Adaptive management for determining environmental flows in the Australian Capital Territory

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Abstract

Environmental flows were introduced into the Cotter River in 1999 as a requirement of the Australian Capital Territory (ACT) Water Resources Act. A multi-disciplinary group comprised of a water utility, ACT Government and research organisations was formed to manage the Cotter River environmental flows program through adaptive management. The objective for the group was to balance water supply demands and environmental water needs. Based on scientific advice, changes were made to the delivery of environmental flows during drought in 2002-2005 and after the January 2003 bushfires. Ongoing ecological assessment formed a major component of the adaptive management approach by informing decisions regarding flow release strategies. Subsequently, the ecological outcomes of the new flow regime were assessed and formed a feedback loop for the decision making process. Another major component of the adaptive management approach was the implementation of a study design that was able to cope with changing questions and unforeseen events such as drought and fire. The success of the environmental flows program has highlighted the importance of collaboration between a utility, government and independent research organisations to ensure a balance between water supply demands and environmental water needs.

Keywords

Environmental flows, adaptive management, AUSRIVAS assessment

Introduction

Adaptive management is a strategy that has been applied to decisions that involve delivery of environmental flows for the Cotter River, which supplies the Australian Capital Territory with drinking water. This experimental approach has been used to gain more understanding of the biological requirements of the Cotter River system and to improve the effectiveness of delivery of flows designed to achieve environmental benefits. A multi-disciplinary group has been formed comprised of a water utility, the ACT Government and research organisations to develop and monitor environmental flows in the Cotter River using the adaptive management approach. A general definition of adaptive management is 'the systematic process of continually improving management policies and practices by learning from the outcomes of operational programs' (ACT Government, 2006).

The purpose of the Environmental Flows Technical Group (EFTG) is to manage the possible conflict between ecosystem and human needs for the Cotter River water. Recent major episodic events that occurred in the Cotter River catchment, which include the current drought and January 2003 bushfires prompted the EFTG to implement active adaptive management and manage possible conflicts between human and ecosystem needs. These natural events have required the adaptive management approach to be flexible and adapt to changing circumstances rather than trying to hold the system in its existing state (Clark, 2002). The introduction of water restrictions in the ACT has also seen a reduction in the volume of water allocated for environmental flows. The aim of this paper is to describe how biological assessments have informed the adaptive flow release strategies that have been employed since the introduction of environmental flows in the Cotter River.

Development of environmental flow guidelines for the Cotter River

Environmental flow guidelines for the Cotter River stemmed from the Coalition of Australian Governments water reform framework as a requirement of the Water Resources Act 1998 (ACT Government, 2006).

While the development of environmental flows criteria for the Cotter River was based primarily on ecological requirements, the economic and social values of the catchment were also considered when allocating volumes of water for the environment. Researchers within the EFTG outlined aquatic processes that had likely been altered by the dams and regulated flows. However, specific flow requirements of local biota before the introduction of environmental flows were not yet clear. Based partly on this ecological advice and logistical advice provided by the utility, ACT Government drafted the environmental flow guidelines. Environmental flows commenced in the Cotter River in 1999 but without clearly defined ecological objectives and only limited information on ecological requirements of the river. The legislation stipulated that ongoing assessment and research studies were to form a major component of the program to remove the uncertainty and to determine if targets and thresholds nominated in the guidelines were appropriate. This information would also help inform managers of the biological outcomes of any changes to environmental flow release strategies.

Ongoing assessment and research studies

Since the commencement of environmental flows ongoing AUSRIVAS assessments have formed a major component of the adaptive management approach by helping inform managers on the biological effects of continually changing environmental flow release strategies (Norris *et al.*, 2004).

