wetland		Number of Wetlands per Study Reach 1 & 2	3	4	5	TOTAL
Herbaceous (H)		**131**	**7**	**199**	**277**	**614**
	H and River Red Gum	19	4	66	90	**179**
	H and Black Box			1	1	**2**
	H and Canegrass			9	1	**10**
	H and Lignum				2	**2**
	H and Reed	1		2	2	**5**
	H and Dead Trees				1	**1**
Canegrass (CG)					14	**14**
	CG and Reed			1		**1**
Reed (RD)				6	23	**29**
	RD and Open Water			6	3	**9**
	RD and River Red Gum			1	3	**4**
Rush						
	Rush and Dead Trees			1		**1**
River Red Gum (RRG)		**137**	**3**	**128**	**187**	**455**
	RRG and Herb			1		**1**
	RRG and Dead Trees			2		**2**
Black Box					3	**3**
Open Water (OW)		10	1	10	36	**57**
	OW and Canegrass			1		**1**
	OW and Lignum			1		**1**
	OW and River Red Gum	9			1	**10**
Shallow (SH)				6	8	**14**
	SH and Cane	1		1		**2**
	SH and River Red Gum			2		**2**
Dead Trees (DT)				3	2	**5**
	DT and Reed			1		**1**
Impoundment (IMP)		59	3	80	103	**245**
	IMP and River Red Gum				1	**1**
	IMP and Dead Trees			2		**2**
Sewage Pond		4	3	8	17	**32**
Saline				2		**2**

Note: 2 wetlands unassigned. There is a compilation error of 7 wetlands misallocated between Reach 4 and Reach 5 but the source of this has not been resolved. The overall trends are considered robust.

Analysis of Wetland Change
'Change' refers to change as recorded in the database and as noted during field verification by Corrick team, done in 1995-1996.

Cross-tabulation of changes to wetlands, by change in type and change in area, based on information in Wetland layer of database. Two wetlands had incomplete information and could not be cross-tabulated.

	Wetland Type				
	No change Type	**Type becomes 'wetter'**	**Type becomes 'drier'**	**Total**	***as % of Total***
NO change to wetland area	1552	20	0	**1572**	***92.1***
Wetland area reduces	96	51	11	**128**	*7.5*
Wetland area increases	4	2	1	**7**	***0.5***
Total =	**1652**	**43**	**12**	**1707**	
	96.8	*2.5*	*0.7*		***100***

Points to note:

- Less than 10% of wetlands showed a change in wetland type and/or wetland area. The majority of wetlands (91%) apparently did not change. Change is more common in Reaches 4 and 5 where 14% and 10% of wetlands changed either in area and/or in type, which is broadly equivalent to water regime; in Reaches 1 and 2, and Reach 3, this was only 1.3% and 4.8%.
- Reductions in wetland area are 15 times more common than increases in area (7.5% compared with 0.5%).
- Water regime changes to become 'wetter' are 3-4 times more common than to become 'drier' (2.5 % compared with 0.7%).

APPENDIX 6 SCIENTIFIC PANEL FIELD INVESTIGATION

Date: 22nd-24th January 2003

Sites Visited:

Sites visited by the Goulburn Scientific Panel, 22-24 January 2003

Site Number	Reach	Location
1	Lake Eildon to Molesworth	Eildon dam
2	Lake Eildon to Molesworth	Downstream of Alexandra - Binns-McRaes Rd
3	Lake Eildon to Molesworth	Upstream of Alexandra - Breakaway Bridge (Hobans Rd)
4	Molesworth to Seymour	Molesworth Bridge
5	Molesworth to Seymour	Ghin Ghin Bridge
6	Molesworth to Seymour	Downstream of Homewood - Bryants Rd
7	Molesworth to Seymour	Trawool Bridge
8	Molesworth to Seymour	Horseshoe Lagoon
9	Nagambie to Loch Garry	Murchison
10	Nagambie to Loch Garry	Toolamba Bridge
11	Nagambie to Loch Garry	Jolly’s Bend
12	Nagambie to Loch Garry	Mooroopna – Watts Rd
13	Nagambie to Loch Garry	Gemmills Swamp
14	Nagambie to Loch Garry	Cut off meander near Gemmills Swamp
15	Nagambie to Loch Garry	Reedy Swamp
16	Loch Garry to the River Murray	Hurricane Point and Loch Garry
17	Loch Garry to the River Murray	Pogues Road
18	Loch Garry to the River Murray	McCoys Bridge
19	Loch Garry to the River Murray	Wyuna – Murrumbidgee Road
20	Loch Garry to the River Murray	Downstream of Kanyapella - Stewarts Bridge

