The empirical performance of rainwater harvesting systems equipped with real-time control

La performance des systèmes de récupération des eaux pluviales équipés d'une gestion en temps réel

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RÉSUMÉ

Cette étude évalue les performances d'un système de récupération des eaux pluviales, équipé d'une gestion en temps réel permettant de répondre simultanément à trois objectifs : la réutilisation de l'eau pluviale, la réduction des pics de débit et la contribution au débit d'étiage du cours d'eau récepteur. Le suivi d'un système à l'échelle de la parcelle a mis en évidence la capacité d'atteindre les objectifs de réduction des pics et de contribution au débit d'étiage sans entraîner de conséquence significative sur l'approvisionnement en eau du foyer. La gestion en temps réel offre ainsi une solution flexible et fiable permettant de s'adapter au changement climatique. Elle rend possible la construction d'un réseau d'ouvrages connectés et capables d'assurer une gestion optimale et intégrée des eaux pluviales.

ABSTRACT

This study explores the benefits of equipping Rainwater Harvesting Systems with Real-Time Control technology to simultaneously deliver water supply, flood mitigation and a contribution to stream baseflows. Empirical evidence illustrates that such a configuration can simultaneously mitigate peak flows and provide a slow-release to augment dry weather flow in streams, with little adverse effect on the tank's water supply performance. The adaptive control and failure detection provided by this novel approach highlight the possibility to deliver a flexible and reliable system which can adapt to a changing climate. This technology has the potential to deliver a new generation of networked rainwater harvesting and stormwater systems, delivering a true integrated management of stormwater for multiple objectives.

KEYWORDS

Flow Regime, Real-Time Control, Rainwater Harvesting System, Runoff Retention, Water Supply

1 INTRODUCTION

Urbanization results in challenges relating to runoff control and stream degradation (Barron et al., 2013; Haase, 2009; Mitchell et al., 2003). Addressing these challenges would ideally be delivered by Stormwater Control Measures capable of managing stormwater to mitigate high flow runoff, yet delivering steady baseflows to sustain urban stream ecosystems. Rainwater harvesting systems at the household scale have already been shown by some studies to deliver runoff retention benefits (Burns et al., 2015), while simultaneously supplementing potable water supplies. There is, however, scope to further enhance the multi-objective performance of rainwater harvesting systems using Real-Time Control (RTC) technology (Melville-Shreeve et al., 2014; Reidy, 2010). A previous modelling study has demonstrated such potential, but there is a lack of empirical data to give confidence to this concept (Xu et al., 2018). In this study, a rainwater harvesting system was equipped with real-time control to make use of timely water level information and weather forecasts to adaptively respond to each storm event.

2 METHODS

In this study, we monitored an RTC-based rainwater harvesting system in a residential house located in southeast Melbourne. A roof catchment of 36 m^2 was drained into a 2.2 kL tank with two types of end-use connection (i.e. garden irrigation and toilet flushing). The real-time control system was designed to receive weather forecasts and initiate a pre-storm release (i.e. purge before rainfall) through a solenoid valve to make sufficient room for the incoming event, thus minimizing the occurrence of uncontrolled overflow (Fig. 2 b). This was achieved by modelling the predicted inflow according to short-term forecast rainfall from local meteorological organisation. The pre-storm release and unregulated overflow were both discharged into the downstream stormwater drainage network.

The system also provided a baseflow restoration function to improve the flow regime of the downstream waterway. This functionality delivered a “trickle flow” which equates to the amount of baseflow that would theoretically be contributed from the rainwater tank’s catchment area. Flow data from a nearby stream in natural condition (Dobson Creek) without urbanisation was used as a reference, to determine an appropriate target baseflow contribution on a pro-rata (by catchment area) basis.

All inflows and outflows of the system were monitored. Inflows and overflows were conveyed to a weir box with a 5mm wide rectangular slot weir (Fig.1 b). Water depth over the weir was measured and translated into flow rate using the relation established during calibration (Fig. 1 a). In addition to the weir box, a rain gauge was also installed to monitor rainfall and validate system inflow (Fig. 2 a). Pre-storm release, baseflow release and end-use were all monitored by digital water meters (Fig. 2 c and d).

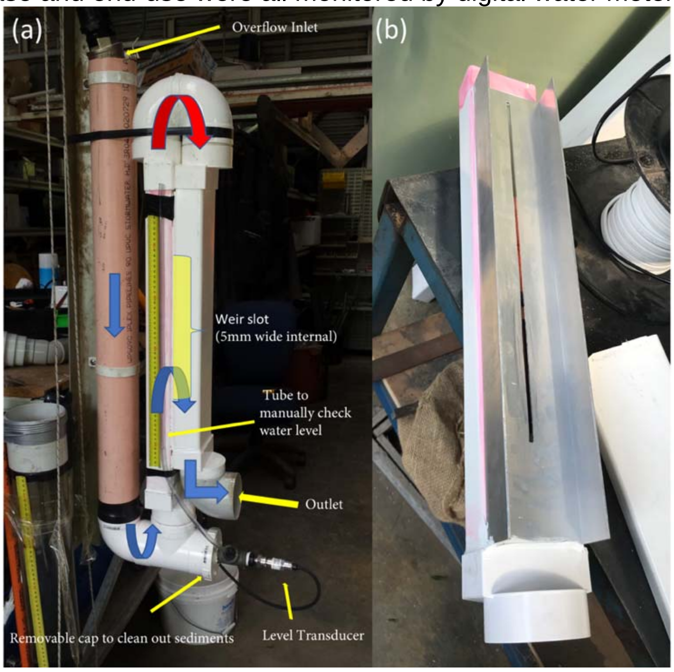

Figure 1. Schematic representation of inflow and overflow weir box (a) and internal rectangular weir (b). Blue and red arrow in (a) represent flow through weir and overflow respectively.