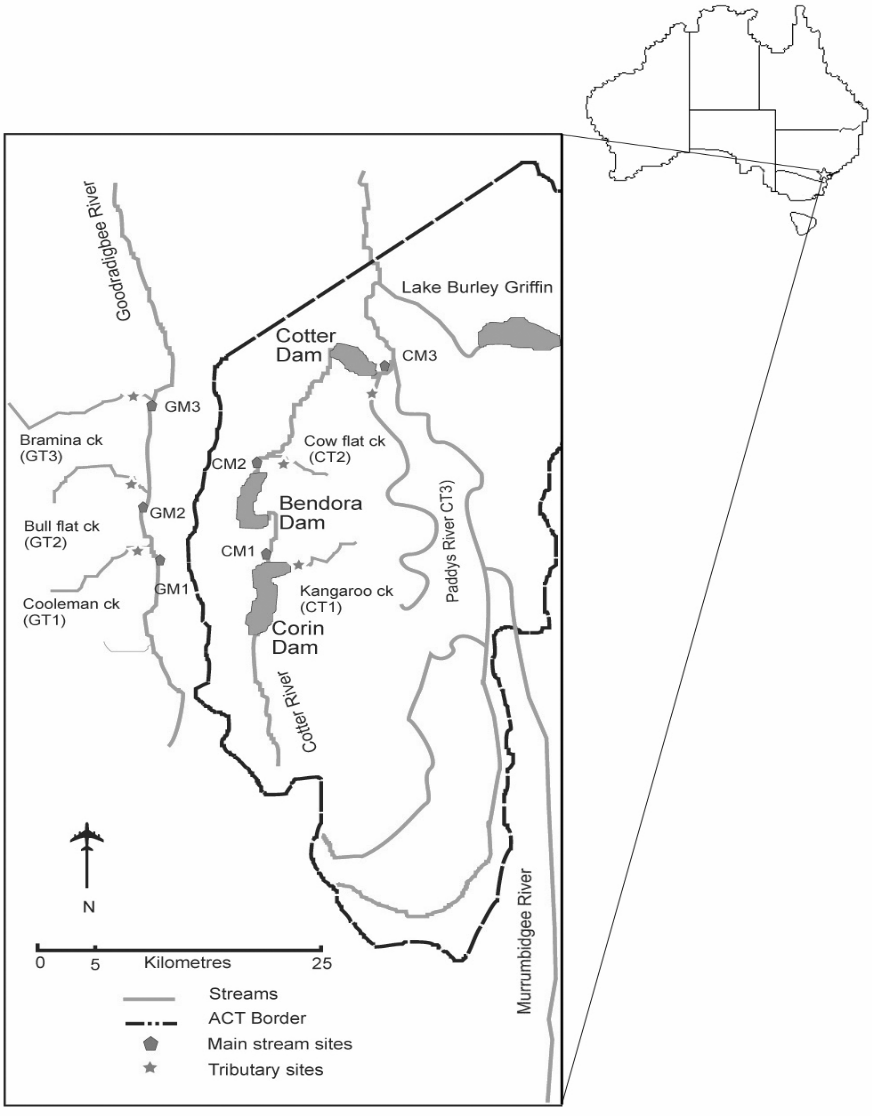

Figure 1. Location of sites downstream of the dams along the Cotter River (CM1, CM2, CM3), tributaries of the Cotter River (CT1, CT2, CT3), the Goodradigbee River reference sites (GM1, GM2, GM3) and tributaries of the Goodradigbee River (GT1, GT2, GT3).

In 2001, additional sites were incorporated into the assessment program to gain more understanding of the biological effects of flow release strategies relative to the biological condition of the neighbouring unregulated Goodradigbee River and tributaries of the Cotter River (Figure 1). The addition of these reference sites has made it possible to disentangle the biological effects of the modified flow regime relative to natural events that have stressed the biological condition of the River. Fish, periphyton and sediment surveys have also been undertaken, however, the results from these studies are not presented in this paper.

Adaptive management

There have been four stages in the implementation of environmental flows in the Cotter River and each represents stages in adaptive management.

1. Introduction of environmental flows
The environmental flow rules originally laid out in the ACT environmental flow guidelines called for the monthly 80th flow percentile or the inflow to the relevant dam (whichever is the lesser) to be released. Then environmental flows were released as 75% of the 80th flow percentile volume for the month and then made up to the full volume at the end of each month (small flushes) because it was not feasible to change the release valves based on inflows on a short-term *ad hoc* basis. Spawning flows for two endangered native fish species were also required but these were not released during the early stages of the program because of the severe drought that has afflicted the region from 2001 to the present.

AUSRIVAS assessments made up to 2001 revealed that macroinvertebrate assemblages had responded positively to the environmental flow release strategy (Table 1, and 2). Further research also indicated that the end of month flushes (spike flows) stimulated stream metabolism and refreshed periphyton assemblages, which are an important component at the base of the river food chain (Chester & Norris, 2006). Spike flows then became an integral component of the environmental flows program. Based on these scientific assessments the delivery of environmental flows remained unchanged until the drought became more pronounced.

Table 1. AUSRIVAS assessments of sites in the Cotter and Goodradigbee River catchments 1997 to 2003. Additional data sourced from honours projects undertaken at CRCFE-UC (Bevitt 1996, Roberts 2000, Chester 2003), and the Environmental Flows monitoring program 2000-2006.