Discussions with Stakeholders

22nd January

The Scientific Panel met with Ed Meggitt near Alexandra. Points raised included:

- Trout farms are a non-consumptive user of water from the Goulburn River;
- Trout farms are a source of nutrients to the Goulburn River but discharges are licensed with the EPA and there are ongoing efforts to reduce the loads being released (recent nutrient reduction measures had decreased TP loads from trout farms by approximately 50%;
- The livelihood of trout farms depends on the quality of water in the Goulburn River, particularly temperature, dissolved oxygen and flow;
- Water temperature in January was reaching 23^{o}C in the afternoons due to water retention time in Eildon pondage. Optimum temperature for trout farming is 14oC. Normally water

temperature is 17oC in January. Additional releases from Eildon in the low flow season would be beneficial for trout by reducing temperature;
- Water in the Goulburn River near Alexandra is normally very clear but appeared to be more turbid than usual, presumably due to the low levels and scouring in Lake Eildon;
- Minor floods do not pose problems for the trout farms. The 1993 flood (54,000 ML/d) was of concern but ultimately did not result in losses or large scale damage due to the presence of levees at the 1 in 70 ARI;
- There are not many levees in the upper reaches of the Goulburn as water generally gets away quickly.

23rd January

The Scientific Panel met with Dianne McPherson, Jeff Lodge, Ross Wealhouse, Ross Pogue, Nick Roberts, Ian Park and Gordon O'Brien at Murchison. Points raised included:

- Options for delivering water to wetlands include physical works as well as floods;
- Care needed in refilling Lake Eildon as water levels have been low for a long time;
- Eildon can fill in a flood year and there is little opportunity for controlling large floods. Full release from Eildon is equivalent to bankfull at Murchison. The addition of tributary inflows results in flooding;
- Water in the river at Murchison was considered to be clearer prior to the construction of Eildon (e.g. 1-2 m)
- Summer freshes had been largely eliminated since the 1960's/1970's. Local backwaters start filling when water levels are at approximately 80% bankfull. Summer flows were thought to be considerably higher than they are now and the river almost never stopped flowing;
- Overbank flows that used to occur about every three years are far less frequent (equivalent to 31 ft on the Shepparton gauge). These flows caused a flush of growth in riparian vegetation and activity along the river, including that of birds, frogs and snakes. The majority of billabongs fill at 33 ft, while almost all are filled at 35 ft on the Shepparton gauge;
- There were localised stands of what was later identified as *Potomageton tricarinatus* (floating pondweed) along the river
- Carp seem to have reduced in numbers while Murray cod numbers seemed to have increased over the last 18 months. Redfin used to be plentiful 20 years ago but are now rare. Carp were thought to have contributed to a loss of vegetation along the banks;
- There was a never a river improvement trust for the lower Goulburn River, so wood has never been removed.
- Groundwater was thought to contribute to localised bank slumping near Nagambie and in other locations along the lower Goulburn River. It was suspected that this was due to low flows in the river and high groundwater tables;
- Unrestricted grazing was noted as impacting on bankside vegetation and a risk to local water quality (nutrients, organic matter, pathogens);
- Phalaris was noted as a problem as it was thought to reduce the diversity of riparian vegetation;
- Stakeholders identified what they considered to be important aspects of the flow regime that should be returned. This included increased flood frequency (32-34 ft at Shepparton) at the right time of year, preferably coinciding with natural rainfall events in the upper catchment, and also some fluctuation of low flows. Flow management should ensure that that the rate of reduction in flows is not too fast to avoid sudden drops in water levels.

APPENDIX 7 FLOODPLAIN HYDROLOGY

The Hydrology of Floodplain Wetlands in the Goulburn River Downstream of Lake Eildon

The Hydrology of Floodplain Wetlands in the Goulburn River Downstream of Lake Eildon

Michael Stewardson
CRC for Catchment Hydrology
March 2003

Lake Eildon to Molesworth

There are numerous wetlands along the Goulburn River floodplain between Lake Eildon and Trawool. This study examines the upper 60 km section of this reach, between Lake Eildon and Molesworth Bridge. A plan of this river reach, supervised by G.L. Thomson and drawn in 1934, shows the elevation of channel banks including low points where floodwaters might breakout of the channel and into floodplain wetlands. This plan provides a unique opportunity to examine the commence-to-flow levels for floodplain wetlands in the mid-Goulburn River. This study uses data from this plan, the Wetlands data base held as part of the BioMap GIS by The Department of Sustainability and Environment (DSE) and historic flood level data recorded in the DSE's Flood Data Maps (also on GIS) to estimate commence-to-flow discharges for wetlands along the 60 km reach downstream of Lake Eildon. The method is briefly described followed by the results.

