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Stratified hydraulic conductivity testing of green infrastructure: A lysimeter bioretention cell study

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Bioretention cells, also referred to as 'rain gardens', are Green Infrastructure features with a functional role of managing urban flood risk and relieving pressure on traditional grey infrastructure systems. These Sustainable Drainage Systems (SuDS) rely on the use of soil and vegetation to attenuate and discharge stormwater via infiltration into the ground or via underground outlets into sewer networks whilst filtering pollutants in urban runoff and providing value to public space. Soil makes up a large proportion of these systems and plays a key role in providing the storage capacity for retaining stormwater and determining outflow discharges. This role is typically characterised using laboratory or in-field surface assessments of saturated hydraulic conductivity (K_{sat}), which provide an empirical assessment of SuDS performance. Guidance suggests that SuDS substrates should have a K_{sat} that ensures that systems are able to collect and store runoff to provide water retention without becoming waterlogged before the next rainfall event. However, in-field evaluations are rarely conducted due to cost and testing rarely identifies variation with depth through the soil profile.

This paper presents in-field K_{sat} testing from four-purpose built, vegetated bioretention cell lysimeters at the UKCRIC National Green Infrastructure Facility, Newcastle-upon-Tyne, UK, commissioned as part of the Engineering and Physical Sciences Research Council (EPSRC) project 'Urban Green Design and Modelling of SuDS' (EP/S005536/1). K_{sat} was measured using a Soil Moisture Equipment Corporation Guelph Constant Head Field Permeameter to obtain stratified K_{sat} values throughout the 750 mm deep soil profile of the lysimeters. K_{sat} was assessed in the context of four different vegetation treatments, including an unvegetated control lysimeter, an amenity grass covered lysimeter and two mono-cropped lysimeters planted with *Iris sibirica* and *Deschampsia cespitosa*.

Results show that K_{sat} values are systematically variable through the soil column and are a function of confining pressure with soil depth and wash through processes. Trends in porosity with soil depth are shown to be comparable across all lysimeter planting styles with some subtle differences associated with vegetation planting. All lysimeters feature higher K_{sat} values at the near-surface (ranging from 160.2 – 648.0 mm/hr at 0 – 100 mm depth), thought to be due to weathering and wash-through processes associated with near-surface soil strata being exposed to prevalent weather conditions. Where larger vegetation is present, higher K_{sat} values are recorded, reflecting

the presence of root-derived preferential flow pathways. The depth of elevated near-surface K_{sat} values reflects the rooting depth and structure of the plant species studied.

The use of a single K_{sat} value does not adequately capture the spatially variable hydraulic properties of bioretention systems. The results presented herein also have implications for SuDS design and maintenance, suggesting that the hydraulic properties of these systems may change through time. Consequently, SuDS scheme planners and developers should conduct multiple assessments of K_{sat} through the soil profile to provide robust empirically-based model parameter values to ensure that systems are fit for purpose.