	AUSRIVAS BANDS											
Site	**Spring 1997**	**Autumn 2000**	**Spring 2000**	**Spring 2001**	**Autumn 2002**	**Spring 2002**	**Autumn 2003**	**Spring 2003**	**Spring 2004**	**Autumn 2005**	**Spring 2005**	**Autumn 2006**
Below Corin Dam	C	D	B	B	B	A	B	A	B	B	B	C
Below Bendora Dam	B	C	B	A	A	A	C	A	B	B	B	B
Below Cotter Dam	B	B	B	B	A	B	B	B	A	A	B	A
Kangaroo CK	n/a	n/a	n/a	A	n/a	n/a	A	A	A	B	A	B
Cow Flat Ck	n/a	n/a	n/a	X	n/a	n/a	n/a	B	A	B	A	n/a
Paddys R	A	n/a	n/a	A	n/a	n/a	B	B	C	B	B	B
Goodradigbee R	n/a	n/a	n/a	A	n/a	n/a	A	A	X	X	X	X
Goodradigbee R	n/a	n/a	n/a	A	n/a	n/a	A	A	X	A	A	A
Goodradigbee R	n/a	n/a	n/a	X	n/a	n/a	A	B	X	X	A	A
Cooleman Ck	n/a	n/a	n/a	X	n/a	n/a	A	A	X	A	X	A
Bull Flat Ck	n/a	n/a	n/a	A	n/a	n/a	A	X	A	A	A	A
Bramina Ck	n/a	n/a	n/a	A	n/a	n/a	A	A	X	A	A	A

Table 2. Ranking and short explanation of bands for the AUSRIVAS ACT models.

Band	Band Description	O/E Taxa Interpretations
X	MORE BIOLOGICALLY DIVERSE THAN REFERENCE	More families found than expected. Potential biodiversity "hot-spot" or mild organic enrichment. Continuous irrigation flow in a normally intermittent stream. Differential loss of pollution-tolerant taxa (potential impact unrelated to water quality).
A	SIMILAR TO REFERENCE	Expected number of families within the range found at 80% of the reference sites.
B	SIGNIFICANTLY IMPAIRED	Fewer families than expected. Potential impact either on water and/or habitat resulting in a loss of families.
C	SEVERELY IMPAIRED	Many fewer families than expected. Loss of families from substantial impairment of expected biota caused by water and/or habitat quality.
D	EXTREMELY IMPAIRED	Few of the expected families and only the hardy, pollution tolerant families remain. Severe impairment.

2. Demonstrated needs flows

'Demonstrated needs' flows were implemented in December 2002 to maintain water in storage in the face of ongoing drought. Under these conditions required flows were reduced to 50% of the 80th flow percentile or the inflow to the relevant dam, which ever was the lesser. The ecological rationale behind the decision to implement demonstrated needs flows was that although there would be a decline in flow, it was thought there would be sufficient water to protect some ecosystem values while securing potable water. Based on ecological advice provided by researchers in the group it was decided to eliminate monthly spike flows and introduce two much longer duration flushes (flushing flows) with the aim of moving fine sediment and to maximize fish breeding conditions at critical times. The reduction of water allocated for the environment was in line with water restrictions placed on the local community and would ensure some protection of the resource under the drought conditions.

Additionally, bushfires burnt throughout much of the Cotter River catchment confounding the impacts of the drought on water supply and the river's ecological condition by degrading water quality and altering instream and catchment ecological processes. A legacy of the January 2003 bushfires that posed a significant problem for the water utility was turbid water that had accumulated in the reservoirs. Managers of the Cotter River were aware that the increased suspended sediment could be detrimental to the already stressed ecosystem if released without careful management. A strategy was devised to release the turbid water from Bendora Dam with the aim of maintaining drinking water quality and improving the biological condition of the downstream environment. Based on scientific advice it was decided to release pre- and post-clean water flushes either side of the turbid water release to dwarf any potential negative effects the turbid water may have on the downstream biota.

The elevated turbidity levels were the result of large inputs of sediment and organic material along with substantial quantities of ash and charcoal following thunderstorms in April 2003, which is common after fires in Australia and overseas (Lietch *et al.*, 1983; Cannon *et al.*, 2001; Dragovich & Morris, 2002). All sites in the study area had experienced high levels of turbidity before the release from Bendora Dam. Thus, effects of the turbid water release from Bendora Dam on the macroinvertebrate fauna may have been masked, or even insignificant, compared to the effects following the bushfires. However, the release strategy, which included pre- and post-clean water flushes, is also likely to have minimized possible effects. Monitoring during the demonstrated needs flows and after the turbid water release from Bendora Dam in June 2003, revealed no obvious or lasting deleterious effect on the macroinvertebrate community at sites downstream of the dam relative to the reference sites in the Spring of 2003 (Table 1).

3. Drought flows

Without any signs of the drought breaking in January 2004, ACT Government was forced to introduce 'drought flows' that were based on absolute flow volumes of 20 ML day^{-1} with accompanying flushing flows approximately every two months. Also, implemented with this regime was variation of the low flow volume from 10-30 ML day^{-1} fortnightly while maintaining the absolute volume. The basis for this decision was that while there would be further reductions in environmental flows the riverbed would remain wet and maintain some variability in environmental flow releases. Furthermore, the accompanying flushing flows would help maintain riffle habitat by scouring out fine sediment and filamentous algae that would likely accumulate under the low flows.

