BHS 2014

Session 5: Urban Hydrology

ABSTRACTS

Oral presentations

5-1LL: Evaluating the success of urban stream restoration on hyporheic exchange and nutrient retention

Anne Jefferson[1], Sara McMillan[2], and Sandra Clinton[3]
1. Department of Geology, Kent State University, 221 McGilvrey Hall, Kent, OH 44242 USA. Phone: 1-330-672-2746 Email: ajeffer9@kent.edu
2. Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, Indiana, USA. Email: swmcmillan@gmail.com
3. Department of Geography and Earth Sciences, University of North Carolina at Charlotte, 9201 University City Boulevard, Charlotte, NC 28223, USA. Phone: 1-704-687-5967 Email: sclinto1@uncc.edu

In urban watersheds, the capacity of streams to provide essential ecosystem services is often limited as a result of channel straightening, incision and removal of geomorphic features. Stream restoration seeks to provide stream stability whilst simultaneously improving water quality and ecosystem services. Transient storage and hyporheic exchange zones are important regulators of nutrient retention, but it is poorly understood how successful stream restoration activities are at creating ecologically effective storage and exchange zones that improve water quality and nutrient retention. In Charlotte, North Carolina, USA we evaluated restored and unrestored streams to quantify hyporheic exchange and nutrient retention. We measured increased transient storage and greater variability in vertical hydraulic gradients in restored relative to unrestored reaches. However, restored reaches also had lower hydraulic conductivity of bed sediments, which was likely related to restoration practices that reduce the magnitude of hyporheic exchanges. Multiple linear regression analysis of reach scale nitrate and phosphate uptake rates highlighted the importance of water chemistry and temperature but also sediment carbon, which was closely correlated with canopy cover and restoration age. Similar patterns were observed with denitrification rates significantly higher in restored streams near geomorphic features with deposition of organic matter, even though hyporheic exchange was generally low. Whilst current practices of urban stream restoration may be successful in creating channel stability, coupling watershed-scale management of stormwater and nutrients with restoration techniques designed to enhance ecologically effective storage and exchange may be required for holistic success.

5-2L: Nutrient Processing and Floodplain Connectivity Following Restoration in Urban Streams

S. Clinton[1], S. McMillan[2], G. Noe[3] and E. Turner[1]
[1]Department of Geography and Earth Sciences, University of North Carolina at Charlotte, Charlotte, NC, USA. Email: sclinto1@uncc.edu
[2]Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, Indiana, USA. Email: swmcmillan@gmail.edu
[3]National Research Program, U.S. Geological Survey, 12201 Sunrise Valley Drive, Mailstop 430, Reston, Virginia, USA. Email: gnoe@usgs.gov

Floodplains and riparian zones are known to be important locations for sediment storage and nutrient transformations. While extensive research has been conducted on the capacity for riparian zones to buffer sediment and nutrient loads in natural systems, we know relatively little about the water quality function of floodplains in restored streams. Through this research, we investigated the time trajectory for recovery of floodplain nutrient transformations in five restored streams in North Carolina, USA with a range of restoration ages and design approaches. Soil characteristics, including carbon quality were measured in an expanded dataset of 12 urban and forested streams. Carbon content ranged 1.8-16.3%

with the highest content at a forested, unrestored site. Restoration age positively influenced bioavailable carbon (measured as chlorophyll-a, R^2=0.371, $p<0.05$) and negatively influenced bulk density (R^2=0.198, $p<0.05$). Rates of in situ N and P net mineralization and denitrifying enzyme activity in floodplain sediments were positively correlated with monthly sedimentation rates and soil carbon pools. Potential denitrification rates ranged from 1.2 – 80.4 mg m^{-2} h^{-1} with highest rates measured at sites with greatest sedimentation rates. Denitrification and N and P mineralization rates were also positively correlated with restoration age highlighting the potential importance of vegetation and soil organic matter to fuel biogeochemical transformations. These shifts in carbon supply as a stream restoration project matures have the potential to greatly influence biogeochemical processes in multiple ways and thereby overall water quality.

5-3S: Identifying controls on stormflow, nutrient and carbon export from urban watersheds in the Southeastern U.S. with Sustainable Drainage Systems (SUDS).

