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Sectional analysis of stormwater treatment performance of a constructed wetland

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ABSTRACT

Constructed wetlands are among the most common Water Sensitive Urban Design (WSUD) measures for stormwater treatment. These systems have been extensively studied to understand their performance and influential treatment processes. Unfortunately, most past studies have been undertaken considering a wetland system as a lumped system with a primary focus on the reduction of the event mean concentration (EMC) values of specific pollutant species or total pollutant load removal. This research study adopted an innovative approach by partitioning the inflow runoff hydrograph and then investigating treatment performance in each partition and their relationships with a range of hydraulic factors. The study outcomes confirmed that influenced by rainfall characteristics, the constructed wetland displays different treatment characteristics for the initial and later sectors of the runoff hydrograph. The treatment of small rainfall events (<15 mm) is comparatively better at the beginning of runoff events while the trends in pollutant load reductions for large rainfall events (>15 mm) are generally lower at the beginning and gradually increase towards the end of rainfall events. This highlights the importance of ensuring that the inflow into a constructed wetland has low turbulence in order to achieve consistent treatment performance for both, small and large rainfall events.

1. Introduction

Constructed wetlands are among the most common Water Sensitive Urban Design (WSUD) measures for stormwater treatment. It is typically a shallow, extensively vegetated water body with different zones that uses enhanced sedimentation, fine filtration and pollutant uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release the stormwater and then maintain dry weather water levels. Since a constructed wetland serves as a structural measure to treat stormwater runoff, the treatment efficiency is of significant concern (Shutes et al., 1999).

Constructed wetlands have been extensively studied to understand their performance and influential treatment processes (for example Scholes et al., 1999; Terzakis et al., 2008; Pan et al., 2013). However, most past studies have been undertaken considering a wetland system as a lumped system with the primary focus on the reduction of the event mean concentration (EMC) values of specific pollutant species or total pollutant load removal (for example Carleton et al., 2001; Birch et al., 2004). Unfortunately, this type of approach does not permit the detailed investigation of treatment trends within the constructed wetland over the duration of the runoff process, which is critical for the effective design of these treatment systems.

It is hypothesised that the treatment performance of a constructed wetland differs during dry periods (when there is no stormwater inflow) and wet periods (during rainfall events) and also differs at different time periods (sectors) of a runoff event. This hypothesis needs to be viewed in the context of the occurrence of the first flush phenomenon, which refers to a relatively higher pollutant load at the initial part of a runoff event and hence relatively more polluted stormwater will enter the constructed wetland in the early sector of the runoff hydrograph (Deletic 1998; Lee et al., 2004; Alias et al., 2014). This could lead to differences in

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treatment performance between early and later parts of the runoff hydrograph. In-depth understanding of these differences in treatment performance will contribute to the design of more efficient constructed wetland systems. In this context, the research study discussed in this paper adopted an innovative approach by partitioning the inflow runoff hydrograph and then investigating the treatment performance of each runoff segment within a constructed wetland. The new knowledge created will help to enhance the design of constructed wetlands and thereby ensure more effective stormwater treatment systems.

