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In the spotlight

Science into action: How monitoring informs Goulburn River flows and use of water for the environment

By Daniel Lovell and Simon Casanelia

The Goulburn Broken CMA plans and organises delivery of water for the environment on the Goulburn River. Delivery of water for the environment is a complex process which involves input from many stakeholders, including community members, scientists, and government agencies to determine the best plans for the year. It then has to pass formal planning and approval processes at multiple government levels before even a drop of water is delivered.

Once delivery of water begins there is more consultation and adaption to adjust to changing weather, water demands and environmental conditions. Throughout this process, we are always trying to identify how we can maximise the ecological outcomes of the water delivery. This is where the Goulburn MER Program results and direct advice from the scientists is invaluable.

How do monitoring results change delivery of water for the environment?

A number of long-term environmental objectives have been established for the lower Goulburn River including:

- Increase the abundance, spatial distribution and size class diversity of key native fish species (i.e. Macquarie perch, Murray cod, Trout cod, Golden and Silver perch).
- Increase the abundance and richness of aquatic and flood dependant native plant species (i.e. instream and lower bank).

The native fish and vegetation environmental objectives have remained fairly consistent over the past ten years, but the timing and shape of freshes delivered to meet these objectives has evolved over this time. Monitoring results have been critical for the CMA to refine the planning and delivery of the freshes to maximise the ecological outcomes for other objectives, but native fish and vegetation will be discussed here.

The following is an example of how the delivery of freshes over the spring/early summer has changed as our understanding of ecological responses to flow has improved. In 2013-14, water for the environment was used to provide two freshes to stimulate Golden Perch spawning (Figure 1). Secondary aims for the freshes were to encourage the growth and

germination of native vegetation on the bare lower banks (which had not recovered following large floods in 2010) and increasing habitat and food resources for macroinvertebrates by inundating snags.

A short duration fresh was delivered in November and a longer event (>5,600 ML/day for 2 weeks) in December. Both freshes were designed to stimulate Golden Perch spawning and the second fresh in December was also designed to encourage the growth and germination of native vegetation on the lower banks.

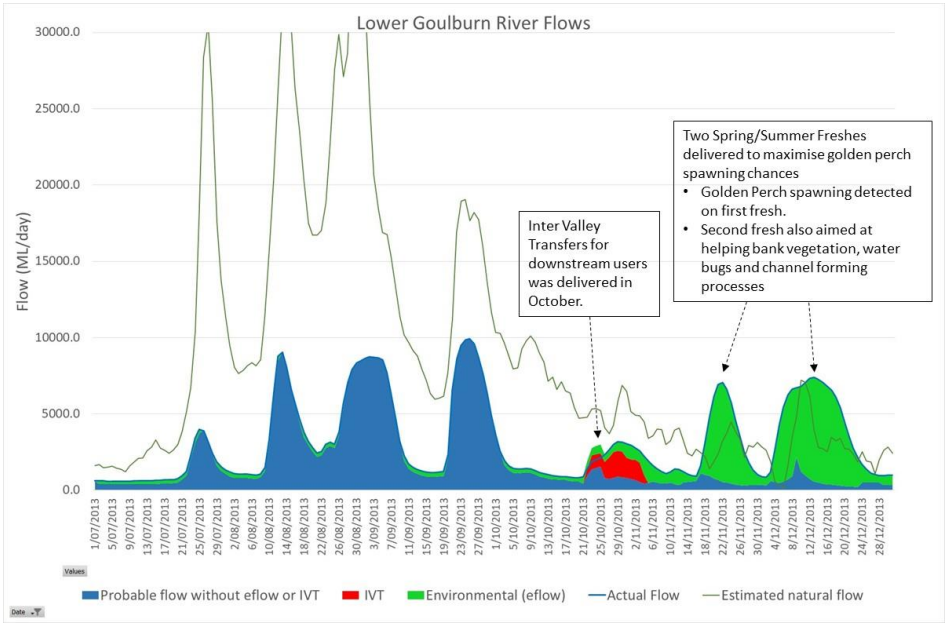

Figure 1: Flow at McCoy's Bridge on the Goulburn River in the 2013-14 season. Deliveries of water for the environment are shown in green as well as other sources.

In 2020-21 the environmental objectives were essentially the same. However, the flow regime delivered to achieve the objectives looked very different as a result of improved understanding based on monitoring outcomes over the intervening 6-year period. The spawning fresh occurred in November like 2013, but the large spring fresh for the vegetation objective was delivered in October with lower flows in December (Figure 2). The volume and duration of IVT flows has also significantly increased during this period.

