Assessing translucent environmental water release in the Murrumbidgee River below Burrinjuck Dam 1999-2002

Report 1 – Background
Regulated and unregulated rivers of the Murrumbidgee catchment and the effect of translucent releases – an Integrated Monitoring of Environmental Flows background report


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Summary

Environmental releases from the major irrigation dams in the Murrumbidgee catchment commenced in 1998. Monitoring of these releases began in 1999 under the Integrated Monitoring of Environmental Flows (IMEF) program.

This project within the IMEF program was designed to monitor the effects of ‘translucent’ releases that are linked to tributary inflows between autumn and spring. These were set by the river flow objectives (RFOs) for the Murrumbidgee River and were outlined in 1998 by the NSW Government. Riffle communities downstream of Burrinjuck Dam were investigated to measure effects of these releases.

Translucent releases linked to tributary inflows were designed to restore stony bed riffles downstream of Burrinjuck Dam. Periphyton, commonly known as fixed algae, and aquatic invertebrate communities on riffle rocks in the Murrumbidgee and its regulated and unregulated tributaries were monitored for two years from 1999. Water quality and a range of other ecological indicators were also monitored during this study.

There are five reports in this study that encompass results from the monitoring program. This first report provides the policy background to the study and outlines the design. Further reports discuss outcomes of the study including those for water quality, periphyton, invertebrates, stream productivity and food webs using carbon and nitrogen stable isotopes.

Introduction

In 1995, the Murray Darling Basin Ministerial Council set a cap on diversions on major regulated river systems which was made permanent in 1997. This set maximum diversions from the Murrumbidgee River at 1993/1994 levels of development. New diversions would only occur when there was growth in the use of existing licences and efficiency measures were introduced. Following the introduction of the Murray Darling basin cap by the Australian government, legislation was introduced to manage water sharing. This included the NSW Water Management Act 2000 and provisions for an environmental share of water allocation for rivers.

The NSW Water Management Act 2000 and the river flow objectives

The Water Management Act 2000 (WM ACT) provides legislative controls on water diversions and water for environmental purposes. The Act allows for the development of water sharing plans in the most regulated rivers in NSW. Eleven river flow objectives for inland rivers were created to guide the development of environmental flow rules and align monitoring with the objectives of the WM Act. The river flow objective 3, to protect or restore a portion of freshes and high flows, and objective 6, to maintain or mimic natural flow variability in all streams, were used to develop translucency rules.

The NSW Government developed objectives for the statewide IMEF program based on expected ecological response to implementation of rules addressing the NSW river flow objectives (Chessman and Jones 2001).

The objectives developed at the time were:

- to measure changes in the hydrology, habitats, biota and ecological processes in the major regulated river systems following the application of environmental flow rules
as far as practical, to infer relationships between these changes and environmental flows through statistical analysis and an understanding of ecosystems processes
• to provide scientific information needed for the environmental flow rules (RFO) review process.

Scientific context
Rivers are subject to dynamic conditions across space and time. This creates an aquatic environment that is naturally stochastic providing extensive small and large scale diversity within habitat conditions. Flow variation is important for aquatic species with microhabitat availability a function of velocity, depth and other environmental variables (Stewardson and Gippel 2003; Thoms 2006). This is particularly true in riffle-pool sequences where flow velocity over boulders and cobbles is complex (Bouckaert and Davis 1998; Downes et al. 1998) and resources patchy for aquatic communities.

Australian rivers exhibit some of the most variable and unpredictable stream flows in the world with the highest inter-annual variability across a range of continents (Thoms & Sheldon 2000; Poff et al. 2006). Australia is one of the most arid continents in the world and the highest per capita water storage in the world (Kingsford 2000). These factors combine to create aquatic ecosystems that support both highly variable instream conditions and very resilient and tolerant communities.

