Hydrologic and water quality responses to catchment-wide implementation of stormwater control measures

Réponses hydrologiques et qualitatives à la mise en place des techniques alternatives à l'échelle d'un bassin versant

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RÉSUMÉ

Bien que de nombreuses études établissent le rôle prépondérant des eaux pluviales dans la dégradation des eaux réceptrices, aucune étude à ce jour n'a démontré une amélioration d'un cours d'eau grâce à la mise en place de techniques alternatives (TAs). Dans ce contexte, nous avons mis en place environ 300 ouvrages de TAs (récupération des eaux pluviales, bassin d'infiltration, etc) dans le but de reproduire un cycle de l'eau plus naturel à l'échelle du bassin versant. Un suivi intensif du cours d'eau expérimental (*Little Stringybark Creek*) ainsi que des cours d'eau dits de « référence » (naturels sans urbanisation) et de « contrôle » (urbanisés, impactés, sans intervention expérimentale) nous permettent de mesurer les réponses hydrologiques, qualitatives et écologiques. Les coefficients de ruissellement sont réduits de manière importante après la mise en place des TAs et nous avons observé de fortes réductions des concentrations de P, N et MES, bien que le niveau de salinité soit resté élevé. La réduction des concentrations et des flux de polluants pourrait être due en partie à une réduction de la capacité de transport de sédiments du cours d'eau liée à la réduction du ruissellement, entrainant la croissance de macrophytes dans le lit. Les résultats sont relativement prometteurs en termes de potentiel de restauration des cours d'eau déjà impactés par l'urbanisation, mais ils démontrent surtout que la dégradation d'un cours d'eau, suite à l'urbanisation de son bassin versant, n'est pas inévitable, à condition qu'une mise en place importante de TAs soit effectuée au début du développement urbain.

ABSTRACT

While many studies have demonstrated the role of stormwater runoff as a primary degrader of streams, none to date have demonstrated an improvement in an urban stream that is the result of mitigation of stormwater impacts. The catchment of a typically degraded urban stream, Little Stringybark Creek, in Melbourne, Australia, was retrofitted to reduce the impacts of stormwater runoff, by treating its quality, retaining it in the urban landscape through infiltration and evapotranspiration, as well as harvesting it as an alternative water resource. Hydrologic and water quality monitoring was undertaken in the study stream along with reference (without urban stormwater impacts) and control (with unmitigated urban stormwater impacts) streams. Runoff coefficients for individual storm events show small but significant reductions over time. Concentrations of suspended sediment, phosphorus and nitrogen reduced substantially following catchment intervention, but salinity levels remained unchanged. Water quality improvements may in part result from reduced sediment transport and increased aquatic macrophyte growth, suggesting that the stream may now, with less frequent disturbance, have greater instream processing capacity. The results are encouraging for stream improvement efforts, but most importantly demonstrate that streams of yet-to-be urbanised catchments could be protected through catchment-wide implementation of stormwater control measures.

KEYWORDS

Catchment retrofit, rainwater harvesting, infiltration, urban stream

1 INTRODUCTION

Many studies around the world have demonstrated the role of stormwater as a primary degrader of streams (Walsh et al. 2005; King et al. 2010). Despite this, there have been few tests of urban stream restoration using stormwater control measures (SCMs). One such study by Roy et al. (2014) implemented small-scale rainwater harvesting (using “rain barrels”) as well as a series of rain-gardens, constructed in partnership with the community, through a financial incentives programme, but observed no significant response in hydrologic, water quality or ecological indicators. They surmised that this was due to an inadequate scale of implementation, relative to the level of imperviousness in the catchment. More recently, Loperfido (2014) compared centralised and decentralised application of stormwater control measures with ‘traditional’ stormwater management, finding that the decentralised approach was the most effective in restoring pre-development hydrology.

In this paper we report results to date of an ambitious retrofit of the *Little Stringybark Creek* (LSC) catchment, an urban catchment on the eastern edge of Melbourne. The study tests the hypothesis that mimicking natural hydrological and water quality processes in the catchment through the catchment-scale implementation of appropriate SCMs will result in a shift in hydrology, water quality and ecological metrics in the receiving stream towards their pre-development levels. In doing so, the purpose of the project is twofold: (i) to demonstrate that ecological condition of waterways degraded by stormwater can be improved, and (ii) to provide evidence to support implementation of appropriate stormwater management standards as part of new urbanisation, to protect existing healthy streams from degradation. This study is thus underpinned by concepts such as the ‘natural flow paradigm’ of Poff et al. (1997), whereby the design of SCMs attempts to mimic natural behaviour of the entire flow regime, including both peak flows and baseflows. To do so, the design of SCMs aims to retain stormwater in the catchment, providing water quality treatment and then using a combination of stormwater infiltration, evapotranspiration (through either raingardens or irrigation), and harvesting for a range of uses (at both household and large scales), while mimicking natural water quality treatment processes.

