The Effect of Catchment Farm Dams on Streamflows – Victorian Case Studies

Neal B.P., Shephard P., Austin K.A. and Nathan R.J.
Sinclair Knight Merz

ABSTRACT
This paper outlines modelling results assessing the effect of catchment farm dams on streamflows in a range of catchments across Victoria. The results indicate that for each megalitre of farm dam storage in a catchment, annual downstream flows are typically reduced by between one and three megalitres. This effect varies between catchments according to rainfall-runoff characteristics, the magnitude of evaporative losses and the nature of demands from farm dams. The greatest effect was observed during low flow events, however some median flow events in drier catchments were also significantly reduced. The hydrologic effect of catchment farm dams, which do not require a water licence, was found to be significant in some instances relative to licensed water use, particularly in drier parts of the State where they form the primary source of water supply.

KEYWORDS
Farm dams, catchment yield, water balance modelling, Victoria

INTRODUCTION
In the temperate and semi-arid upland regions of Victoria in south-east Australia, farm dams are a common means of harvesting and storing water. Farm dams consist of "on-stream dams" located on defined waterways, "off-stream dams" which are supplied by pumping or diverting water from waterways, and "catchment dams" which are supplied from their own catchment but are not located on a waterway. Under current State water legislation, a water licence is not required to harvest water from a catchment farm dam. As a result, catchment farm dams have historically not formed part of the water management regime in Victoria and their effects have traditionally not been taken into account when undertaking catchment water balances to allocate water resources.

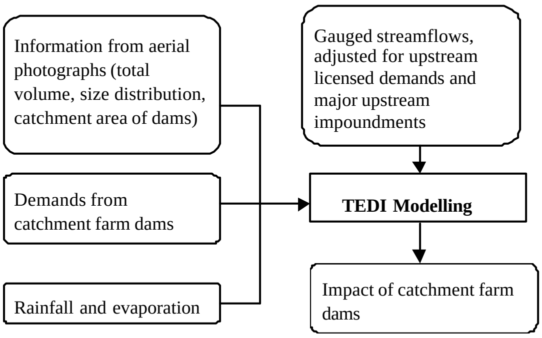
In catchments where surface water resources are already fully allocated, such as in the Victorian catchments subject to the Murray-Darling Basin cap on diversions, or where farm dam development is rapidly increasing, the lack of information about the hydrologic effects of farm dams has been a cause of concern for catchment managers and water authorities. Very preliminary calculations indicate that there may be as many as 80,000 catchment farm dams across the State, with numbers increasing each year. Anticipated increases in catchment farm dam development were considered to have the potential to reduce the security of supply to downstream water users and the environment.

To address this issue, a water balance model was developed to specifically investigate the hydrologic effects of catchment farm dams. This paper illustrates the application of the model to a selection of catchments across Victoria, which display a range of rainfall and streamflow characteristics (Sinclair Knight Merz, July 2000). The outcomes are discussed in terms of the effect of catchment farm dams under average flow conditions and on different parts of the flow regime, the seasonal effects of dams and the magnitude of these effects relative to licensed water use.

WATER BALANCE MODELLING APPROACH
An overview of the modelling approach is shown schematically in Figure 1, which illustrates the key inputs required for modelling. Information on catchment farm dam characteristics, water use and hydroclimatic conditions was collected or estimated for use in the water balance model known as the Tool for Estimating Dam Impacts (TEDI) (User Manual prepared for DNRE (Sinclair Knight Merz, May 2000)). Catchment farm dam volumes were estimated from dam surface areas obtained from aerial photography using the relationship developed by Good and McMurray (1997). Natural catchment inflows were estimated at the catchment outlet by adding back licensed demands to recorded streamflows and correcting for the influence of any major impoundments in the catchment. Flows at the catchment outlet were then apportioned to farm dam inflows on the basis of upstream catchment area. The monthly water balance performed in the model on individual catchment farm dams was given by:

Outflow = inflow – (change in storage) + (net rainfall) – (demand) (1)

Figure 1 – Schematic of modelling approach



TEDI does not model the influence of catchment farm dams in a spatially explicit manner, rather it undertakes the water balance computations for a specified number of farm dams whose sizes are selected stochastically from the known distribution of farm dam sizes in the catchment. The TEDI model is conceptually simple, but its complexity is commensurate with the nature of available data. In a limited number of cases where sufficient data was available, such as that outlined in Nathan et.al. (2000), the TEDI model approach has been independently verified by the statistical analysis of streamflow data. Further information on the TEDI model can be found in ICAM/SKM (1999).