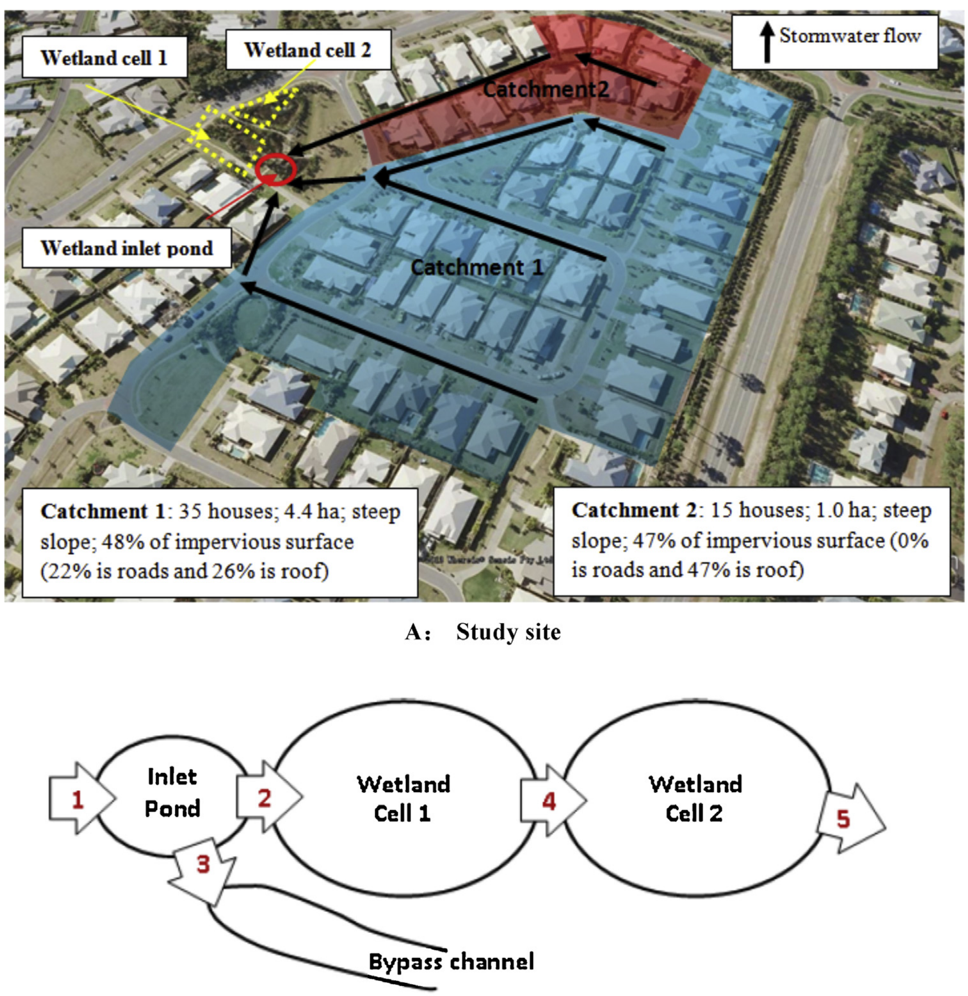
2. Materials and methods

2.1. Study sites

The constructed wetland selected for the study is located at 'Coomera Waters' residential estate, Gold Coast, Australia. The constructed wetland consisted of a sedimentation pond, two wetland cells and an overflow bypass system (see Fig. 1A). The wetland system receives runoff from two small urban catchments that were termed as Catchment 1 and Catchment 2. Stormwater monitoring stations were established to monitor inflows and outflows from Catchment 1 and 2. Stormwater entering the constructed wetland was pre-treated in the sedimentation pond prior to receiving further treatment in the wetland cells. Additionally, the maximum inflow rate which was allowed to enter the wetland cells was controlled by a bypass system. The bypass system is a 7 m wide broad crested weir placed 0.25 m above the crest of the flow transferring pit between the sedimentation pond and cell 1 of the constructed wetland. The weir was located to divert excess stormwater inflow into a bypass channel.

2.2. Sample collection and laboratory testing

The inlet and outlet of the constructed wetland have been monitored from 2008 to 2011 using automatic monitoring stations to record rainfall and runoff data and to capture stormwater



B: The schematic of stormwater flows in the wetland system

- Stormwater entering the wetland system is through the inlet structure to the inlet pond (1);
- The water then flows to wetland cell 1 through a concrete pipe controlled by an inlet pit (2);
- High inflow creates high free surface elevation in the inlet pond leading to part of the inflow to bypass through a channel (3);
- The water from wetland cell 1 flows into wetland cell 2 through a 1 meter wide channel (4) which was assumed as a broad crested weir;
- The water in wetland cell 2 leaves the wetland system through a PVC riser (outlet structure) (5).

Fig. 1. The wetland system.