# Satisfying the need for robust validation datasets in bioretention hydrological modelling

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## Highlights

- Performance metrics from bioretention field monitoring studies have limited predictive ability.
- High temporal resolution field monitoring data is invaluable for hydrological model validation.
- A well validated but sufficiently generic modelling framework permits rapid digital prototyping.

## Introduction

Bioretention is a frequently used practice to help restore urban areas to a pre-development hydrological response. Bioretention cells, infiltration basins, rain gardens, tree pits, and swales are all examples of bioretention devices. Individual devices are often tailored to a specific set of design goals and constraints. However, the fundamental hydrological processes that occur within each of these specialised systems are the same. These processes, in turn, are controlled by the physical properties of the vegetation, fill media and drainage structures.

A wide range of modelling tools have been developed or adapted to enable bioretention systems to be modelled, the most popular of which are SWMM (Rossman 2015), DRAINMOD (Brown et al. 2013, Winston et al. 2016) and HYDRUS 1D/2D/3D (Stewart et al. 2017). All of these models are physically-based to some extent, with outputs dependent upon the physical properties of the system and its components (particularly the fill media). Hydrological performance metrics derived from field monitoring studies provide limited predictive value. However, the collected data is invaluable for validating and refining model capabilities, particularly where high temporal resolution (e.g. 5-minute time steps or smaller) rainfall/inflow and outflow data is available alongside detailed characterisations of the fill media. Model development should be validated against as wide a range of these real data sets as possible.
The aims of this study are:

- to provide a set of highly robust validation datasets for a range of physical system configurations;
- to quantify rates of evapotranspiration for common bioretention vegetation under well-watered and water-limited conditions;
- to demonstrate the effects system configuration can have on hydrological performance using a simple hydrological modelling framework

## Methodology

**Bioretention Column Configurations**

The bioretention columns are 1000 mm tall and 160 mm in diameter. The columns are designed to replicate the full depth and profile of pilot-scale bioretention lysimeter facilities at the National Green Infrastructure Facility (NGIF), Newcastle-upon-Tyne, UK. Each column has a 180 mm drainage layer of 4-40 mm aggregate, overlain by a 120 mm transition layer of 2-6 mm aggregate, topped by a 700 mm layer of 'Grey-to-Green' (G2G) fill media made from recycled materials (Figure 1A). The fill media is comprised of 50% quarry waste material (5-20 mm), 25% of crushed recycled glass, 15% of green-waste compost, and 10% of topsoil from sugar beet washings. There are 6 bioretention column configurations, each with 3 replicates, for 18 columns in total (Figure 1B). Four of the configurations are microcosms of the NGIF lysimeters, with an unvegetated control, reference amenity grass, a high-water use monoculture (*Deschampsia Cespitosa*) and lower water use monoculture (*Iris Sibirica*). The two remaining column configurations are amended style columns. The first of these contains an amended version of the G2G fill media with an altered particle size distribution to conform to current UK CIRIA guidance for bioretention media texture (Woods Ballard et al. 2015). The final column configuration is identical in physical configuration to the NGIF reference amenity grass columns but inoculated with worm colonies.