CASE STUDY CATCHMENTS

Five catchments across Victoria were selected for investigation based on consideration of:

- The presence of farm dams in high numbers in the catchment;
- The existence of information on catchment farm dam properties;
- A manageable catchment size for data collection (nominally <200 km^2);
- The availability of good quality streamflow records; and
- Representation of a range of climatic and hydrologic conditions.

The characteristics of these catchments are shown in Table 1. The volume of catchment farm dams as a percentage of mean annual flow ranged from 0.3% in the Ten Mile Creek and Running Creek catchments to 3.1% in the Mount Cole Creek catchment.

Table 1 – Case Study Catchment Information

Gauging Station Number	Location	River Basin	Catchment Area (km^2)	Period of Record	Mean Annual Flow (ML/yr)	Current[1] Volume of Catchment Farm Dams (ML)
226409	Ten Mile Creek at Delburn	La Trobe	46	4/1959 to 7/1975	8,188	26
229620	Arthurs Creek at Arthurs Creek	Yarra	105	6/1976 to 12/1988	10,127	150
415245	Mt Cole Creek at Crowlands	Wimmera	158	5/1985 to 12/1998	16,097[2]	366
402206	Running Creek at Running Creek	Kiewa	126	5/1966 to 12/1998	36,681	106
229215	Woori Yallock Creek at Woori Yallock	Yarra	322	6/1963 to 12/1998	94,381	678

Note: (1) Current volume is based on most recently available aerial photography, typically in the late 1990's.
(2) Calculated from de-trended streamflows.

The Ten Mile Creek catchment is dominated by on-stream dams (additional to the volume of dams specified in Table 1) that mainly supply water for potato crops. Streamflows in the Ten Mile Creek catchment are perennial and apart from the large number of on-stream dams the flows are unregulated.

The Arthurs Creek catchment contains comparable numbers of on-stream, off-stream and catchment dams. Agricultural development in the region includes orchards and some pasture. Arthurs Creek can potentially become dry in the summer, although it is not ephemeral (meaning that dry periods do not occur every year). A portion of the catchment is regulated by Running Creek Reservoir (345 ML capacity), located on a tributary to Arthurs Creek. The influence of this reservoir was removed from the inflow time series by performing a water balance on the reservoir.

The Mt Cole Creek catchment contains a high level of catchment dam development. No licenses were identified for on-stream or off-stream dams. The creek is often dry in summer, although it is not ephemeral. The catchment is regulated by two storages: Mt Cole Creek Reservoir (810 ML capacity) which is situated on Spring Creek, and an unnamed storage located on a tributary which is comparable in size to Mt Cole Creek Reservoir. Spills rarely occur from the Mt Cole Creek Reservoir, so this part of the catchment was removed from the analysis. In the absence of any data, the effect of the unnamed storage on Spring Creek was ignored when estimating natural inflows.

The Running Creek catchment contains a moderate level of catchment dam development, and no licenses were identified for on-stream or off-stream dams. Streamflows are perennial, and no significant upstream impoundments are present.