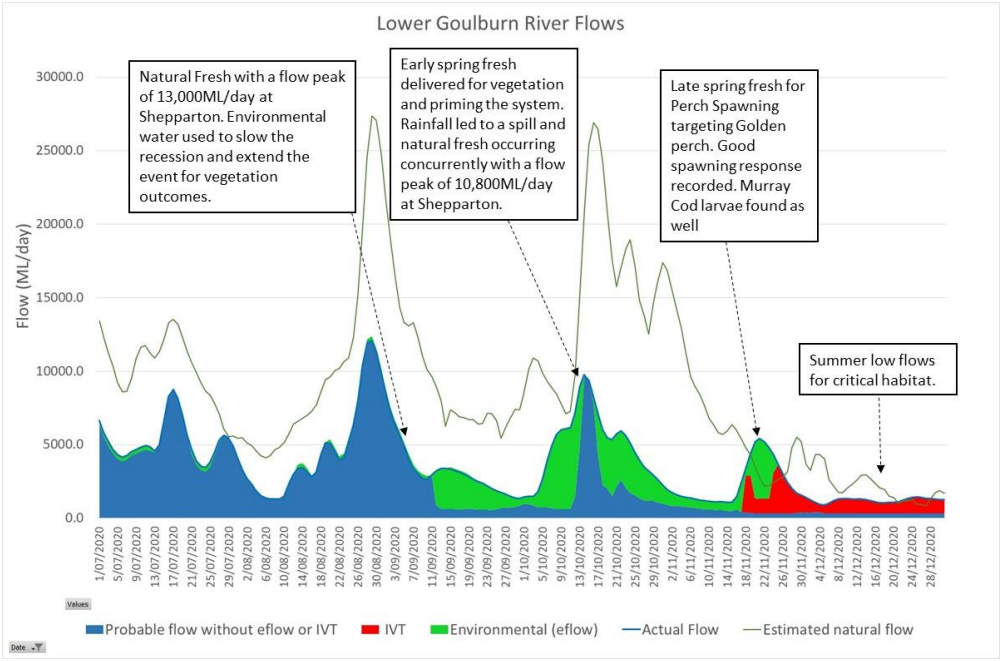

Figure 2: Flow at McCoy's Bridge on the Goulburn River in the 2020-21 season. Deliveries of water for the environment are shown in green as well as other sources.

What monitoring results changed your planning?

Using the monitoring results, we were able to evaluate the success of the 2013 freshes for fish and vegetation. In 2013, Golden Perch spawning was detected during the first pulse in November (Figure 3), but not during the second pulse. Through subsequent monitoring and evaluation of spring freshes, the conditions required to stimulate Golden Perch spawning have been identified with greater certainty. These included:

- The water temperature needs to be greater than 18 degrees Celsius
- The peak magnitude of a fresh needs to exceed 5,000 ML/day
- Spawning responses are more likely to occur in November (spawning may also occur in October and December if the above conditions are met)
- Larger spawning responses are more likely if there were prior high flows in late spring

In addition to the monitoring results and scientific advice, community feedback plays a large role in management of water for the environment. In 2013 there was negative community feedback on the December fresh as the high flows impacted fishing during the opening weeks of the Murray Cod season. As a result of this feedback, environmental freshes now aim to finish before the opening of the Murray Cod season (1st December) with low flow for at least a week prior to allow the banks to dry.

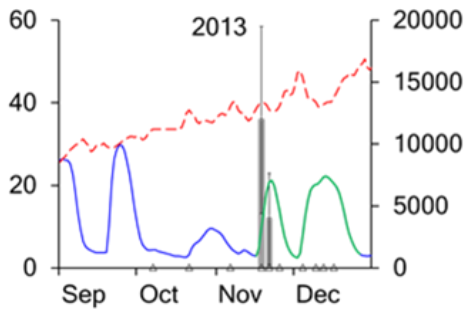

Figure 3: Golden perch spawning results in 2013 there was spawning in Nov, but not on pulse in Dec. The number of detected eggs per sampling run is shown in grey bar chart (left Y axis) and observed flow at McCoy's Bridge is represented by the blue/green line (ML/day on the right Y axis).

Vegetation monitoring results and scientific advice have also significantly changed the timing, magnitude, duration and sequence of freshes, especially over the critical germination and growing periods. The results and advice have provided the following information, which is considered critical to bank vegetation growth and recovery:

- Over the cooler months of the year (Autumn to early Spring) vegetation can survive near permanent inundation.
- Following the first spring fresh a period of low flows for 8-12 weeks is needed for new plants to grow and establish prior to the hot summer months.
- Inundation of bank vegetation during late Spring to Autumn for more than 10 days significantly impacts its health and longer periods of inundation will kill it.
- Lower bank vegetation is critical to help prevent erosion and notching and can help trap sediment and rebuild the banks.

Based on this information the first 14-day spring fresh is now prioritised for earlier delivery in September/October followed by a period of low flows. With the second spring fresh now in November, this can mean a shorter than ideal growing period for vegetation and creates a trade-off between achieving good vegetation outcomes and stimulating golden perch spawning in the same season. The potential negative impacts to vegetation are compounded with the increased volumes of IVT flows since 2013-14. A Golden Perch spawning action is not required every year, however, in those years when it is not delivered downstream, ecological outcomes in the lower Murray may be compromised. Consideration of delivering the November fresh occurs each year and takes into account the extent of natural flows over winter/spring, availability of water for the environment, the condition of lower bank vegetation, the length of time since the last spawning event, and ecological needs in the lower Murray

Monitoring has also shown that:

- The delivery of a spring fresh in September/October prepares the system for summer and helps macroinvertebrates, primary productivity and channel forming processes when flows are greater than 7,600ML/day.
- Freshes primarily derived from unregulated tributary flows carry more sediment, seed and carbon which maximises ecological outcomes. Where possible, the delivery of freshes to achieve Goulburn River ecological objectives now maximises the use of unregulated tributary flows and minimises releases from Lake Eildon.

In hindsight, could anything have been done differently in 2013-14?

Yes, the fresh in December would not have been delivered. The natural fresh in September would have met vegetation objectives, and to protect and maximise vegetation outcomes over summer there would have been one fresh in conjunction with the IVT delivery in October/November. With current knowledge this would have likely achieved the Golden Perch spawning objective and given the best potential to maximise outcomes for vegetation and macroinvertebrates over summer.

Catchment conditions and flows during 2020–21

From June through early July flow in the lower Goulburn River averages 1300 ML/day. The flow was principally comprised of regulated low flows and environmental water, which was used to maintain base flows (Figure 4).