Method

Commence-to-flow levels were obtained for each wetland shown on the BioMap plan from the levels shown on the 1934 survey plan. The 1934 plan provides elevations at closely spaced intervals along both banks for the river[1]. The general location of channel outlets for each wetland were located based on the pattern of water movement over the floodplain as indicated by water courses on both the 1934 plan and the wetlands map and arrows on the 1934 plan. Where wetlands were located adjacent to the main river, this was a relatively simple task. Where they were at a greater distance, more judgment was required. Low elevations in river banks were chosen as point through which the river spills. It is likely that the surveys included the lowest points in the natural channel levees along the Goulburn River because of their importance to flood analysis. The levels show a general trend to lower levels downstream along the river with greater variability about this general trend at greater distance from Lake Eildon (Figure A7.1).

[1] The 1934 plan uses an old datum for all survey levels. The conversion to AHD for this datum was determined by comparing flood levels recorded on this plan and in the DSE flood data map (in AHD). The conversion used in this study is AHD = 0.305 x H - 0.595 where H is the level recorded on the Strom plan in units of feet.

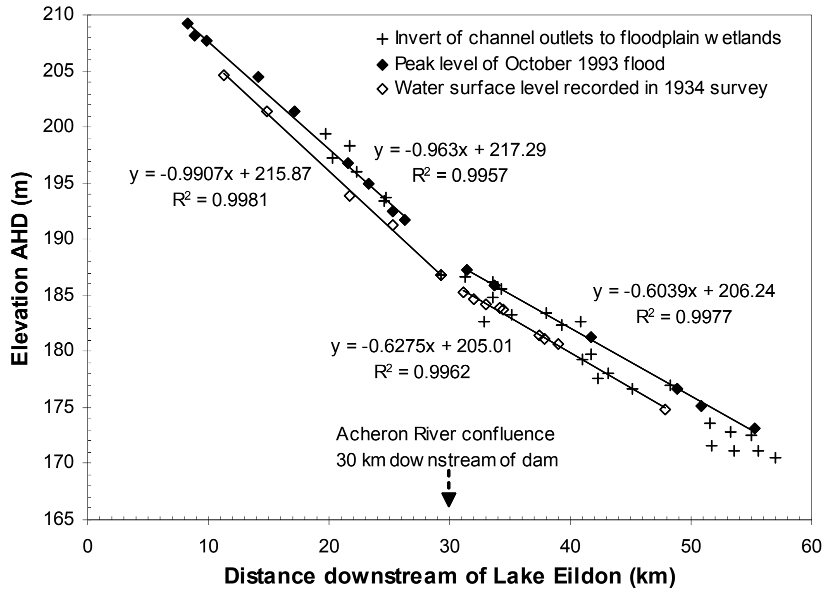


Figure A7.1: Water surface profiles and elevation of channel outlets to floodplain wetlands along the Goulburn River between Lake Eildon and Molesworth Bridge

In order to transform the commence-to-flow levels to a discharge, a model of water surface profiles is required for this reach of the river. Peak flood levels are often surveyed following major floods in Victoria. These flood levels are recorded in the Flood Data Maps available from a GIS held by Department Sustainability and Environment (DSE). Such a survey was conducted following a flood in October 1993. In total, 15 observations of peak flood level for this event are available for this reach of the river (Figure A7.1). The peak flood discharge at the Eildon gauge for this event is reported to have been 48,000 ML/day (HydroTechnology, 1995). Flow was held at or near this peak for more than one day (Figure A7.2). The relatively extended nature of this event means that attenuation of the flood peak along the 60 km reach would be small. Flows recorded in the Rubicon and Acheron rivers for this period also indicate relatively constant flows over the duration of the flood peak. Based on the available data, the peak flood discharge estimated for the Goulburn River downstream of Acheron River (Table A7.1) is 51,000 ML/day.

Table A7.1: Estimated peak instantaneous flow for the October 1993 flood in the Goulburn River

Reach of the Goulburn River	*Instantaneous Flood Peak (ML/day)*
Lake Eildon to Rubicon River	48,000
Rubicon River to Acheron River	49,000
downstream of Acheron River	51,000

The 1993 flood levels show a break in slope 30 km downstream of the dam, at the confluence with the Goulburn River. This may be the consequence of a change in grade, roughness or width of the floodplain at this point in the floodplain. Two linear functions, used to represent the 1993 flood profile were fitted to the observed flood levels by regression (Figure A7.2). Water levels at the time of the survey were also recorded on the 1934 plan. These were also examined and show a consistent gradient with the break of slope at the Acheron River confluence. The flow at the time of survey is not available and would probably have varied over the period of surveying.