Rivers flowing west from the Great Dividing Range in south eastern Australia characteristically comprise bedrock controlled gorges with downstream boulder/cobble riffle-pool sequences. These sections have highly complex flow dynamics, with patchy litter accumulation creating small scale habitat within riffles in particular (Gordon et al. 2005). Riffles therefore support high biological diversity with periphyton forming in small patches across a riffle where current, water depth and chemistry all interact to create suitable environments. Consequently, invertebrates find suitable habitat close to food sources and flow habitat preferences. Many riffle invertebrates graze directly on periphyton selectively grazing on a range of plant species related to size and palatability. Other invertebrates utilise litter that flows from upstream reaches and accumulates in areas of low flow velocity. Filter feeders position themselves in sites of high flow velocity to catch debris and plankton as it flows past. A schematic of a riffle food web is presented in Figure 1.
Construction of dams and other regulation of rivers for irrigation and hydro-electricity impact on these processes. There is substantial evidence of the ecological impact of large dams both in Australia (Marchant and Hehir 2002; Boulton and Brock 1999; Grows and Grows 2001) and globally (Power et al. 1996; Collier 2002; Guija and Hunziker 2000). These impacts are created by a range of flow changes including alteration of natural seasonality, changed rates of rise and fall, altered nutrient chemistry of outflow water, distorted hydraulics and changes to natural water temperatures. Restoration of aspects of the flow regime provides the opportunity to potentially improve flow impacted aquatic communities (Puckridge et al. 1998) by restoring important components of the flow hydrograph.

The Murrumbidgee River catchment is highly impacted by river regulation with stored water used primarily for hydroelectric generation and irrigation. The Snowy Mountains Hydro-electric Scheme regulates the upper catchment tributaries. The scheme releases 1,026 gigalitres (GL) of stored water into Blowering Dam while diverting 550 GL from the headwaters of the Murrumbidgee River (MDBA 2007). Burrinjuck storage at full level holds 1,026 GL and Blowering Dam, 1,628 GL. At full supply level, this represents 61 percent of the mean annual flow (MAF) of the Murrumbidgee River.

The Murrumbidgee River is therefore one of the most developed rivers in the Murray Darling basin with around 53 percent of all flow diverted (MDBA 2007). The long term extraction limit is 1,925 GL, or 44 percent of mean annual flow (MAF) at Wagga Wagga.
Environmental flows in the Murrumbidgee

In March 1998, the Murrumbidgee River management committee set a number of environmental flow rules based on objectives for river restoration. These included:

- increased opportunities for fish migration and breeding during winter and spring in the river and its anabanches
- improved variability in flow with consequent increases in food availability and instream condition
- reduction in conditions favourable to algal blooms by providing increased flow through pools
- an environmental contingency allowance for improving floodplain inundation.

From these objectives, environmental flow rules were developed and include:

- the transparency rule: release a minimum of 615 million litres per day (ML/d) from Burrinjuck Dam and 560 ML/d from Blowering Dam unless inflows are lower in which case releases are to be at least equivalent to inflows. Minimum flows of 300-315 ML/d are required to support basic river ecological processes and non environmental provisions such as basic rights for landholders and to prevent sedimentation of infrastructure. This flow rule operates all year
- the translucency rule: between April and October, a proportion of natural inflows into Burrinjuck Dam are to be released related to the daily flow in the Goodradigbee River and catchment weather conditions.

The Murrumbidgee regulated water sharing plan was developed in December 2002 and subsequently gazetted in July 2004. Further details are available from the NSW Office of Water web site: [www.water.nsw.gov.au](http://www.water.nsw.gov.au)

Environmental flow rules in the Murrumbidgee River were developed in part to reduce degradation associated with flow immediately downstream of Burrinjuck Dam. Previously, winter and spring flows in excess of the minimum required for dam maintenance and for stock and domestic use downstream of Burrinjuck were retained for summer irrigation releases. Recognition that ecological functioning in the river could not be improved without restoration of part of the natural hydrograph led to the introduction of translucent flows.

Daily releases during winter and spring relating to a proportion of upstream tributary inflows were aimed at restoring a small portion of natural flow in the river downstream of the major storage. Small dam releases to maintain a minimum flow or transparent releases were factored into total releases on a daily basis.

These small scale flows related to inflows, were to be used to improve riffle wetted habitat and flow complexity in the reach to the Tumut River confluence, a distance of about 100 kilometres. The objective was to improve instream ecology by increasing flow variability, habitat and complexity. The premise of translucent releases was that the Murrumbidgee River would be restored and become more like the Goodradigbee River, an unregulated tributary.

The Tumut River did not receive translucent releases and as a consequence it was not expected to change. This meant that it could be a control so that ecological changes could be measured. The Goobarragandra River, being a tributary of the Tumut River, would act as a reference for the Tumut River.
The IMEF program initiated a monitoring program downstream of Burrinjuck Dam to identify any improvements in the ecology of the river following the introduction of translucent environmental flows.

Aims and objectives of this study

From these objectives and with the river flow objectives in mind generic ‘hypotheses’ or conceptual models were developed to guide IMEF projects and provided a basis for scientific design of projects. In the Murrumbidgee catchment, the environmental flows rules governed IMEF project design with hypothesis 4 (Chessman and Jones 2001) used as the generic hypothesis.

