# Urban Green DaMS: Bioretention Column Detention Data

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## D1. Introduction

This dataset is a complete record of all data compiled as part of a series of five controlled inflow tests to identify the detention behaviour in a series of differently configured bioretention columns. The experimental work was conducted at The University of Sheffield's Arthur Willis Environment Centre in Sheffield, UK, from September 2020 to June 2022 (21 months). This data accompanies the journal article 'Bioretention column detention test data for percolation model evaluation' (Stovin et al., *Submitted*). The dataset was collected, processed and compiled for publication by Dr Simon De-Ville as part of the Urban Green DaMS project, EPSRC Grant Number EP/S005536/1.

## D2. Data Structure

The data consists of five individual files which each represent a distinct detention trial. Files are named using a '`DetentionData_YY-MM.dat`' convention where `YY` is the trial year, and `MM` is the trial month. Within each file is a data table with the following variables:

- `Elapsed_t_min`, the elapsed experiment duration in minutes.
- `Inflow`, inflow applied to the column per time-step as a mm depth.
- `X_Outflow`, observed outflow from each column per time-step as a mm depth, where `X` indicates the column configuration (`C`: Unvegetated Control, `AG`: Amenity Grass, `DC`: *Deschampsia Cespitosa*, and `IS`: *Iris Sibirica*).
- `X_VWC_Y`, calibrated volumetric water content (VWC), where `X` indicates the column configuration (as above) and `Y` the depth of measurement (`0`: 500 mm, `1`: 300 mm, and `2`: 100 mm) or the weighted mean VWC (`Bulk`).

## D3. Experimental Set-up

### *D3.1. Bioretention Columns*

A set of 12 Bioretention Columns was constructed to explore the effect of vegetation treatment and water stress on evapotranspiration (ET) in bioretention systems. These 12 columns replicate the full depth profile of pilot-scale bioretention lysimeters located at the National Green Infrastructure Facility (NGIF), Newcastle, UK. Columns were numbered from 1 to 12 and are herein refered to as C1 to C12. Each column was 152 mm in internal diameter (160 mm external) and 1100 mm tall and comprised (from bottom to top): a 180 mm drainage layer of 4/40 mm aggregate, a 120 mm transition layer of 2/6 mm aggregate, a 700 mm layer of growing media, and a 100 mm ponding zone (Figure D3.1a). The growing media for this study was sourced locally within Sheffield, UK, and comprised 100% recycled waste components. A complete characterisation of the media was conducted as part of:

De-Ville, S., Green, D., Edmondson, J., Stirling, R., Dawson, R., and Stovin, V., **2021**. Evaluating the Potential Hydrological Performance of a Bioretention Media with 100% Recycled Waste Components, *Water*, 13, 2014.

Four vegetation treatments were trialled (in triplicate) across the 12 columns (Figure D3.1c). These were: an unvegetated control (C1—C3), an amenity grass mix (C4—C5), a tufted hair-grass (C6—C8, *Deschampsia cespitosa* 'Goldtau') and an iris (C9—C11, *Iris sibirica* 'Ruffled Velvet').

Six of the twelve columns contained a moisture content probe array: a single unvegetated column (C2), all three amenity grass columns (C4—C6), a single *D. cespitosa* column (C8) and a single *I. sibirica* column (C11). The moisture content probes were positioned vertically at depths of 100, 300 and 500 mm (Figure D3.1a).

A complete description of the bioretention columns is provided in:

De-Ville, S., Edmondson, J., Green, D., Stirling, R., Dawson, R., and Stovin, V., **2024**. Effect of Vegetation Treatment and Water Stress on Evapotranspiration in Bioretention Systems, *Water Research*, 252.