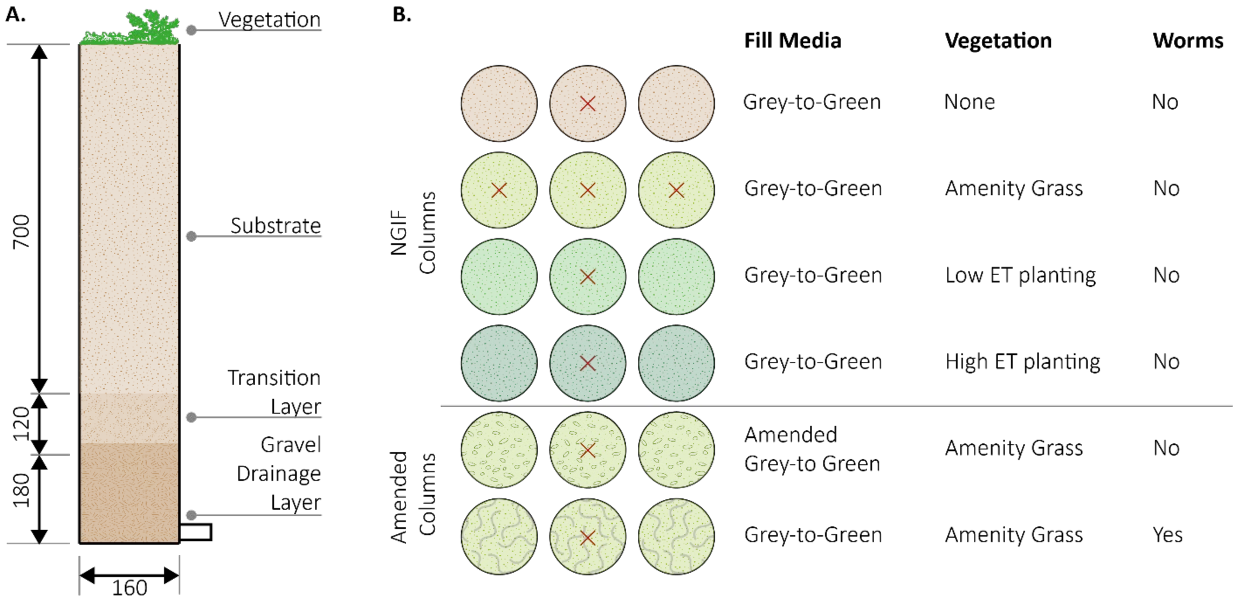


**Figure 1. A.** Bioretention column cross section, all dimensions are in mm. **B.** Bioretention column configurations, red crosses indicate columns with embedded moisture content sensors.

### Monitoring Programme

After a 4-month period of vegetation establishment all 18 bioretention columns were placed in a climate controlled facility where conditions were maintained at typical summer conditions for Sheffield, UK. The maximum daytime temperature was 18°C and minimum night-time temperature was 15°C with 17 hours of light exposure during the day starting at 05:00. Humidity was maintained as close as possible to 65%. Each column was initially saturated with water for before being allowed to drain to field capacity. All columns were then left in the climate chamber for 21 days over which time they were not irrigated.

Eight bioretention columns were instrumented with moisture content sensors, one in each configuration except for the reference amenity grass where all columns were instrumented. Where moisture probes were present, they were at depths of 100, 300 and 600 mm which permitted the observation of a moisture content profile within the fill media at a temporal resolution of 1 minute. In addition to these moisture content probes the column mass was continuously monitored using load cells. Mass losses, in the absence of drainage, enabled a determination of evapotranspiration rates (per hour) as this was the only means by which mass could have been lost.

### Assessing Hydrological Performance

Prior to establishment and again prior to the climate chamber test each column was subject to a series of constant intensity simulated rainfall events to assess hydrological detention performance. These simulations were repeated to assess changes in hydrological performance in response to ageing processes. Future planned testing will expand this dataset to capture the establishment dynamics of bioretention systems over an 18-month period.

Using a modified version of the simple 1D hydrological model presented in Beretta et al. (2018) predictions of hydrological performance for the seven physical configurations were made using a 1-year continuous rainfall and climate profile from Sheffield, UK.

## Results and discussion

The climate chamber tests are to be conducted in July 2020, and as such there are no results to present at this time.

## Conclusions and future work

The ability to predict bioretention hydrological performance is crucial to the ensuring future systems are designed appropriately to achieve the desired hydrological benefits. Only through the continued application of modelling techniques to observed laboratory or field data can these techniques be refined such that model genericism and confidence in model output is greatly increased. When a robust modelling framework has been developed it can be utilised to inform and refine design guidance in response to material availability and the pressures of climate change.

This work forms part of the wider Urban Green DaMS (Design and Modelling of SuDS) research programme currently underway at the University of Sheffield (EPSRC EP/S005536/1) and Newcastle University (EPSRC EP/S005862/1). The data collected as part of this study and that from the pilot-scale lysimeters at the National Green Infrastructure Facility will be used to fulfil the overall project aim: to provide the required modelling tools and parameter values, and develop the robust design guidance - equivalent in quality to that for pipes and other hard engineering interventions - that is necessary to enable the widespread implementation of vegetated bioretention cells for stormwater management.

## References

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