Hypothesis 4 is:

- protecting or restoring a portion of freshes and high flows and otherwise maintaining natural flow variability (RFOs 3 and 6) through off-allocation use restrictions and dam releases, will induce scouring of silt and sloughing of biofilms from stony substrata, resetting biofilm development and improving habitat quality for some invertebrate scrapers and their predators and spawning conditions for gravel-spawning fishes.

Objectives

A flow monitoring study was designed to monitor the ecological effects of flow change brought about by the introduction of translucent releases downstream of Burrinjuck Dam. Hydrological effects of flow rules in the Murrumbidgee River caused by altered flow regimes were measured comparatively with natural tributaries and with the Tumut River. The Tumut River had little change to its highly modified flow regime. The spatial and temporal design is outlined below.

Aims

To identify the ecological effect of introduction of translucent flows in the Murrumbidgee River downstream of Burrinjuck dam on:

- riffle periphyton communities
- riffle invertebrate communities particularly in invertebrate scrapers and their predators.

The spatial design used included the Goodradigbee and the Goobarragandra rivers as reference sites and the Tumut River as a negative control site that is regulated but not subject to the introduction of translucent releases.

The premise of the monitoring study was that translucency flows would reset periphyton communities on rocky riffles downstream of Burrinjuck leading to early successional stages of ecological community development. The effect was a more palatable food source and healthier aquatic communities (Figure 2). This would lead to long term improvement in the ecology of riffle aquatic communities in the Murrumbidgee River downstream of Burrinjuck Dam.
Figure 2. Conceptual model for expected ecological response to translucent flows

- ‘Translucency’ releases
- Increases winter spring flow variability
- Scours rocky riffle biofilm
- Resets early successional periphyton
- Stimulates patchy ecological community structure
- ‘Healthier’ river

Study null hypotheses

A number of more testable null hypotheses were developed to set the boundaries of the study:

- there will be no significant effect of the introduction of translucency flows on riffle periphyton communities in the Murrumbidgee River downstream of Burrinjuck Dam compared to control sites and reference conditions
- there will be no significant effect of the introduction of translucency flows on riffle invertebrate scraper communities in the Murrumbidgee River downstream of Burrinjuck Dam compared to control sites and reference conditions
- there will be no significant effect of the introduction of translucency flows on riffle periphyton productivity in the Murrumbidgee River downstream of Burrinjuck Dam compared to control sites and reference conditions
- there will be no significant increase in ecological similarity between the Murrumbidgee River and its unregulated tributary as a result of the introduction of translucent releases.
- There will be no significant difference in the ecology of the Murrumbidgee River and the Tumut River following the introduction of translucent releases.

Methods and site description

Study area description, site locations and details

Study area description

The Murrumbidgee River rises in the south east Alps of New South Wales flowing into Tantangara Reservoir where the majority of flow is diverted by the Snowy Mountains Hydro-electric Scheme into Eucumbene storage. Below Tantangara, the river runs in a south easterly direction before turning north near Cooma and flowing through the Australian Capital Territory (ACT). The river lies in the temperate zone of south east Australia that experiences peaks of rainfall and runoff in winter and spring with hot dry summers. This sets the template
for flows in western rivers flowing out of the New South Wales Alps. The Murrumbidgee River is one of the largest, draining 84,000 km² (Wallbrink et al.1996) and 1,609 km long.

Main tributaries of the Murrumbidgee River upstream of Burrinjuck dam include the Molonglo, Queanbeyan, Goodradigbee and Yass rivers. The Molonglo and Queanbeyan rivers are heavily regulated through the ACT. The Molonglo sewage treatment plant output flows into the lower Molonglo River, releasing treated waste water back into the Murrumbidgee just upstream of Burrinjuck Dam. Mean annual diversion between 1996-2009 to ACT is 58,758 ML/year (reference: http://www.actewagl.com.au/water/facts/statistics.aspx).

The Goodradigbee River runs out of what was near pristine forest environment with minimal regulation in the upper reaches. The Yass River catchment has been under agriculture since early European settlement with poor soils and sometimes extreme salinity contributing to lower water quality downstream.