2 METHODS

2.1 Study design

The study uses a Before After Control Reference Impact (BACRI) design, whereby changes over time in the intervention catchment (LSC) are compared to trends in three reference catchments (forested, unaffected by urban stormwater runoff) and three control (affected by urban stormwater runoff, no intervention) catchments. We hypothesise that over time, with implementation of SCMs, hydrology and water quality of LSC should become more like that of the reference catchments and less like that of the controls. The LSC catchment is approximately 4.5 km^2 in area, and had a total imperviousness of 13.5% (8.5% connected or effective imperviousness, EI) prior to implementation of SCMs, with almost all impervious surfaces confined to the upper 2 km^2 of the catchment.

2.2 Monitoring

Monitoring of Little Stringybark Creek and its reference and control catchments (thus 7 catchments in all) commenced in 2001, although with some gaps because of funding constraints. Hydrology has been monitored since 2009 using various methods—instream weir-based flow gauges and stage-discharge relationships developed using a Sontek FlowTracker (Sontek; San Diego, USA). Total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), and Electrical conductivity (EC) are measured during dry weather (by regular grab samples on a monthly basis) and during storm events. All water quality analyses were carried out with standard methods in accredited laboratories (National Association of Testing Authorities [NATA]; http://www.nata.asn.au). Other water quality variables and ecological metrics are also monitored, but not reported here.

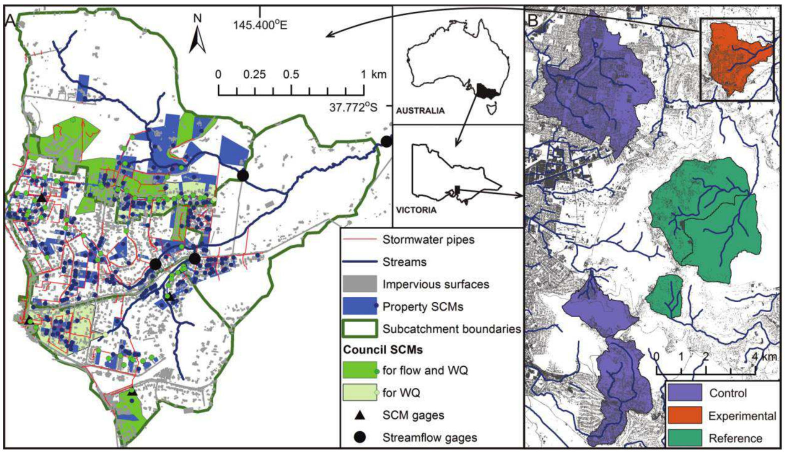

Figure 1. Study design showing experimental (Little Stringybark Creek), control & reference catchments. Little Stringybark Creek is shown in detail on the left, including the three tributaries (Source: Walsh et al. 2015).

2.3 SCM implementation

Stormwater control measures were implemented on both private land (using financial incentives to householders) and public land (in partnership with the local council), with works starting early 2009, and largely completed by the end of 2013. To date 292 SCMs have been constructed, resulting in runoff from 11 ha of connected impervious surfaces being intercepted, reducing the effective imperviousness from 8.5% to around 6%. It is important to note that 6% is above the level at which stormwater-derived degradation to water quality and ecological indicators has been observed (Walsh et al. 2005). Works should be completed by mid-2016, but physical constraints in the catchment (primarily through the lack of available locations to construct SCMs) mean that the overall LSC catchment will retain an EI of around 4.5 to 5%.

2.4 RESULTS & DISCUSSION

2.4.1 Hydrology

Streamflows in all studied catchments, including LSC and the Brushy Creek control catchment, declined over time, primarily as a result of reduced rainfall. However, there remained an effect due to time ($p<0.01$), with the best linear model (based on Akaike Information Criteria) including rainfall, antecedent rainfall, seasonality and time. When the runoff coefficient for rainfall events up to 25 mm is considered, a significant reduction can be observed over time in LSC, but not Brushy (Figure 1; analysis undertaken by dividing the data in two (early: 2009-2012 & late: 2013-2015). Analysis of other ecohydrological metrics (flow peaks, baseflows, seasonality, flashiness) will be presented at the conference.

