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Assessing the role of urban developments on storm runoff response through multi-scale catchment experiments

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Many communities across the world face the increasing challenge of balancing water quantity and quality issues with accommodating new growth and urban development. Urbanisation is typically associated with detrimental changes in water quality, sediment delivery, and effects on water storage and flow pathways (e.g. increases in flooding). In particular for mixed rural and urban catchments where the spatio-temporal variability of hydrological responses is high, there remains a key research challenge in evaluating the timing and magnitude of storage and flow pathways at multiple scales. This is of crucial importance for appropriate catchment management, for example to aid the design of Green Infrastructure (GI) to mitigate the risk of flooding, among other multiple benefits.

The aim of this work was to (i) explore spatio-temporal storm runoff generation characteristics in multi-scale catchment experiments that contain rural and urban land use zones, and (ii) assess the (preliminary) impact of Sustainable Drainage (SuDs) as GI on high flow and flood characteristics. Our key research catchment, the Ouseburn in Northern England (55km2), has rural headwaters (15%) and an urban zone (45%) concentrated in the lower catchment area. There is an intermediate and increasingly expanding peri-urban zone (currently 40%), which is defined here as areas where rural and urban features coexist, alongside GIs. Such a structure is typical for most catchments with urban developments. We monitored spatial precipitation and multiscale nested (five gauges) runoff response, in addition to the storage dynamics in GIs for a period of 6 years (2007-2013). For a range of events, we examined the multiscale nested runoff characteristics (lag time and magnitude) of the rural and urban flow components, assessed how these integrated with changing land use and increasing scale, and discussed the implications for flood management in the catchment.

The analyses indicated three distinctly different patterns in the timing and magnitude of the contributions of the different land use zones and their nested integrated runoff response at increasing scales. These can be clearly linked to variations in antecedent conditions and precipitation patterns. For low antecedent flow conditions, the main flood peak is dominated by urban origins (faster responding and larger in relative magnitude); for high antecedent flow conditions, rural (and peri-urban) sources are most dominant. A third type of response involves mixed events, where both rural and urban contributions interact and reinforce the peak flow response.

Our analyses showed that the effectiveness of the GIs varied substantially between the different events, suggesting that their design could be improved by introducing variable drainage rates and strategic placements to allow for interactions with the stream network. However, more information is needed on the spatio-temporal variability in water sources, flow pathways and residence times. This is of particular importance to also assess other multiple benefits of GIs, including the impacts on water quality. These challenges are currently addressed in two new case study catchment in the North East of Scotland (10km2) which are undergoing major land use change from rural to urban. Here, integrated tracer and hydrometric data are being collected to characterise the integrated impacts of urbanisation and GIs on flow pathways (nature and length) and associated water quality.