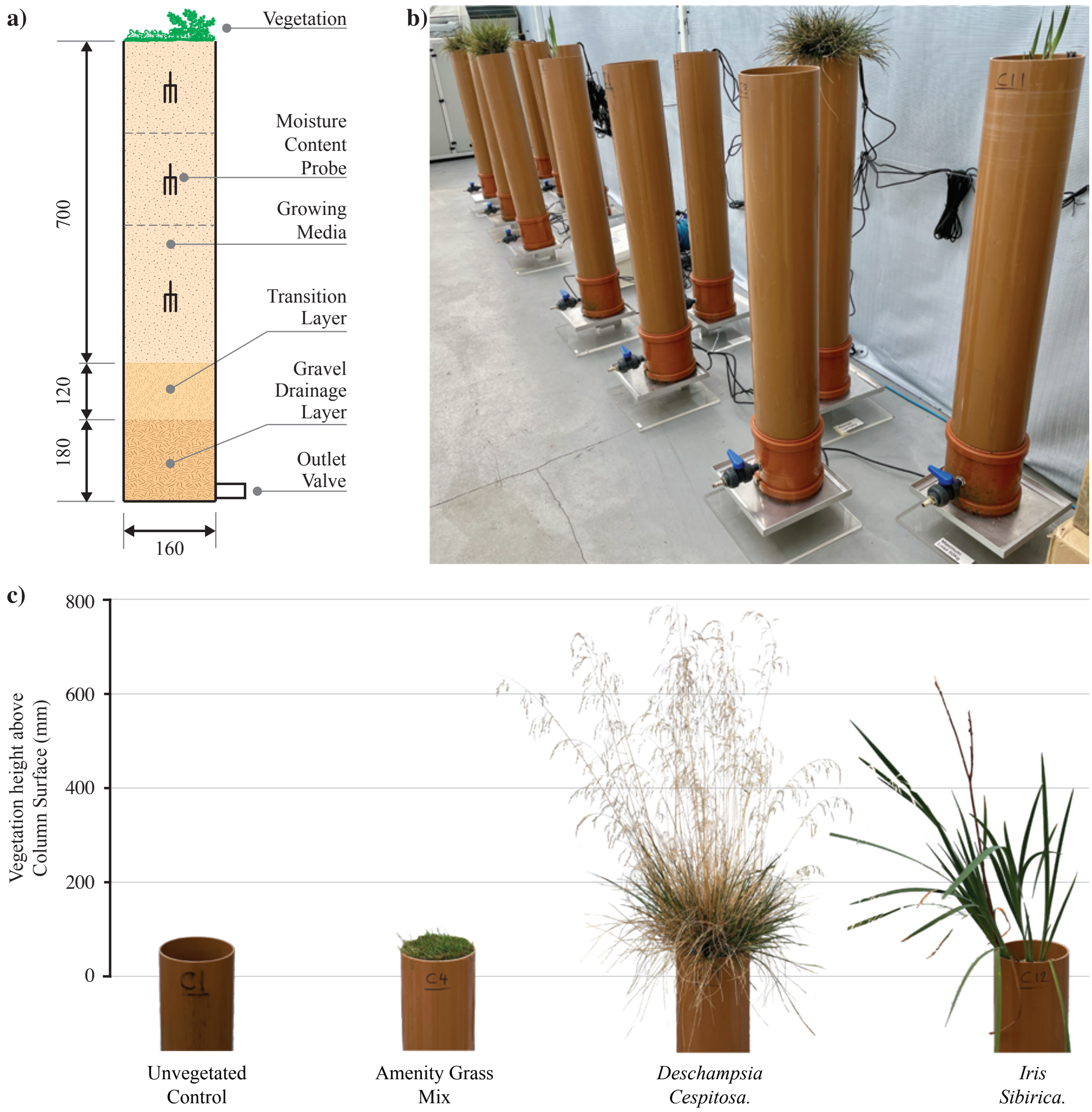


Figure D3.1: The Bioretention Columns: a) Schematic cross section that indicates moisture probe locations (where installed) and soil volumes associated to each probe. b) Assembled columns on load cells inside growth chamber (April 2021). c) Examples of the four vegetation treatments (September 2021).

*D3.2. Detention Trials*

Five detention trials were conducted across the duration of the ET study, taking place directly before or after an ET trial. The parameters of each of these five trials are presented in Table D5.1. Detention trial data was collected from unvegetated control column C2, amenity grass column C5, *D. cespitosa* column C8 and *I. sibirica* column C11 (referred to herein as `C`, `AG`, `DC` and `IS` respectively).

Prior to all detention trials the bioretention columns were saturated by closing the column's outlet valve and applying water until a constant ponded head of at least 50 mm was maintained. Columns were left in a saturated condition for 24 hours. The outlet control valve was then opened and the columns allowed to drain freely under gravity for a period of 2 hours to achieve field-capacity. Columns were then subjected to the inflow applications detailed in Table D5.1.