In mid-July a winter fresh was delivered down the lower Goulburn River. The fresh had a peak magnitude of approximately 9,000 ML/day at McCoy's Bridge. The fresh peaked on the 30 July and was delivered using predominately mid Goulburn River tributary inflows generated by widespread rainfall. Environmental water was used to slow the recession of the fresh downstream of the Goulburn Weir. Unregulated inflows from the Broken River and Seven Creeks elevated flow briefly in mid-August before the flow slowly receded back to approximately 1,500 ML/day. The fresh aimed to:

- Provide organic matter and carbon to the channel to support food webs.
- Connect low lying off-channel habitats including wetlands and anabranches.
- Maintain channel features such as deep pools and benches by transporting and depositing sediments.
- Provide cues for platypus to nest higher up the bank.
- Deposit seed and sediment on the banks to encourage the growth and establishment of native plants.
- Provide cues for fish movement and dispersal.

In September high rainfall totals in the upper catchment generated a large fresh down the lower Goulburn River. The fresh had a peak magnitude of approximately 19,000 ML/day at Shepparton (approximately bankfull) and 15,000 ML/day at McCoy's Bridge. Again, environmental water was used to slow the recession of the fresh downstream of the Goulburn Weir. The fresh connected off-channel habitats higher on the floodplain including Gemmill's Swamp and Wakiti Creek.

Under natural (unregulated) conditions both the winter and spring flows would have been high enough to generate significant overbank flows and floodplain connection.

For those interested our hydrograph for flows in the lower Goulburn River are updated regularly and are available online at https://fchmccoys.hydronet.com/.

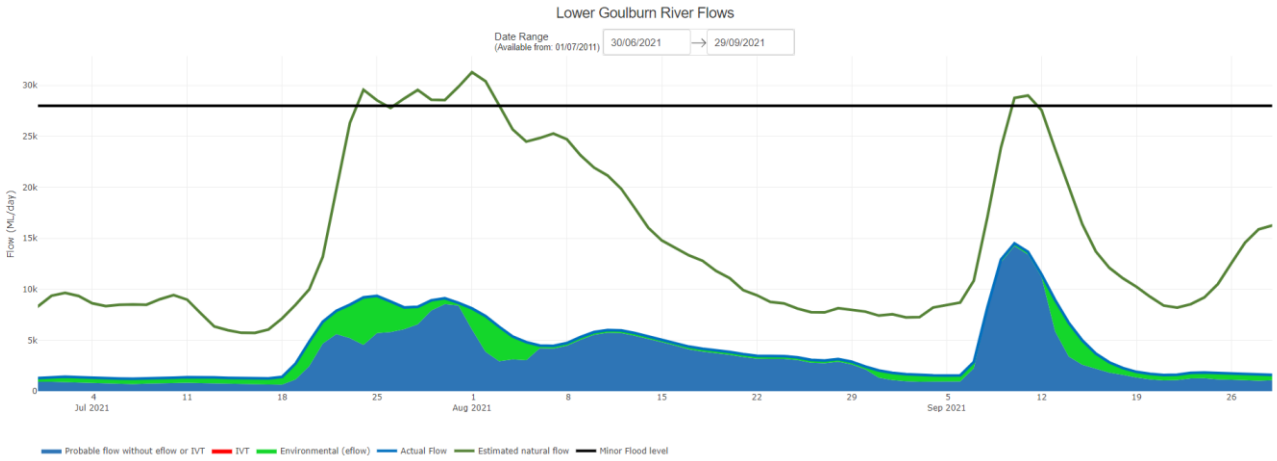

Figure 4: Hydrograph for the lower Goulburn River from July-September 2021 at McCoy's Bridge (data source https://fchmccoys.hydronet.com/).

Core monitoring

Fish

The focus of work in the last quarter has been entering the data from the annual population surveys, which were undertaken in May and June 2021. Eleven species of fish (nine native and two exotic) were collected in the surveys, including the nationally threatened Trout Cod, and Unspecked Hardyhead which has not been recorded in the LTIM-MER surveys but is occasionally collected in low numbers in the Goulburn River (Figure 5). The small-bodied Australian Smelt was the most abundant species collected, and the exotic Carp was the most abundant large-bodied species collected, similar to the results of previous surveys.

Figure 5: Trout Cod (left) and Unspecked Hardyhead (right) collected in the annual population surveys (photos: Wayne Koster)

Riverbank vegetation

Getting out in the field this spring was challenging due to COVID-19 restrictions, high natural flows and wet weather. Despite these challenges we managed to get a team of ARI staff out to complete the surveys at McCoy's Bridge and Loch Garry on the 28th and 30 September 2021, respectively. Monitoring was carried out on the recession of a natural high flow which peaked at around 14,000 ML/day on the 10 Sept 2021 and had only receded to <2,000 ML/day a week before monitoring. At the time of monitoring flows were ~ 1,700 ML/day at McCoy's Bridge.

The conditions at the site reflected the recent recession of high natural flows. The following observations were made (see Figure 6a-e).

- Much of the bank within 1-2 m of the water was bare, but at some locations sedges (*Cyperus eragrostis* and *Cyperus exaltatus*) were reshooting at the water's edge (Figure 6a and 6d).
- Creeping Knotweed (*Persicaria prostrata*) which is usually very prevalent higher up bank had died back but was also reshooting (Figure 6b).
- There was visual evidence of both erosion and sediment deposition and cracking of mud drapes.

- Introduced annual grasses tended to be dominant at higher elevations and included Oat (*Avena* spp.) and Great Brome (*Bromus diandrus*) and to a lesser extent Ryegrass (*Lolium* spp.) (Figure 6c).
- On the bench at McCoy's Bridge Nth the previous stands of Water Pepper (*Persicaria hyropiper)* and Pale Knot Weed *(Persicaria lapathifolia)* had senesced and reshooting *Cyperus* spp. were prevalent (Figure 6e).
- There were very few germinants as water levels had only recently receded and it was early in the growth season.
- The sedge Poong'ort (*Carex tereticaulis*) which tends to occur at higher elevations was flowering at both McCoy's Bridge and Loch Garry. Plains Sedge (*Carex bicenoviana*) was observed flowering at Loch Garry.