Ongoing monitoring of macroinvertebrate assemblages throughout the 'Drought flows' indicated that, in the short term, the Cotter River was in worse condition than at the corresponding time in 2001, before environmental flows were modified. However, despite the natural disturbances the biological condition was better than before the introduction of environmental flows in 1999 (Table 1). The fires had exacerbated the negative ecological effects of the altered flow regime because the nutrients and organic matter had been added to the river were not flushed as they had been in the Goodradigbee River and tributaries. Therefore, it was likely that the recovery time of the assemblages had been limited under the regulated flows.

4. Cotter Dam recommissioning

Without any signs in the drought breaking early the summer of 2005 the Cotter Dam and its storage was reinstated as a source of water for Canberra's water supply. While there is only a short length of substantially modified river downstream of Cotter Dam to the confluence with the Murrumbidgee River (~2km), it harbours platypus, eastern water dragons, the vulnerable Murray River Crayfish and most importantly the endangered Macquarie Perch. Therefore, the ACT Government engaged the same scientific panel to estimate the volume of water that might be released from the dam to maintain some ecosystem values in this section of the river. It was decided that flows once a month to once in two months of ~100 ML d^{-1} would be needed to allow adult fish movement between pools, and to also facilitate dispersal of aquatic fauna between the Murrumbidgee and Paddys Rivers. Experimental releases also established that flows of this magnitude would inundate ephemeral edge habitats and to help rejuvenate riffle condition, as well as help to maintain channel capacity. Low-flow variability was also introduced in the period between flushes from 5-15ML day^{-1} fortnightly.

AUSRIVAS assessments taken since the reduction in flows below Cotter Dam has revealed that this site has recovered more rapidly than the other two regulated sites since the fires even under the reduced flows (Peat *et al.*, 2005, Table 1), possibly because most sediment resulting from the fires has been trapped upstream of the Cotter Dam. However, it is still not clear if the reduction in flows will have any negative long-term biological effects on this reach of the Cotter River.

Conclusion

Overall, the biological condition of the Cotter River has improved with the introduction of environmental flows. The success of the adaptive management program for the Cotter River was marked by the re-evaluation of past decisions in light of new scientific information. The success of the program has also highlighted the importance of collaboration between a utility, government and research organisations to ensure a balance between community and environmental water needs. The approach will continue to implement more efficient ways of releasing water to benefit both the environment and community. This will be achieved through informed decisions based on scientific advice provided by ongoing biological assessment and investigative studies.

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References

ACT Government. (2006). *Water Resources Environmental Flow Guidelines*. Environment ACT, Canberra.

Bevitt, R. C. (1996). *Rapid biological monitoring of the upper Murrumbidgee River catchment: reference site selection and the precision of a subsampler*. Honours thesis, University of Canberra.

Cannon, S.H., Bigio, E.R., & Mine, E. (2001). A process for fire-related debris flow initiation, Cerro Grande Fire, New Mexico. *Hydrological Processes* 15, 3011-3023.

Chester, H. L. (2003). *Dams and flow in the Cotter River: effects on instream trophic structure and benthic metabolism.* Honours thesis, University of Canberra.

Chester, H., & Norris, R. (2006). Dams and flow in the Cotter River, Australia: Effects on instream trophic structure and benthic metabolism. *Hydrobiologia* 572, 275-286.

Clark, M. J. (2002). Dealing with uncertainty: adaptive approaches to sustainable river management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 12, 347-363.

Dragovich, D., & Morris, R. (2002). Fire intensity, slopewash and bio-transfer of sediment in eucalypt forest, Australia. *Earth Surface Processes and Landforms* 27, 1309-1319.

Leitch, C.J. Flinn D.W., & van de Graaff R.H.M. (1983) Erosion and nutrient loss resulting from Ash Wednesday (February 1983) wildfires: a case study. *Australian Forestry* 46, 173-180.

Norris, R. H. Chester, H., & Thoms, M. C. (2004). *Ecological Sustainability of Modified Environmental Flows in the Cotter River during Drought Conditions January 2003 –April 2004* Final Report. Cooperative Research Centre for Freshwater Ecology, Building 15, University of Canberra, ACT, 2601.

Peat, M., Chester, H., & Norris, R. (2005). River ecosystem response to bushfire disturbance: interaction with flow regulation. *Australian Forestry* 68, 153-161.

Roberts, K. (2000). *The effects of drought on community structure of stream macroinvertebrates.* Honours thesis, University of Canberra.