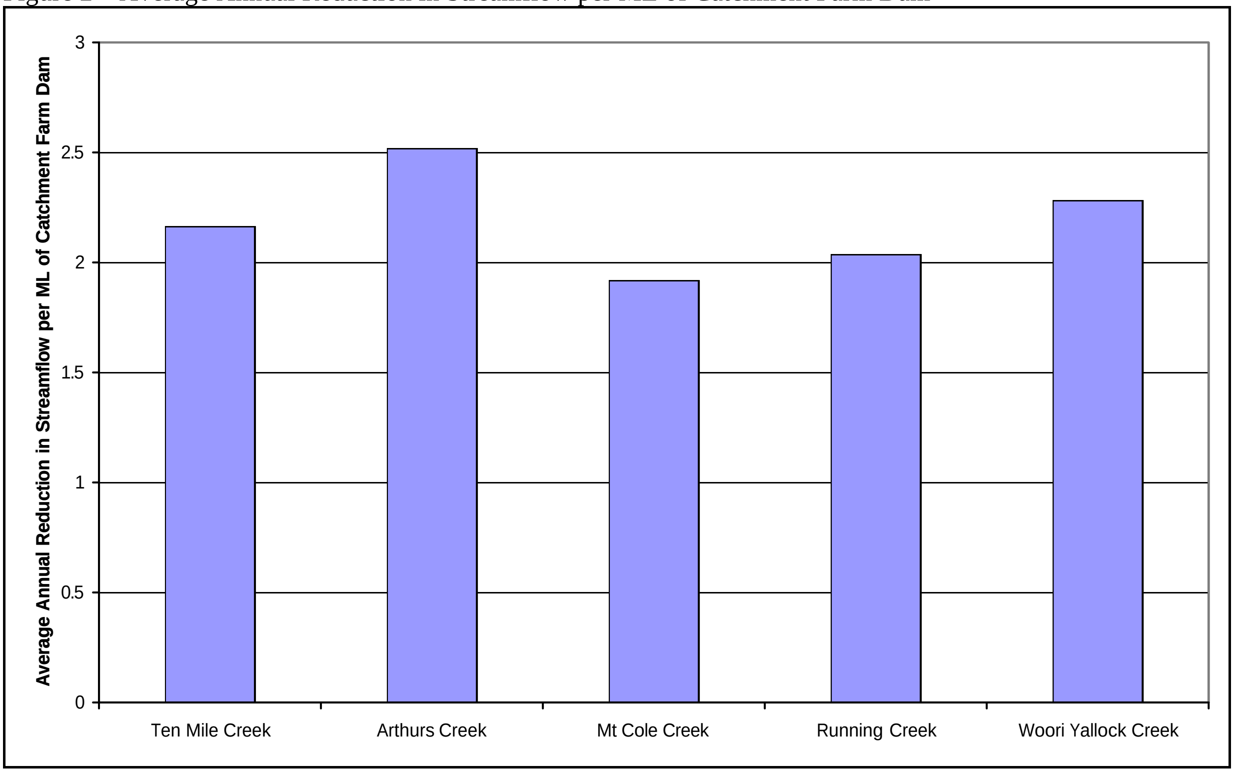
The Woori Yallock Creek catchment contains a very large number of small catchment dams. It is estimated that 86% of dams are less than 0.5 ML in volume. Streamflows are perennial, and no significant upstream impoundments are present.

RESULTS

Average flow reductions due to catchment farm dams

Conceptually, when a catchment farm dam is full, inflows are passed downstream unaffected by the dam. Catchment farm dams are often less than full because the volume of water in the dam is reduced throughout the year by evaporation and water use from the dam. When the dam is less than full, water will be trapped in the dam until such time as the dam fills and spills downstream. This water trapped by the dam is prevented from reaching areas downstream. It can be seen that the presence of catchment farm dams can both reduce the magnitude of downstream flows via extraction from the dams and evaporation, and effect the timing of downstream flows.