*Figure 6. (a) Bare areas within 1-2 m of water's edge, (b) Creeping Knotweed (*Persicaria prostrata*) reshooting among healthy Common Tussock Grass (*Poa labillardierei*), (c) introduced annual grasses dominant at higher elevations, (d) reshooting* Cyperus *spp. at water's edge and the introduced perennial Coolah Grass (*Panicum coloratum*) slightly further up the bank, (e)* Cyperus *spp. prevalent on the bench at McCoy's Bridge (Photos: Kay Morris)*

Macroinvertebrate condition

This quarter, macroinvertebrate data were prepared for analysis and the annual report was prepared. The 2020-21 findings have overall supported the findings from 2019-20, whereby spring freshes and other environmental water deliveries appear to have small positive impacts on the macroinvertebrate fauna, particularly the large-bodied crustaceans in the Goulburn River. There is some evidence to suggest that the larger unregulated flows in winter/spring 2020-21 have increased the abundance of some macroinvertebrate taxa and large bodied crustaceans, which may be due to an increase in food supply for macroinvertebrates (increased organic carbon brought in by the flows).

2021-22 sampling commenced in September after the natural high flow events and before the spring fresh was delivered. Across many of the sites, complex habitat (snags, CPOM, logs) had moved significantly. For example, Figure 5 shows how the banks have changed after the recent natural flood events, where complex habitat in now covering our fixed photo point at Salas Road Murchison.

Figure 5. a) Banks in 2020 in the Goulburn River at Salas Road Murchison, b) Recent complex habitat formation after natural flood events in the Goulburn River at Salas Road Murchison September 2021

Figure 6. A yabby caught in a bait trap at Cemetery Bend

Stream metabolism

Dissolved oxygen loggers remained in place over the July-September period. Data were prepared for analysis for annual reporting.

Bank condition

The focus for bank condition work this quarter has been (1) processing, analysis, and reporting based on previously collected 2020-21 data and (2) a single drone monitoring visit prior to the start of the 2021 Spring fresh. Key findings from the 2020-21 data include:

- Environmental flows continue to contribute to erosion, but not in a manner that causes damage to the long-term physical form of the Goulburn River. The location, pattern and depth of erosion indicates that these flows are, overall, resulting in positive outcomes to channel form through the resetting of lower bank steepening caused by erosion from prolonged and non-varying irrigation deliveries.
- Major drivers of erosion are duration of inundation, the duration of maximum flow (longer duration above 5,000 ML/day for example leads to more change to upper bank zones) and the daily rate of rise and fall.
- Spring and Autumn freshes resulted in flows above 5,000 ML/day, influencing the upper bank. The Autumn fresh included a longer time above this flow and had a slower rate of fall that may have helped minimise any instances of major erosion in sensitive areas of the lower bank.
- Increased deposition corresponded to the source and timing of the water delivery (i.e., dam versus tributary delivered water). The Spring fresh had an estimated 37% tributary flow contribution versus 9% during the Autumn fresh. Greater deposition depth was observed over the Spring fresh as a consequence.
- Environmental watering events saw erosion and deposition spread over a wide vertical range of bank elevations and no mass-failure events. This indicates that environmental flow events with appropriate rates of rise and fall, which reach the upper bank zones, and which consider prior events, will lead to positive long-term results.

Monitoring this quarter was completed just before the start of the Spring fresh in late September. A thick layer of freshly deposited sediment was observed over a wide vertical range of bank elevations at all sites following high winter flow events (>9,000 ML/d in July and >14,000 ML/d in early-mid September). While geomorphic change analyses are yet to take place, on-site observations suggest that the deposition is helping to repair previous erosion by infilling notches. The question is: *Will this sediment be there after the Spring Fresh?* If the answer is Yes, then the sediment has been given time to consolidate and this process of bank repair through post-IVT freshes is working (Figure 7).

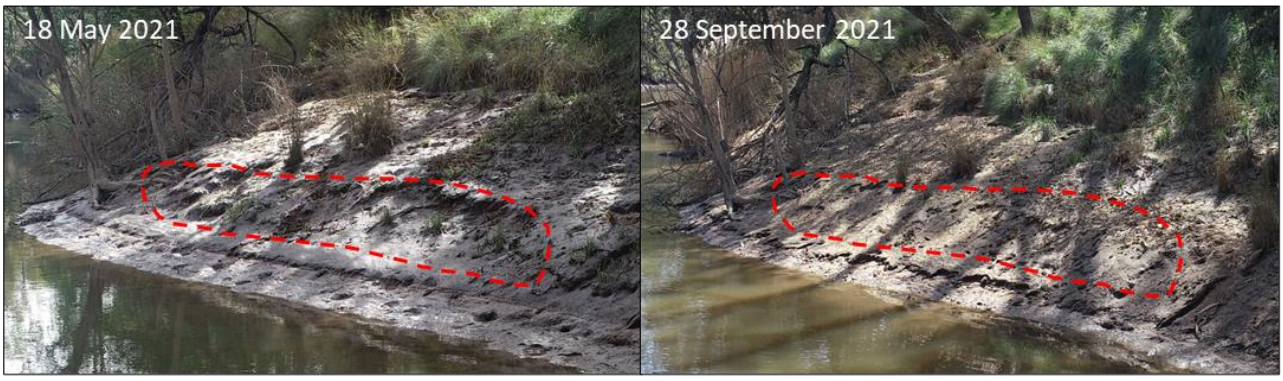

Figure 7. Photos from Darcy's Track (Bank D) in May and September 2021 showing infilling of notches with deposited sediment.