Trial I was conducted on columns prior to the establishment of any of the vegetation treatment, i.e. all columns were unvegetated. Inflow was applied to the surface of each column via a network of 11 0.5 l/hr Netafim drippers supplied with water via a mains connection. Application of inflow was controlled by a solenoid valve connected to a Campbell Scientific CR800 data logger to provide automated repeat applications of inflow. Each of the four bioretention columns was subject to three flow applications, each of a 5 mm/min constant intensity (approximately equal to the mean inflow intensity for an M30-60 design storm in Newcastle with a 10:1 loading ratio) for a 10-minute duration with an inter-application period of 20-minutes. Outflow from the column's control outlet was directed to an Aercus Instruments WS2083 tipping bucket gauge with a calibrated tip-depth of 0.085 mm which recorded at a 1 s temporal resolution. Moisture content data was not collected during this trial.

Trial II was conducted at the end of the first ET trial in May 2021. Vegetation had been allowed to establish since planting in October 2020. Inflow was applied to the surface of each column via a network of 11 infinite rate drippers (i.e. non limiting) with flow rates controlled by a connected peristaltic pump drawing from a constant head reservoir. The pump was controlled by a Campbell Scientific CR800 data logger to provide automated repeat applications of inflow. The flow application regime was the same as Trial I with outflow gauged using the same tipping bucket gauge. Volumetric water content data was collected from the 3-probe vertical array as dielectric permitivity. Pump control and data collection operated at a 5 s temporal resolution. The `DC` column was not tested during this trial.

Trial III was conducted prior to the second ET trial in August 2021. Vegetation was considered to be fully established during this trial (Figure D3.1c). Inflow application used the same techniques as Trial II but with a higher constant application intensity of 9.2 mm/min (approximately equal to the mean intensity for an M30-60 design storm in Newcastle with a 19:1 loading ratio) applied for a 20-minute period separated by a 40 minute inter-application period. The application period was lengthened to achieve a period of equilibrium between inflow and outflow rates which had not been observed during the shorter 10-minute flow applications. Column outflow and volumetric water content data were collected at a 5 s resolution for all column configurations.

Trial IV was conducted after the second ET trial in September 2021. Vegetation was in approximately the same condition as during Trial III. Inflow application used the same techniques as Trial II but three variable intensity 60-minute duration design storm profiles were applied separated by a 120 minute inter-application period. The applied design storms were all derived for Newcastle-Upon-Tyne, UK, and represented the M10-60, M30-60 and M100-60 design rainfalls for the column area only (a 1:1 loading ratio). Column outflow and volumetric water content data were collected at a 5 s resolution for all column configurations.

Table D3.1: Summary of Trial Target Conditions

| Trial | Date | Inflow Type | Inflow Intensity (mm/min) | Inflow Depth (mm) | Application Duration (min) | Inter-test Duration (min) | No. of Applications |
|---|---|---|---|---|---|---|---|
| I | 09/2020 | Constant | 5 | 50 | 10 | 20 | 3 |
| II | 05/2021 | Constant | 5 | 50 | 10 | 20 | 3 |
| III | 08/2021 | Constant | 9.2 | 184 | 20 | 40 | 3 |
| IV | 09/2021 | Design Storm | 1.4* | 22.7 | 60 | 120 | 1 |
| | | Design Storm | 1.8* | 29.1 | 60 | 120 | 1 |
| | | Design Storm | 2.4* | 38.2 | 60 | 120 | 1 |
| V | 06/2022 | Design Storm | 1.8* | 29.1 | 60 | 120 | 1 |
| | | Design Storm | 5.5* | 87.3 | 60 | 120 | 1 |
| | | Design Storm | 11.0* | 174.6 | 60 | 120 | 1 |

*Peak Intensity

Trial V was conducted after the third ET trial in June 2022. Vegetation was observed to be similar in appearance and density to that during Trial II. Inflow application used the same techniques as Trial IV but inflows were scaled to represent a 5:1 loading ratio. Higher peak inflows were not possible due to the limited maximum flow rate of the peristaltic pump. The `DC` column was not tested during this trial.

### D4. Data Processing

Outflow data collected using the tipping bucket gauge was converted to an equivalent mm depth distributed over the column surface area, where each tip of the gauge was equal to 0.085 mm. Volumetric moisture content data was evaluated from the collected dielectric permittivity data using a lab-derived calibration equation detailed in section D5.