Figure 2 – Average Annual Reduction in Streamflow per ML of Catchment Farm Dam



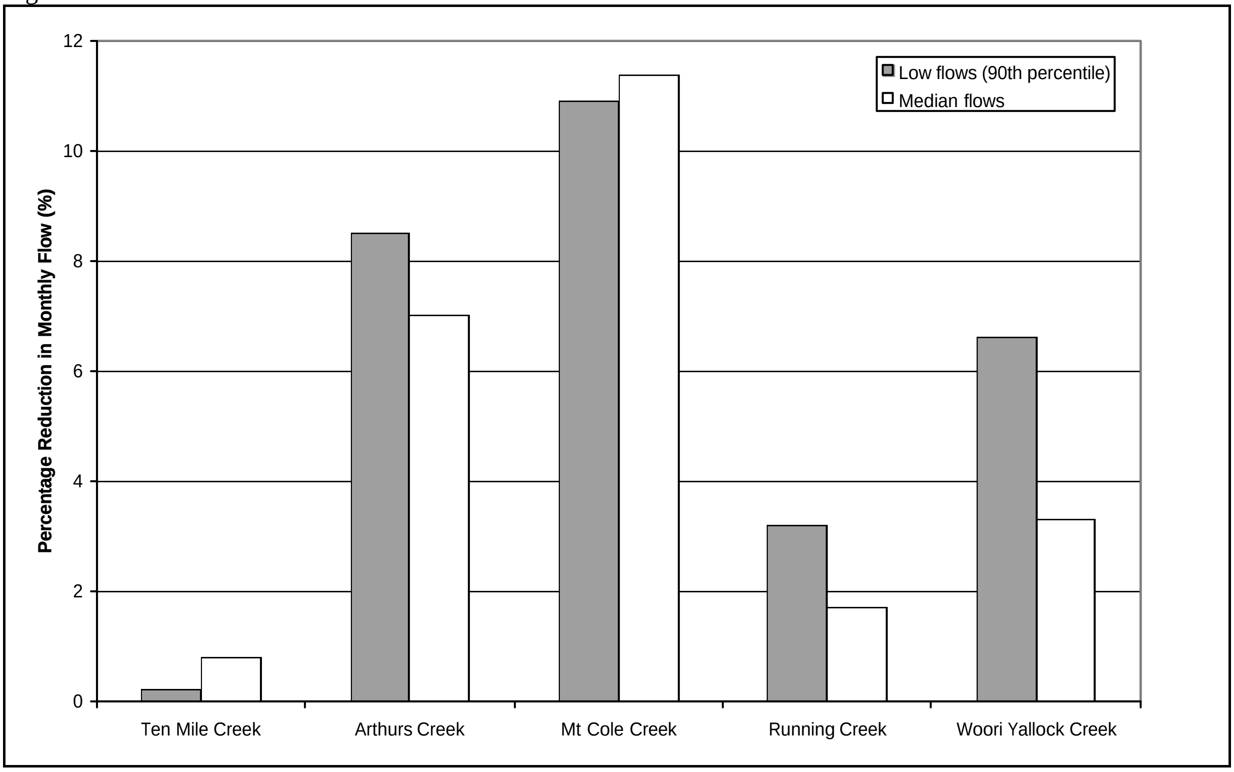
The modelling results of the average reduction in streamflow at the catchment outlet are shown in Figure 2. This figure shows that on average over the period of modelling, the annual reduction in flow due to each megalitre of catchment farm dam was in the order of 1.5 to 2.5 ML. Total reductions in mean annual flow ranged from 0.6% (Running Creek) to 4.4 % (Mt.Cole Creek) at the catchment outlet. It is important to note that reductions in flow are greatest immediately downstream of the dam (100% capture of runoff during some events) and decrease gradually further downstream as streams receive inflows from other parts of the catchment not affected by farm dams.

The variability in flow reduction between catchments can be explained by regional differences in inflow characteristics and net evaporation. In the Mt Cole Creek catchment, the potential to reduce *average* flows is limited because the majority of inflows occur during high rainfall events during winter and spring. The ability to extract water from the dams for consumptive use is constrained by the low availability of inflows during periods of demand in summer and autumn. The average impact on streamflows in Ten Mile Creek, Arthurs Creek and Woori Yallock Creek is greatest because of the greater availability of inflows and the ability to meet demands throughout the year. The effect of catchment farm dams on average streamflows in the Running Creek catchment is less than these three catchments, despite having a high natural catchment yield throughout the year. This is principally due to the much lower net evaporation in this very elevated part of the State.