Contingency monitoring activities

Monitoring sediment and seed deposition using turf mats

Sediment and seed deposition results from retrievals of artificial turf mats during the previous year were analysed and discussed as a part of the 2020-21 annual reporting. Key findings include:

- In general, greater peak flow height and longer inundation duration results in the deposition of more sediment and greater seed abundance and species richness. These results support the role for greater magnitude and longer duration freshes to support the recovery of banks affected by IVT flows.
- More sediment and greater seed abundances are generally deposited on bars, and also benches in some cases, which highlights the important role of shallow profile features on the lower banks for vegetation recruitment.
- Over 60 plant species were identified in turf mat deposits. Increased seed taxonomic richness correlated well with inundation duration and mass of sediment deposited. Thus, longer duration freshes will promote sediment deposits with greater species diversity.
- While more species were typically deposited on bars, some species were preferentially deposited on higher bank features, such as *Eucalyptus camaldulensis* (River Red Gum), and at different times of year.

Retrieval of turf mats prior to the Spring fresh this quarter was hampered by flows and weather. A narrow window between naturally high flows for most of September and the onset of environmental water delivery at the end of the month was further compromised by heavy rains affecting access to the study sites. Consequently, only turf mats from McCoy's Bridge were retrieved (except for those on the bar). These are yet to be analysed but field observations align with those during the bank condition monitoring, suggesting that high flows resulted in sediment deposition on all habitat features, including the highest ones – ledges (Figure 8).

Figure 8. Photo of turf mats draped in deposited sediment on the ledge at McCoy's Bridge, retrieved prior to the 2021 Spring fresh (29/09/2021).

Native fish contributions to the Murray River

Fish eggs and larvae were sampled using drift nets at three sites around the Goulburn-Murray junction: the Murray River immediately upstream and downstream of the Goulburn River junction, and in the Goulburn River immediately upstream of the Murray River confluence. This sampling was conducted on five occasions at weekly intervals from around late October to late November 2020 in conjunction with the regular larval sampling.

There was no noticeable increase in the catches of Golden Perch eggs in the Murray River following spawning in the Goulburn River (Figure 9). Catches of Silver Perch eggs in the Murray River downstream of the junction increased slightly in late November, coinciding with spawning being detected in the lower Goulburn River (Figure 9).

Spawning of Golden and Silver perch in the Murray River occurs over a broader time frame than in the Goulburn River. This finding may reflect differences in flow conditions between the rivers. For instance, in the Murray River there is often a sustained high discharge throughout the late spring-summer spawning period due to irrigation demand,

whereas in the lower Goulburn River discharge is often relatively low throughout the spawning period with the exception of short duration targeted environmental flow pulses.

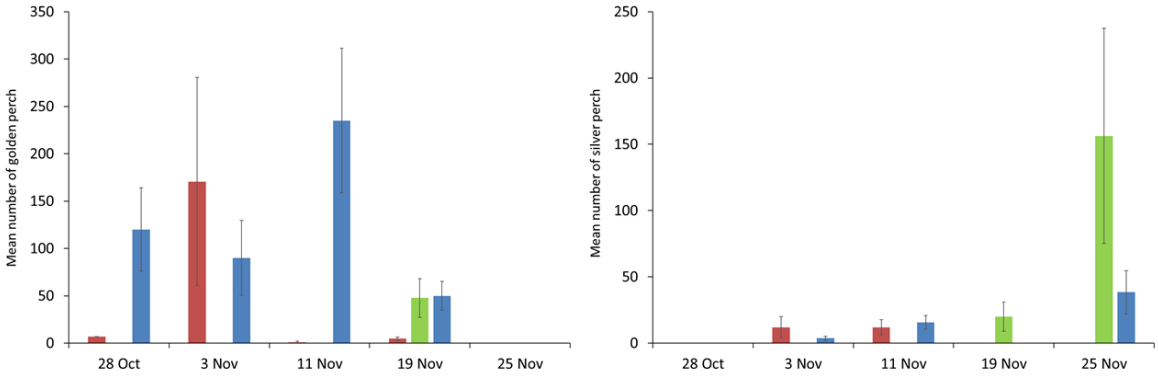

Figure 9. Mean (±se) number of Golden Perch (top panel) and Silver Perch (lower panel) eggs/larvae collected in the lower Goulburn (green), and Murray upstream (red) and downstream (blue) of junction.

Research activities

Integrated Research Project

Our integrated research project is focused on understanding the importance of slackwaters (shallow, slow flowing habitats) as areas for a range of biota and ecosystem processes. We are studying how the number and quality of slackwaters is affected by changing river flows to inform flow management and protect these areas.

One measure of slackwater quality is the amount of plant detritus (leaves, bark, twigs) available as sources of food and habitat for small organisms (aquatic insects, shrimp, small fishes). Plant detritus accumulates by deposition in hydraulic dead-zones such as slackwaters, but is readily flushed away by increased flows during freshes. We predict that slackwaters with more structural features (woody snags) will better retain accumulated plant detritus during freshes, providing a more continuous supply of resources to resident organisms.

In late June 2021 we established a large field experiment to increase woody structure in slackwaters by driving hardwood garden stakes into the riverbed. We expect the stakes to accumulate and retain plant resources and predict that these resources will attract and support large numbers of shrimp, insects and small fishes compared to Control areas without stakes.

Experimental design

The field experiment was established in 24 slackwaters across 4 sites (3 Wide, 3 Narrow slackwaters per site) (Figure 10). To allow direct comparisons between Wide and Narrow slackwaters, slackwater area was standardised to areas 30 m long and 1.5 m wide (the mean width of Narrow slackwaters at our sites). Within each slackwater area we established four replicate treatment areas (4 m X 2.5 m = 10 m^2): two 'Control' areas without stakes, and two 'Stakes' areas with 30 stakes arranged in pairs and distributed at random (Figure 11).