The Tumut River is a major tributary of the Murrumbidgee River downstream of Burrinjuck Dam. Blowering Dam regulates the Tumut River, the most downstream of several hydroelectric dams of the Snowy scheme. The Tumut River is highly oligotrophic and affected by cold water pollution, converging with the Murrumbidgee River just upstream of Gundagai. The Tumut River provides water for irrigation diverted by the Snowy Mountains Hydro-electric Scheme into Blowering Dam including 1,026 GL per year of which 550 GL is diverted from upper Murrumbidgee tributaries at Tantangara Reservoir and numerous aqueducts throughout the alps.

The upper catchment the Murrumbidgee River and its tributaries have been influenced by past glacial processes. This has helped to create a series of well defined pool and riffle sequences set within broad v-shaped valleys. These are then punctuated by areas of strongly bedrock controlled gorges with poor floodplain features and deep, narrow v-shaped valleys. The longitudinal profile of the river shows relatively steep stream slopes from the upper reaches of the Murrumbidgee to Burrinjuck Dam that effectively constitutes a break in slope. Just below Blowering and Burrinjuck dams the river flows into incised cobble run/pool sequences with braided streams further downstream.

Major tributaries downstream of Burrinjuck and Blowering storages include Tarcutta Creek (MAF 133.4GL), Jugiong Creek (MAF 82.2GL), Adelong Creek (MAF 38.5GL) and Muttama Creek (MAF 36.5GL). Ecologically important natural tributaries to the regulated river include the Goodradigbee River (MAF 303.3GL) that flows into Burrinjuck Dam and the Goobarragandra River (MAF 291.3GL) and then into the Tumut River.

The hydrology of the Murrumbidgee River is substantially altered. Burrinjuck Dam has a storage capacity of 76% of mean annual inflow of 1,350ML/annum (Parliament of NSW 2000 – Question 1152). This storage capacity, used primarily for summer irrigation, means that seasonality of flows downstream of Burrinjuck Dam are skewed by around four months. Peak flows in the Murrumbidgee are now during summer.

Rainfall exhibits a winter spring peak. This generally varies between 600 and 1,000 mm, increasing with altitude into the Australian Alps.

The geology of the Murrumbidgee River valley is formed and underlain by ancient palaeozoic fractured crystalline rocks with younger tertiary basalts in the alpine and montane zones. Sequential sedimentary deposition, igneous activity, consequent folding and faulting has resulted in mountain building in the east of the catchment. Long term fluvial and glacial erosive processes have formed the gully structure and depositional basin to the west of the catchment (Young and McDougall 1993; Taylor and Butt 1998).
Site selection
Sites were chosen as close as possible to existing flow gauging stations. All sites that were chosen had cobble or large cobble/small boulder riffles in pool riffle sequences. Where possible, sites were sampled, however due to flood and high flow events, some sites had to be changed or could not be sampled at all times.

This study was based on comparison of four river segments with different flow regimes. Two sites (riffles) were sampled in each river in order to provide a measure of within-segment variability.

The following points outline the general site locations within each river reach:

- Murrumbidgee River from Burrinjuck Dam to the Tumut River confluence - regulated flow with environmental water provisions
- Goodradigbee River from Brindabella to Burrinjuck - reference segment with natural flow regime. (Although an aqueduct in the headwaters of the Goodradigbee River diverts some flow to Tantangara Dam on the upper Murrumbidgee River, its effect on the flow regime in the lower Goodradigbee River is negligible.)
- Goobarragandra River – a reference segment with natural flow regime.
- Tumut River from Blowering Dam to the Murrumbidgee River confluence – a regulated river without environmental water provisions other than minimum flow – transparent releases. Total flow volume in this river has increased as a result of inter-basin diversion by the Snowy Mountains Hydro-electric scheme.

The Murrumbidgee catchment includes urban areas and extensive agricultural development. The sampling sites were located downstream of such activities and of the major regulating impoundments. The largely unregulated Goobarragandra and Goodradigbee rivers have forested catchments with only small agricultural areas upstream of the study sites. Catchment areas upstream of the study sites are approximately 13,100 km² for the Murrumbidgee River, 1,630 km² for the Tumut River, 670 km² for the Goobarragandra River and 1,160 km² for the Goodradigbee River. Consequently, the Murrumbidgee is an 8th order stream while the Tumut River is 7th order, the Goodradigbee River 5th order and the Goobarragandra River 6th order.
Figure 3. Spatial and temporal design for IMEF hypothesis 4 study, Murrumbidgee

Spatial Scale

Control River - Tumut
Reference River 1 Goobarragandra
Reference River 2 Goodradigbee
Test River Murrumbidgee
Within event: August – October 2000