### D5. Mass Balance

The MATLAB script archived with the data includes analysis of mass balance, which is presented for each trial in Figure 2 of the script output. Table D5.1 summarises the mass balance observed in each Trial. In many cases the tests were terminated soon after the third application of inflow, before the columns had fully drained back down to field capacity. For example, the data for Trial I shows outflow recovery rates of 82-88% for the C, AG and IS columns, for which outflow recording stopped after 150 minutes. The *Deschampsia cespitosa* column, on the other hand, achieved a 98% recovery, associated with a much longer recording period, around 900 minutes (15 hours). Where moisture content data was available (Trials II to V), the difference between bulk moisture content at the start and end of each Trial, $\Delta S$, was included within the calculation of mass balance. In most cases the mass balance errors for Trials II to V were within 5%. While the moisture probes were calibrated specifically for the growing media utilised here, there are limitations to the accuracy of the recorded data due to the fact that the probes only sample a small proportion of the heterogeneous media. The mass balance reported here is therefore considered to be acceptable.

Table D5.1: Mass Balance Data for All Trials

| | Mass Balance (%) | | | |
|---|---|---|---|---|
| Trial | C | AG | DC | IS |
| I* | 88 | 85 | 98 | 82 |
| II | 100 | 87 | - | 111 |
| III | 101 | 102 | 95 | 100 |
| IV | 97 | 98 | 95 | 105 |
| V | 96 | 95 | - | 93 |

*Calculations did not include $\Delta S$

### D6. Moisture Content Probe Media Specific Volumetric Water Content Calibration

*D6.1. Rationale*

Moisture content probes (METER 5TMs) have been utilised to evaluate the moisture content dynamics of the Grey-to-Green (G2G) media in the evapotranspiration column experiments. METER suggest that their factory calibration 'may not be applicable to all soil types,' and so a specific G2G calibration is desirable.

*D6.2. Methods*

*D6.2.1. Experimental Set-up*

A single 5TM moisture content probe was placed horizontally at the mid-depth of a 130 mm deep layer of air-dried G2G. The probe was oriented so all measurement prongs were aligned horizontally. The G2G media was contained within a 300 mm diameter acrylic column with a perforated base overlain by a fine mesh to retain the media within the column (Figure D6.1). A constant intensity inflow was evenly applied to the upper surface of the media via a dripper network to raise the moisture content to a 'high value' above typical operating moisture content. In practice, this led to the saturation of the media and the generation of a modest ponded head (< 10 mm). The inflow was stopped, the media was allowed to freely drain and then continue to dry via evaporation. The mass of the fill media was monitored using a calibrated load cell array. The total experiment duration was 105-days.

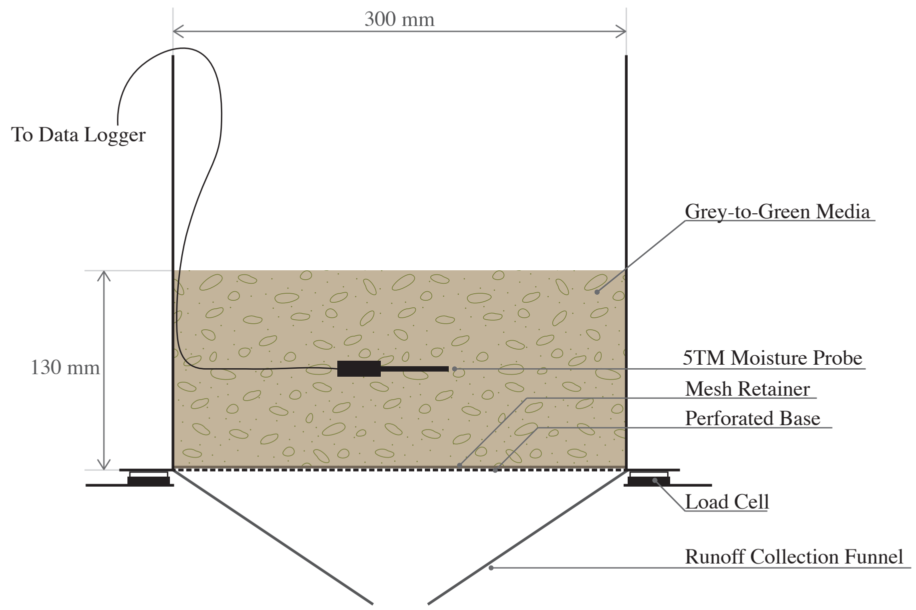


Figure D6.1: Schematic Diagram of Experimental Set-up.