Relative effects of catchment farm dams on low and median flows

Farm dams were considered to have less effect on flows when the dams were closer to capacity during the wetter months of the year. This was investigated by comparing the effect of catchment farm dams on the monthly flow exceeded in 90% of months (i.e. a low flow) and the median monthly flow. The results are shown in Figure 3. This figure indicates that the percentage reduction in monthly low flows is generally greater than the percentage reduction in monthly median flows. The percentage reduction in high flows, not illustrated in this paper for reasons of brevity, was found to be negligible because of the large volume of water in these flow events and the higher probability that dams would be at or near capacity at the start of high flow events.

Figure 3 – Reduction in low flows relative to median flows.



The greater flow reduction at median flows in the Mount Cole Creek catchment is due to the intermittent nature of flows in this relatively dry part of the State. The median flow event occurs during late autumn, when the dams in this catchment are well below capacity and hence the median flow is significantly reduced. The low flow event occurs at the start of summer, when the dams still have volume in storage from spring rainfall events. This effect is also observed to a lesser extent in the Ten Mile Creek catchment where some median flow events occur at the end of autumn and start of winter.

Farm dams have also been found to increase the frequency, duration and variability of low flow spells. With increasing farm dam development, low flow spells have also been found to commence earlier in the year and occur in more months of the year. The results of spell analyses are not presented in this paper.

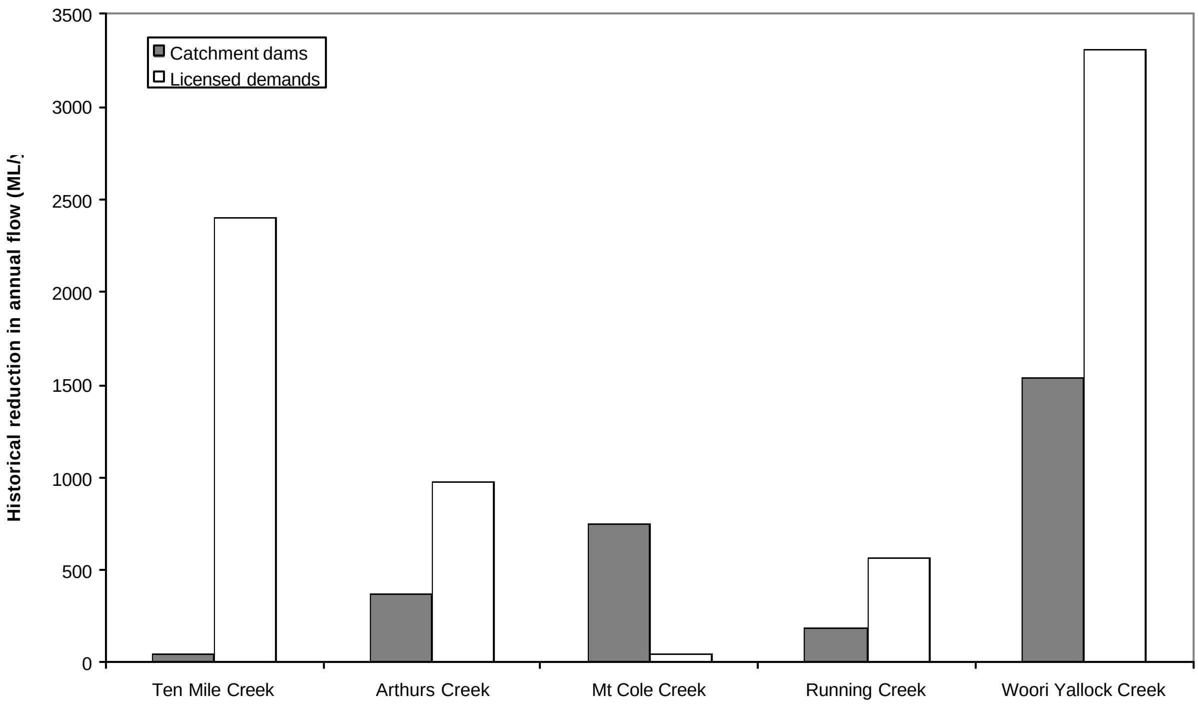
Seasonal effects of catchment farm dams
As discussed above, the nature of effects throughout the year is highly dependent on the seasonal pattern of inflows. Where inflows to catchment dams are intermittent (and generally lower), use of water from these dams is reliant upon winter inflows. The magnitude of winter impacts is therefore greater than the magnitude of summer impacts, when natural inflows are typically small or non-existent.