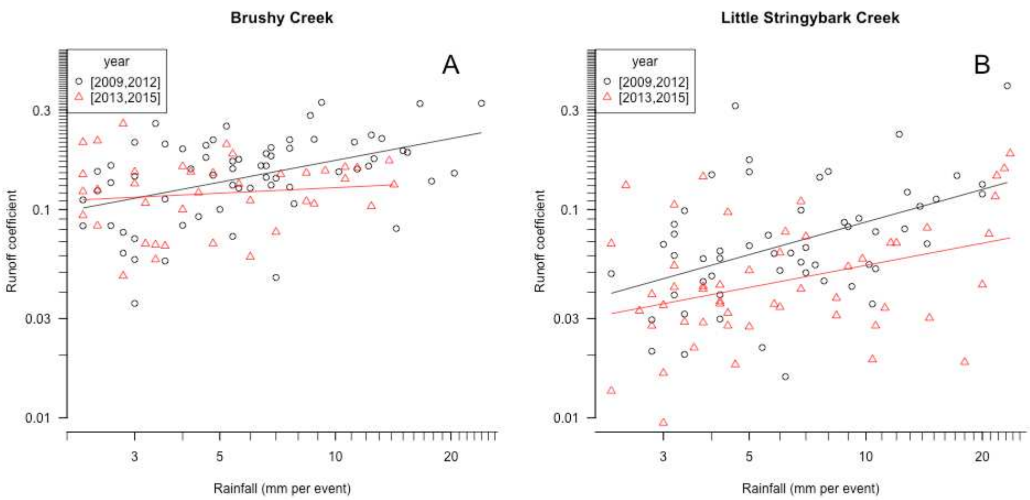

Figure 2. Changes in runoff coefficient for rainfall events up to 25 mm, following SCM implementation. A. Brushy Creek, B. LSC. Analysis of covariance (covariate, rainfall) showed a significant decline in LSC, but not Brushy.

2.4.2 Water quality

TSS, TP and TN (as well as dissolved nutrient components) have demonstrated significant reductions (in both baseflow and storm event mean concentrations) since implementation of SCMs to the extent that some variables now fall within the local objectives for rural streams (Figure 3). The reductions to date have been greater than our models predicted, which we hypothesise may be due to re-establishment of macrophytes in the channel, as a result of decreased sediment transport rates. Further research is proposed to test this hypothesis. EC has not changed following our SCM implementation, which may be because (i) other sources such as wastewater contributions remain or (ii) the increase in infiltration is mobilising saline groundwater. Ongoing investigations will seek to better understand this behaviour.

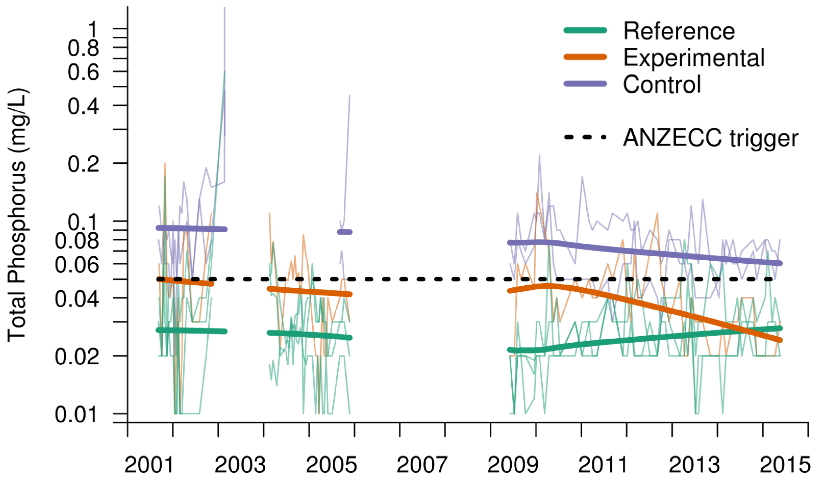

Figure 3. Reduction in baseflow total phosphorus concentrations in LSC (experimental), compared to control and reference streams. Narrow lines are measured data, thick lines are lowess smoothers to illustrate mean trends. The ANZECC trigger is the local objective for rural streams (ANZECC/ARMCANZ 2000).

3 PERSPECTIVES

Implementation of SCMs in the experimental catchment are scheduled to be completed by mid-2016 and monitoring will continue. We will undertake further hydrologic analysis, comparing behaviour of a wide range of ecohydrologic metrics between the experimental catchment and its reference and control catchments (this work will be presented at the conference). Further research is also being undertaken to understand links between the hydrologic changes and water quality behaviour, and in particular to understand the fate and consequences of the large volumes of stormwater infiltrated within the catchment.

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