Treatment areas were divided into two zones centered around the 1000 ML/day water level. Discharge in the Lower Goulburn River rarely falls below 1000 ML/day, so we established a 6 m^2 'permanently wet' zone below the 1000 ML/day water level and 4 m^2 'lower bank' zone above the 1000 ML/day water level. In the lower bank zone, we will test whether added structure can improve the retention of deposited seeds and promote recruitment of plants.

Since establishing the experiment, the treatment areas were fully submerged by freshes in winter (≤ 9,400 ML/day) and spring (≤ 14,400 ML/day), but a recent site visit confirms that the stakes have survived these elevated flows at Darcy's Track and are beginning to accumulate plant detritus as intended (Figure 11c).

Data collection

All treatment areas were surveyed before inserting stakes to determine the background densities of wood, vegetation and detritus prior to manipulation. The experiment will run for at least 12 months, with multiple surveys (wood, vegetation, detritus) and samples of aquatic organisms scheduled during this time. Covid lockdowns have delayed spring sampling until November 2021.

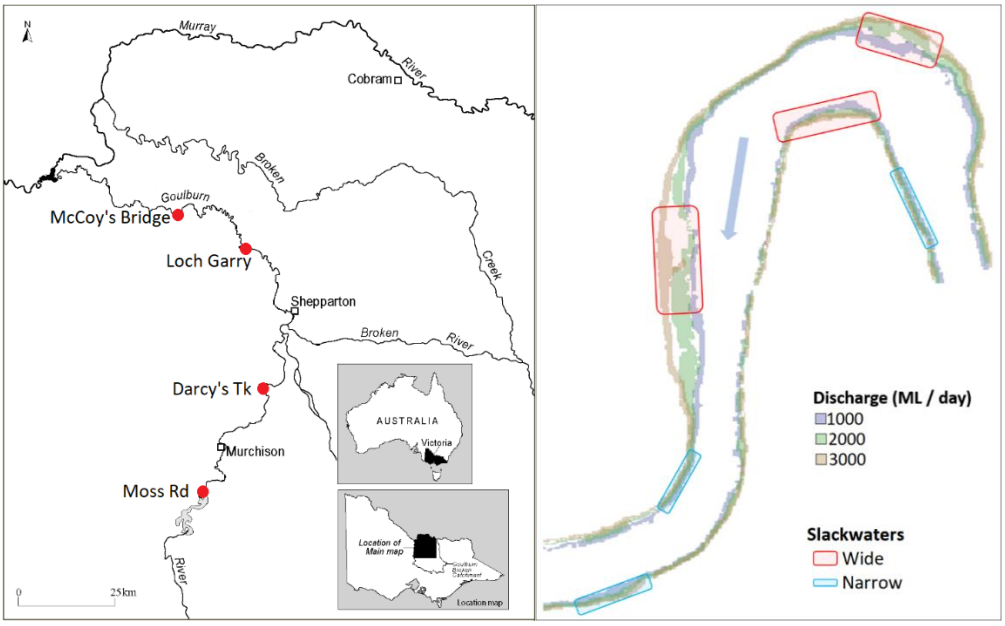

Figure 10. (Left) The four experimental sites, distributed along the lower Goulburn River between Nagambie and Kotupna. (Right) Layout of a representative site (McCoy's Bridge), with three Wide and three Narrow slackwaters. Wide slackwaters are large areas of slackwater. Narrow slackwaters are sections of a continuous band of slackwater (~1.5 m wide) along the channel margins.