*D6.2.2. Data Analysis*

Volumetric water content (VWC, $\theta$) was determined from gravimetric water content by assuming the density of water to be 1000 kg/m$^3$. Throughout the experiment, the rate of evaporation declined as matric suctions within the drying media increased. This led to the collection of considerably more data points in 'dry' conditions compared to 'wet' conditions. This skewed distribution of data points will lead to a biased calibration toward the drier media condition. A uniformly weighted distribution of dielectric values was determined by identifying the mean VWC for 0.01 increments of dielectric (sensor resolution). These uniformly weighted data were used to generate a cubic best fit calibration equation.

*D6.3. Results*

The observed relationship between dielectric permittivity (DP) and volumetric water content (VWC) is presented in Figure D6.2. The results follow similar patterns to those presented in the literature, with decreased sensitivity (higher gradient, large change in VWC for small change in DP) at the dry and wet ends of the moisture content ranges, and a region of elevated sensitivity (low gradient) at the midpoint of the moisture content range. This relationship suggests the data is suitable for the application of a cubic best-fit calibration curve.

What is not shown from Figure D6.2 is that 50% of the collected data is for dielectric values of $< 7.83$. This represents less than one-fifth of the range of observed dielectric values (4.60  23.6). A cubic best-fit calibration curve was fitted to the uniformly distributed data set with the resultant relationship:

$$\theta = 1.1775 \times 10^{-4}\mathrm{DP}^3 - 0.0045 \times \mathrm{DP}^2 + 0.0720\mathrm{DP} - 0.2158 \qquad \text{(D6.1)}$$

where the model fit statistic $R^2$ (Nash and Sutcliffe, 1970) had a value of 0.991.

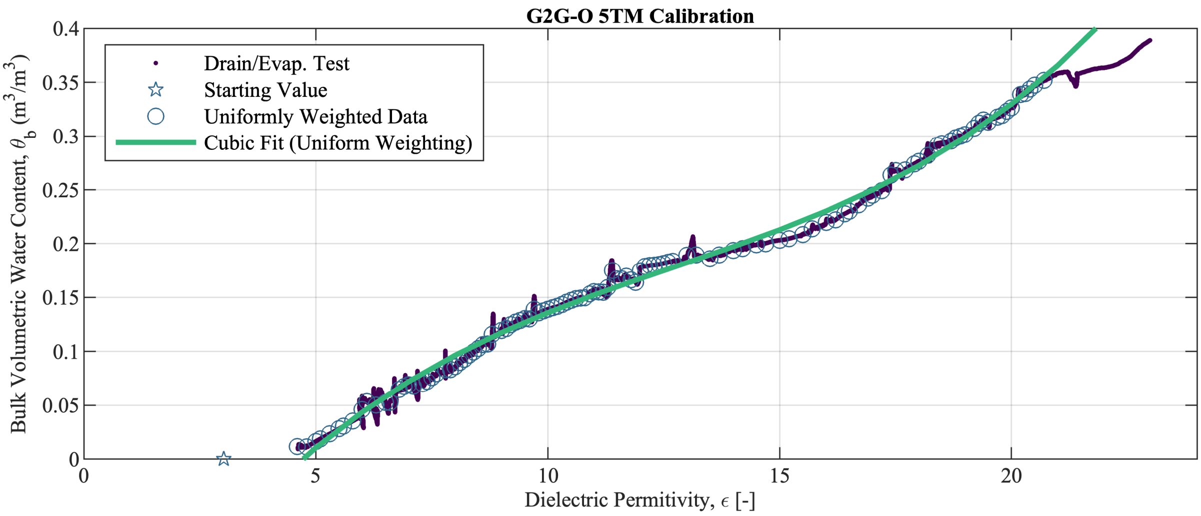


Figure D6.2: Scatter plot of observed Dielectric Permittivity and Volumetric Water Content data, including uniformly weighted data points and the resulting cubic best fit model.