Temporal Scale

Within years
Summer
Autumn
Winter
Spring – early
Spring - late

Between years
July 1999
to
November 2001

Reference River 1
Goobarragandra
Reference River 2
Goodradigbee
Test River
Murrumbidgee
The study was based on a post hoc monitoring design as described above. Two riffles were chosen within each river within a maximum of 15 km and minimum of 100 metres between riffles.
Temporal design

Sampling was performed seasonally and was also related to major flow periods (Figure 3 and Table 1). Thus representing ‘before’ and ‘after’ irrigation flows (November and February); a period of time after irrigation flows; the beginning of translucent releases (May); before and after environmental flows and at the end of translucent releases (July, August, October and November). In 2000, an individual environmental flow event was also sampled in the Murrumbidgee (on the day, two weeks after and six weeks after the event). Thus providing seasonal sampling: before, during and after translucent release periods and also from a specific event.

Table 1. Sampling occasions: IMEF hypothesis 4

<table>
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<tr>
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<th>Oct-99</th>
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<th>May-00</th>
<th>Aug-00</th>
<th>Sep-00</th>
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Indicators chosen and methods

The hydrology of the Murrumbidgee River following the introduction of translucency flows was expected to lead to an increase in scouring events on the rocky riffles downstream of the dam. These events were expected to be significant enough to scour attached mature periphyton and organic material from the surfaces of riffle rocks.

Instantaneous flow was measured as the primary hydrological variable. Antecedent hydrological parameters were calculated for each site (Growns andMarsh 2000) and these were related to ecological responses. Froude numbers were calculated for each periphyton sample (Gordon et al. 2005).

Rocky riffle periphyton and invertebrate communities (Petts and Calow 1996, Boulton and Brock 1999) were chosen to monitor ecological response of the introduction of translucency. Further indicators of ecological function were later introduced including rock periphyton community production, respiration (P:R) ratios (Bunn et al. 1999; Udy et al. 2001) and stable isotope measurements (Peterson and Fry 1987) of riffle periphyton and invertebrates. Water quality attributes including nutrients were measured as another influence on the ecological community.

Periphyton and invertebrates were measured using quantitative cobble sampling and processed according to standard sampling methods (Prescott 1978). More detailed methods are given in the relevant chapters. Water quality was measured and nutrients analysed according to standard methods (APHA1998) and standards in a NATA registered laboratory. Stable isotope analysis was performed as described in the IMEF Methods Manual (method 14 and 17) [http://dnr/stop/pdf/imm14.pdf](http://dnr/stop/pdf/imm14.pdf) and [http://dnr/stop/pdf/imm17.pdf](http://dnr/stop/pdf/imm17.pdf) and in Chessman et al. 2009). Productivity:respiration methods were performed using chambers with circulating flow and dissolved oxygen logging at 5 minute intervals.

The indicators used were introduced at different times in the study design in response to increased knowledge of the ecosystem as monitoring progressed. High and dangerous flows led to changing sampling sites in the Goobarragandra River and also to the inability to sample the Tumut River on all occasions. There was no mechanism to allow flow management to facilitate sampling in the regulated rivers at any time, so monitoring was reactive. In August 2000, there was a planned environmental water allocation release in the Murrumbidgee River where sampling was possible as the release was being made. The
other rivers were flooding due to winter rainfall so sampling could only be achieved for the Murrumbidgee River downstream of Burrinjuck.

Figure 5. Spatial monitoring design

Productivity sampling in February and May 2000 were performed in situ, with chambers placed within river sites, however later sampling was performed in specialised trailer with circulating water. An additional site per reach was included from September 2000 onwards. No P:P or isotope work was possible for the Tumut River in September 2000 due to high flows.

Outline of report series

This report is the first of a series reporting on the Integrated Monitoring of Environmental Flows program in the Murrumbidgee. This study was performed to monitor the impact of introduction of translucent releases from Burrinjuck Dam as a first step to developing the Murrumbidgee regulated river water sharing plan.

This particular report, background to IMEF hypothesis 4 – report 1 provides the setting for the following reports:

Report 2 – Water quality of the IMEF hypothesis four rivers
Report 3 – Periphyton responses to translucent releases in the Murrumbidgee
Report 4 - Invertebrate responses to translucent releases in the Murrumbidgee
Report 5 – Productivity of the Murrumbidgee River and its Tributaries.

Stable isotope results are reported elsewhere (Chessman et al. 2009).
<table>
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