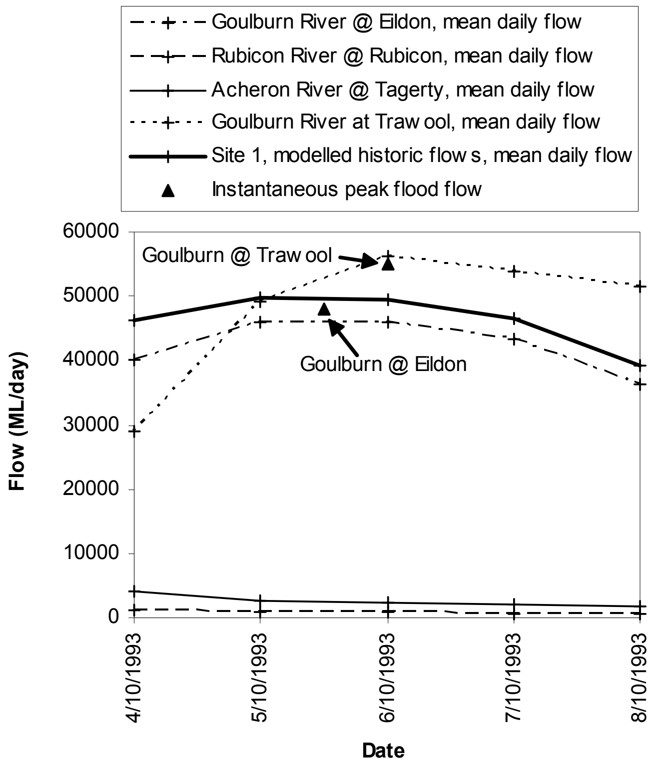


Figure A7.2: Mean daily and instantaneous flows during the October 1993 flood in the Goulburn River and its tributaries downstream of Lake Eildon

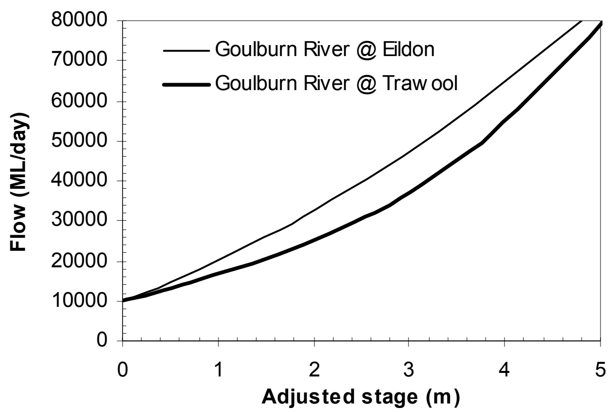


Figure A7.3: Rating curves for the Goulburn River at Eildon and Trawool gauges.

A comparison of rating curves for the gauges on the Goulburn River at Eildon and Trawool (Figure A7.3) show some consistence. Out of channel flows are reported to commence at 10,000 ML/day. The increases in stage from 10,000 Ml/day and 50,000 ML/day at the Eildon and Trawool gauges are 3.2 m and 3.8 m respectively. This observation supports the assumption of a uniform rating curve (adjusted for channel elevation) along the 60 km reach of the Goulburn River downstream of Lake Eildon. For this purpose, the Trawool gauge rating curve is used. Field inspections of the river suggest that the hydraulic characteristics at the Trawool gauge are representative of this reach of the river. The Eildon gauge is located immediately downstream of the re-regulation weir and Lake EIldon. It is likely that the channel and floodplain are modified at the gauge as a consequence of construction of these impoundments and not representative of the downstream Goulburn River. A power law was fitted by regression to the Trawool rating curve for the range of flows 10,000 ML/day to 50,000 ML/day

$$Q = 2210 \text{ x } (H\text{-}H_0)^{1.7}$$

Where Q is the discharge in ML/day, H is the stage in m to the AHD (Australian Height Datum) and H_0, is a reference level for the section.

The October 1993 flood profile provides an estimate of H and Q along the length of the reach. Using this profile, it was possible to estimate the reference stage (H_0) along the 60 km river reach. This analysis provides a model of the stage corresponding to any point along the reach for any discharge greater than 10,000 ML/day. This model was used to estimate the commence-to-flow discharge for the channel outlets for wetlands along mid-Goulburn River between Lake Eildon and Molesworth Bridge.