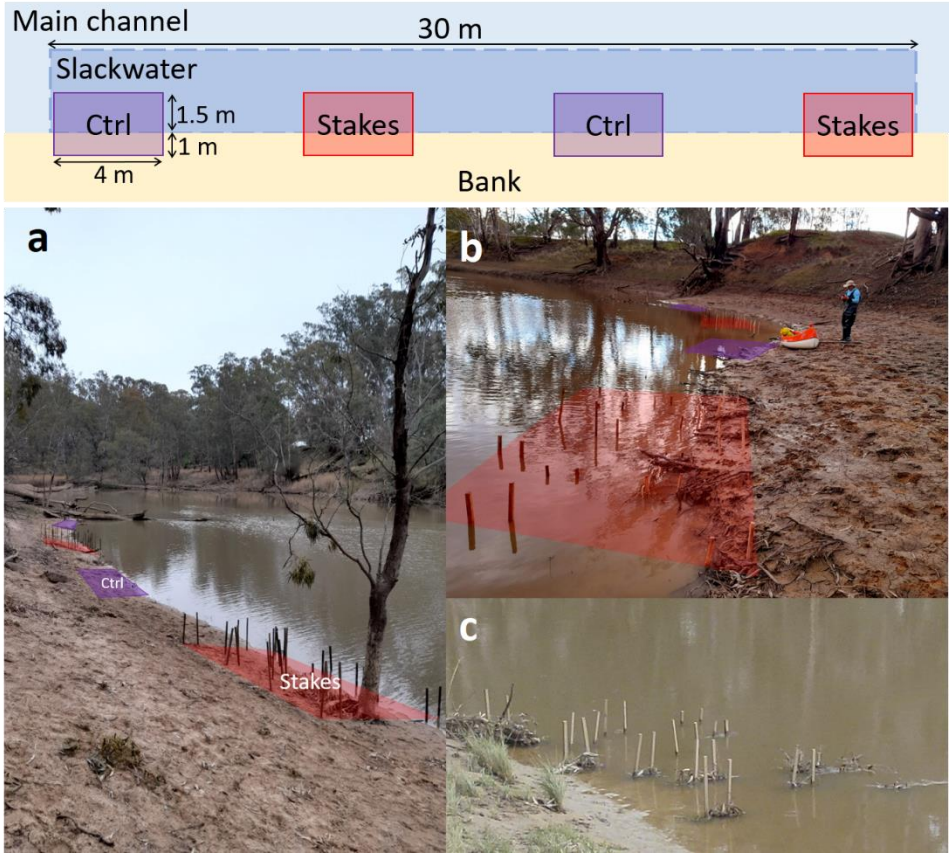

Figure 11. (Top) Layout of treatment areas with (Stakes) and without (Control) stakes in experimental slackwaters. Treatment areas are spaced 4.7 m apart and extend 1.5 m into the water and 1 m up the bank at a discharge of 1000 ML/day. (Bottom) (a & b): Examples of treatment areas at time of setup (a: Moss Rd, discharge 800 ML / day; b: McCoy's Bridge, Discharge 1200 ML / day). (c) Sites visits in September confirmed that the stakes have survived high flows during winter and spring freshes and are starting to accumulate plant detritus (Photos: W. Bovill, D. Lovell).

Communications and engagement

Story Mapping

To reach more members of the community, a new tool is being created to share research findings. This tool is a story map, an interactive map platform that combines a mixture of content from videos, pictures, and infographics to explain how environmental flows impact fish, vegetation, physical habitat, stream metabolism and macro-invertebrates (Figures 12 & 13). The detailed scientific research has been distilled and re-authored to be accessible to the wider community and presents a new and exciting way to share information and updates with the community.

The story follows the journey of a droplet of environmental water through the entire Goulburn River, stopping to discuss the benefits of environmental water at different spots along the way.

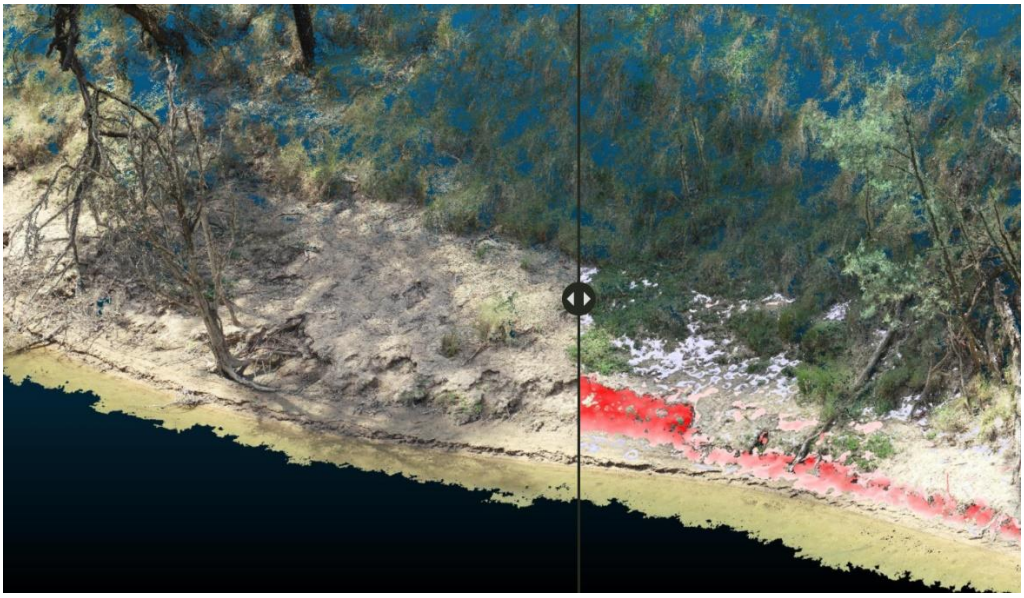

Figure 12. An interactive swipe tool is used to demonstrate how river flows impact bank condition.

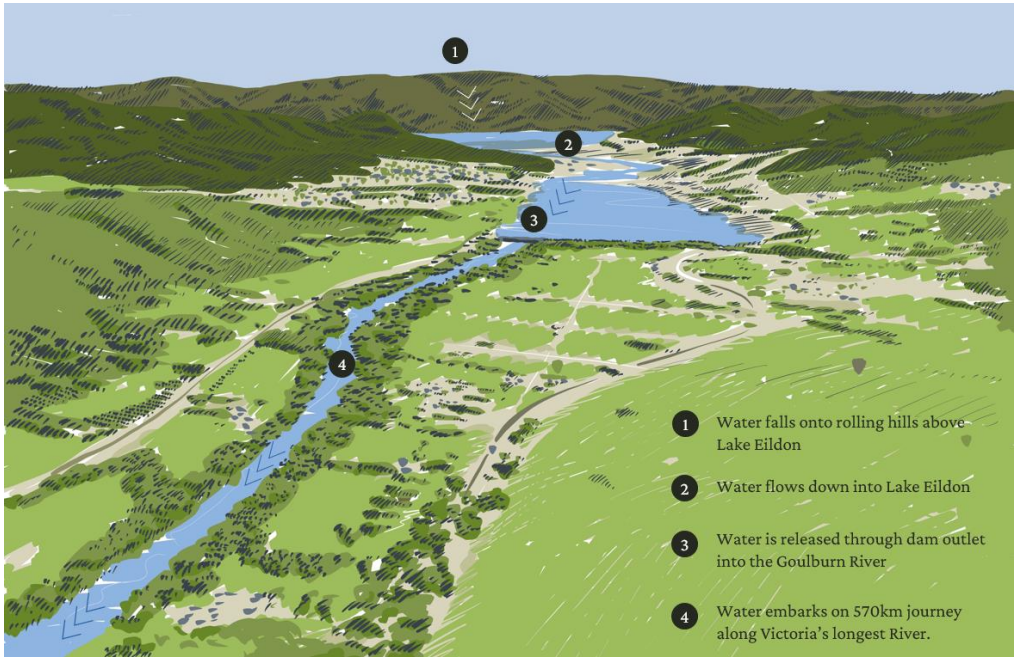

Figure 13. An artistic diagram highlights the flow path of environmental water through Lake Eildon.