Figure 2. (a) Rain gauge, (b) solenoid valve for pre-storm discharge and baseflow release, (c) and (d) shows water meter to monitor end-use and active discharge through valve.

3 RESULTS AND DISCUSSION

Our monitoring confirms that allotment-scale rainwater harvesting systems operated by RTC technology could simultaneously achieve runoff retention and natural flow regime restoration benefit, with a very small impact on the security of water supply provided to the householder (Figure 3). Such a configuration could minimise system overflows during the monitoring period by proactively creating sufficient room for incoming rain events. The released volume can be adapted to each rainfall event, but this of course relies on the accuracy of forecast.

In addition, the adaptive control and failure detection provided by this novel approach highlights the possibility to deliver a flexible and reliable system, which can be readily adapted to changing climate and can overcome the maintenance risks associated with householder-maintained rainwater tanks.

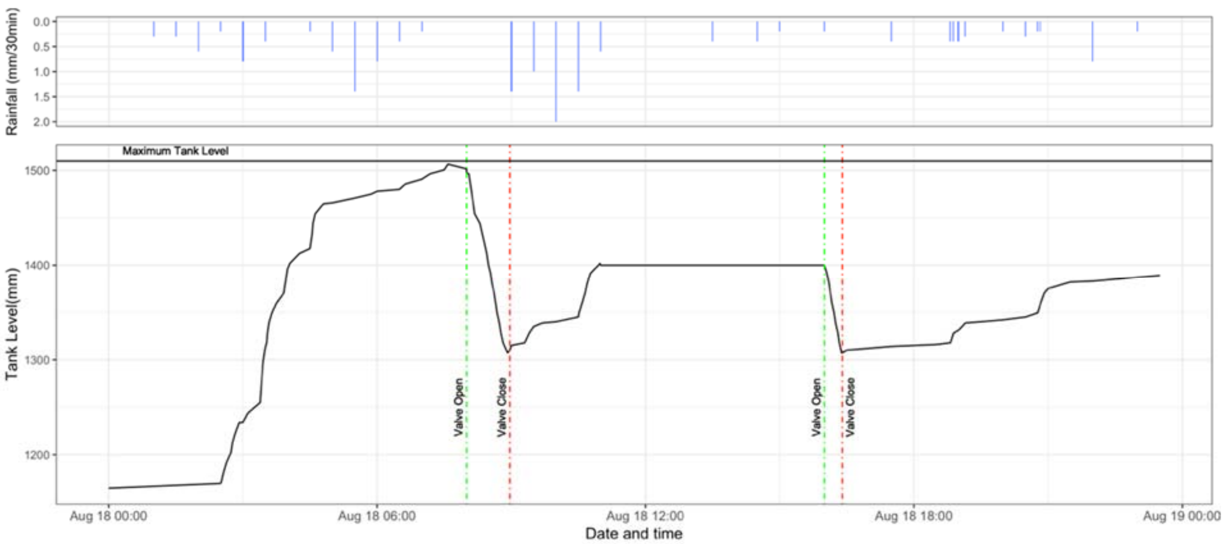

Figure 3. 24-hour trace plot for rainfall (top) and rain tank volume (bottom). Vertical dot lines indicate valve opening and closing for pre-peak discharge.

This technology could also potentially play a major role at larger scales, taking advantage of the networking and scale-optimisation that it provides. The interconnection ability of real time control allows individual allotment scale tanks to communicate and work in a systematic way. Operation of this network can be achieved by a central control model, which could constantly predict catchment-wide targets for flood mitigation and urban streamflow restoration purposes. The identified tasks can then be distributed to each system in the network considering the real-time system state (e.g. geographical distribution and storage level). Additionally, working systems within the network could temporarily replace failed systems (or systems under maintenance) by taking over the allocated tasks, thus creating a more resilient stormwater management network. One challenge associated with this network operation is to build a fast optimisation model and reliable communication network, to allow real-time data transmission and decision making.

4 CONCLUSION

This study monitored the performance of a real-time controlled rainwater harvesting system. The adaptive feature of such a configuration can simultaneously deliver runoff retention and baseflow restoration, while still supplying household demand. The active control and failure detection provided by this novel approach highlight the possibility to deliver a flexible and reliable system which can adapt to changing climate. This technology has the potential to deliver a new generation of networked rainwater harvesting and stormwater systems, delivering a true integrated management of stormwater for multiple objectives.

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