Results

The dominant wetland type in this river reach is Shallow Freshwater Marsh (Figure A7.4). Other wetlands types occurring in the reach are Shallow Freshwater Marsh, Deep Freshwater Marsh and Permanent Open Water. There is a general trend to lower commence-to-flow discharges in the reach downstream of the Acheron River confluence (30 km downstream of the dam).

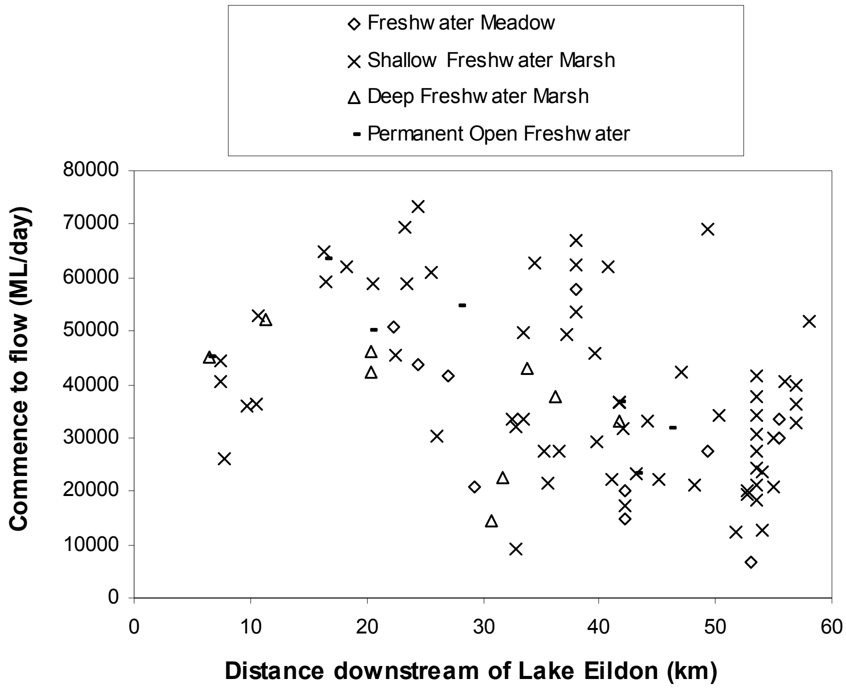


Figure A7.4: Commence to flow discharges for various wetland types along the Goulburn River between Lake Eildon and Molesworth Bridge.

A relationships is established between discharge and the area of wetlands along this reach that are filled from by spills from the river for the four different wetland types (Figure A7.5).

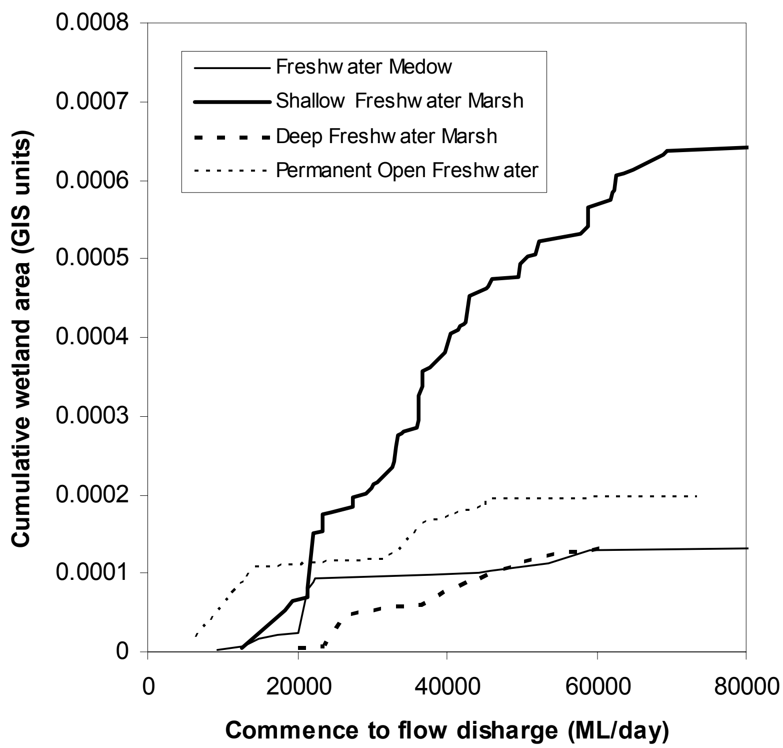


Figure A7.5: Area of wetlands of various types filled by increasing flows in the Goulburn River between Lake Eildon and Molesworth Bridge.