The team is currently in the process of seeking feedback from the technical team as well as focus groups in the community. This tool is expected to become publicly available at the end of October 2021.

Ongoing engagement

The following activities were undertaken between July and September 2021.

- The benefits of environmental flows and monitoring continue to be highlighted in monthly columns (Country News (paid) – circulation 45,000; and Shepparton Adviser (free) – readership 70,000).
- The Goulburn Broken CMA shared social media posts from partners (VEWH, CEWO, Flow-MER and MDBA) relating to water for the environment, seasonal watering plans and monitoring of other sites (Figure 14).
- The Winter fresh was promoted via social media, newsletters and newspaper articles.
- For World Rivers Day, GB CMA staff and local partners promoted the values of the Goulburn River and other local waterways on a One FM radio segment.
- GMW, GB CMA and NCCMA held a joint webinar to discuss their roles, responsibilities, current projects and how they work together. Topics discussed included river health and environmental water management.

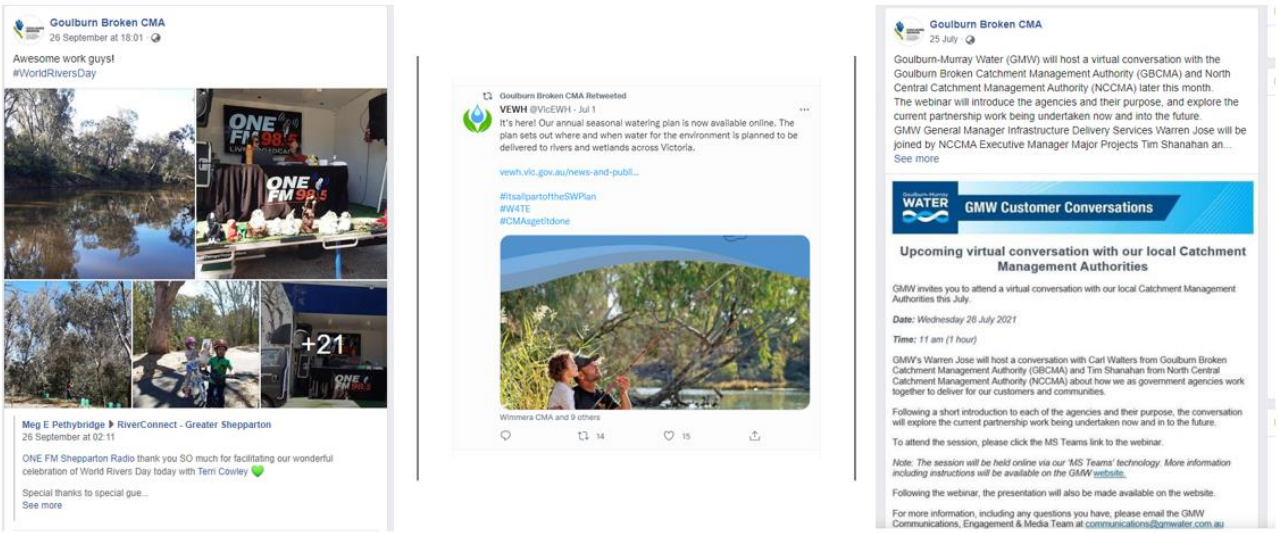

Figure 14. Social media examples

Activities calendar

Activity	Current quarter (Jul-Sep 2021)	Upcoming quarter (Oct-Dec 2021)*
River flows		
Flow deliveries	Water for the environment used to maintain base flows and deliver Winter and Spring fresh	Water for the environment used to maintain base flows.
Monitoring activities		
Fish	Data analysis. 2020-21 Annual Report contributions.	Preparing for larval drift sampling and radio-tagging study
Vegetation	Data analysis. 2020-21 Annual Report contribution. Pre-spring fresh surveys (Sep)	Post-spring fresh surveys (late October/early November)
Macroinvertebrates	Data analysis. 2020-21 Annual Report contribution. Pre-spring fresh surveys (Sep)	Post spring fresh survey. Laboratory processing
Metabolism	Ongoing data logging and processing. 2020-21 Annual report contribution	Ongoing data logging and processing
Bank condition	Data analysis. 2020-21 Annual Report contribution. Pre-spring fresh surveys (Sep)	Post-spring fresh surveys (late October/early November). Data analysis
Reporting and Evaluation activities		
Monitoring data entry	Ongoing as required	Ongoing as required
Annual report	Preparing 2020-21 Scientific report	Preparing 2020-21 Summary report
Contingency/Research activities		
Turf mat monitoring	Post Winter fresh mat retrievals and placement. Seed analysis from spring and summer retrievals	Post-Spring fresh mat retrievals and placement. Seed and sediment analysis from pre- and post-spring retrievals.
Collaborative research projects	Field surveys to determine effects of increased habitat complexity on use of slackwaters by fish and macroinvertebrates	Data analysis (Survey 2). Spring survey and sampling of experiment. Sample processing (invertebrates).
Communication and engagement		
CMA led activities	Ongoing engagement activities*	Ongoing engagement activities*

** Field and engagement activities are dependent on Covid-19 restrictions*

FLOW Monitoring Evaluation Research

Lower Goulburn River

Australian Government
Commonwealth Environmental Water Office

THE UNIVERSITY OF MELBOURNE

JACOBS

streamology waterway science and management

Arthur Rylah Institute for environmental research

VICTORIA State Government Environment, Land, Water and Planning

YORTA YORTA NATION ABORIGINAL CORPORATION

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

RMIT UNIVERSITY AQUEST

VICTORIAN ENVIRONMENTAL WATER HOLDER

MONASH University

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