Where inflows to catchment dams are perennial (and generally higher), the dams remain relatively full throughout the year. In this situation the water supplied from the dams is rapidly replenished, diminishing the role of winter filling. Under these conditions, the impact of the dams on streamflows closely matches the water demands supplied from them. The magnitude of summer impacts is therefore greater than the magnitude of winter impacts.

Efficiency of water supply
The efficiency of water supply from farm dams is dependent on the magnitude of evaporative losses. Delivery efficiency was found to vary considerably depending on catchment location. In the wetter and more upland areas of Victoria it was found that for every 100 ML of water supplied, around 10 ML is lost to evaporation. In the drier areas it was found that for every 100 ML of water supplied, around 70 ML is lost to evaporation.

Relative effects of catchment farm dams and licensed diversions
The effect of catchment farm dams was placed in the context of licensed diversions within the catchment, as shown in Figure 4. Catchment farm dams are the preferred source of water in the Mount Cole Creek catchment and consequently the reduction in average annual streamflow due to catchment farm dams was found to be significantly higher than that due to licensed diversions. In the Woori Yallock Creek, Running Creek and Arthurs Creek catchments, the reduction in flow due to catchment farm dams was a significant proportion of the reduction in flow due to licensed diversions. Only in the Ten Mile Creek catchment were the effects of catchment farm dams overwhelmed by the effect of on-stream dams. It can be seen from this information that at the catchment scale, catchment farm dams can be a significant component of the catchment water balance and in some cases can produce a greater effect than local licensed diversions.

Figure 4 – The effect of catchment farm dams relative to licensed diversions



CONCLUSIONS
In this examination of the hydrologic effects of catchment farm dams in five catchments in Victoria, it was found that:

- Average annual streamflows were reduced by 1.5 to 2.5 ML/yr per ML of farm dam in the catchment;

- Total reduction in average annual flow ranged from 0.6% to 4.4%, depending on the nature of inflows and net evaporation;
- Percentage reductions in streamflow were typically higher during periods of low flow;
- Percentage reductions in median streamflows at the start of winter were significant in drier catchments;
- Reductions in streamflow due to catchment farm dams were significant relative to licensed water use in some catchments.

It can be concluded from this analysis that catchment farm dams can have a significant influence on catchment outflows, particularly during periods of low flow, and should be considered an essential component of any catchment water balance.

FURTHER STUDY

The results presented in this paper are from the first stage of a three part study examining the hydrologic effects of farm dams in Victoria. Options for further investigation centre around refinement of the inputs to the water balance model and/or the regionalisation of impacts from these and other case studies to the State as a whole. For reasons of brevity, the effect of catchment farm dams on low flow spells is not presented in this paper.

REFERENCES

M. Good and D. McMurray (1997): The Management of Farm Dams and their Environmental Impact in the Mount Lofty Ranges in ANCOLD Seminar on “Dams and the Environment” (updated). Water Resources Group, South Australian Department of Environmental and Natural Resources.

Integrated Catchment Assessment and Management Centre and Sinclair Knight Merz (ICAM/SKM) (1999): Impacts and implications of farm dams on catchment yield. Research report prepared for the Murray-Darling Basin Commission, Natural Resources Management Strategy, project R7028.

R.J.Nathan, B.Neal, W.Smith and N.Fleming (2000): The impact of farm dams on streamflows in the Marne River catchment. World Water Congress, Melbourne 2000. Sinclair Knight Merz.

Sinclair Knight Merz (May 2000): User Manual, Tool for Estimating Farm Dam Impacts (TEDI) prepared for the Department of Natural Resources and Environment (Victoria), Environment Australia and Melbourne Water, project WC01240.200.

Sinclair Knight Merz (July 2000): Impacts of Farm Dams in Five Catchments prepared for the Department of Natural Resources and Environment (Victoria), Environment Australia and Melbourne Water, project WC01240.100.

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