C. Bell[1], S. McMillan[2] & S. Clinton[3]
[1]Infrastructure and Environmental Systems, University of North Carolina at Charlotte, Charlotte, North Carolina, USA
Phone: +1 585-490-9753 Email: cbell49@uncc.edu
[2]Department of Civil and Environmental Engineering, University of North Carolina at Charlotte, Charlotte, North Carolina, USA
Phone: +1 704-687-1223 Email: smcmillan@uncc.edu
[3]Department of Geography and Earth Sciences, University of North Carolina at Charlotte, Charlotte, NC, USA
Phone: +1 704-687-5967 Email: sclinto1@uncc.edu

The hydrologic and biogeochemical patterns of catchments are altered by urbanization. This research was conducted to understand the timing and magnitude of water and solute export during storm events in two urban and two suburban watersheds with Sustainable Drainage Systems (SUDS) in Charlotte, North Carolina, USA. We analyzed stream flow response during 110 rainstorms from June 2010 – December 2011, and 47 of these storms were sampled to identify concentration patterns of four environmentally reactive solutes (nitrate, soluble reactive phosphorous (SRP), dissolved organic carbon and dissolved organic nitrogen). Storms were analyzed across a range of antecedent moisture and precipitation magnitude. Results from analysis of hydrologic data showed that the rainfall-runoff ratio was higher at the urban (47-49%) than the suburban sites (37-39%). Classification and Regression Tree analysis also showed that the amount of urban area unmitigated by SUDS was the primary control over the time lag between precipitation and the stormflow, and that other environmental variables explained deviations in this time lag at only the least developed site. Event mean concentrations (EMC) of nitrate were significantly higher at sites with wetland SUDS (0.448 mg-N/L) compared to those with wet detention SUDS (0.207 mg-N/L). However, SRP EMCs were controlled by land use: suburban sites (0.218 mg-P/L) were significantly higher than urban (0.026 mg-P/L), likely due to land use history. All solutes exhibited a “concentration pattern”, in which nutrients levels mimicked discharge. The study shows urbanization leads to more runoff, exported quicker, and that SUDS and land use history influence storm solute concentrations.

5-4S: Influence of stormwater management structures on denitrification activity in urban streams in Charlotte, North Carolina, USA.

Erin N. Looper[1] and Sara K. McMillan[2]
[1]Department of Earth Sciences, University of North Carolina at Charlotte, Charlotte, North Carolina, USA. Email: elooper@uncc.edu

[2]Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, Indiana, USA. Email: swmcmillan@gmail.com

Urban stream ecosystems are vulnerable to impacts associated with land cover change, primarily increases in impervious surfaces that lead to increased delivery of runoff and pollutants to receiving streams. In an effort to curtail the effects of urban runoff on receiving water bodies, sustainable drainage systems (SuDS) are implemented to reduce the quantity and improve the quality of the water entering urban streams. This study assessed the influence of SuDS on receiving urban streams in Charlotte, North Carolina, USA during baseflow conditions and storm events to better understand the effects of SCMs on stream ecosystems across varying degrees of urbanization. Denitrification activity was analyzed during baseflow conditions to identify the patterns of denitrification in receiving streams with different SCM types and land development histories. Patterns of sediment microbial community functional resistance and resilience following floods were also assessed to evaluate the influence of SuDS during storm events. Ambient denitrification (DNF) rates and denitrification enzyme activity (DEA) were measured on composite sediment samples collected upstream and downstream of the SuDS-stream confluence during baseflow and before and after storm events. Denitrification activity was enhanced by SuDS in watersheds with low impervious surfaces, increasing denitrification potential by 22-83% downstream of the SuDS. Microbial functional resistance was reduced downstream of the SuDS; however, microbial community function was observed to be highly resilient downstream of the SuDS. This work will help guide future management decisions regarding implementation of SuDS within urban landscapes and further our understanding of the effects of hydrologic disturbance on instream biogeochemistry.

Poster presentations

5-1P: Characteristics of trends of daily and annual precipitation total across Scotland

Muhammad Afzal, Alexandre S. Gagnon, and Martin G. Mansell
Faculty of Science and Technology, University of the West of Scotland, Paisley Campus, PA1 2BE, Scotland, UKTelephone: +44 (0) 141 849 4089 E-mail: Muhammad.Afzal@uws.ac.uk

Identifying different characteristics of rainfall helps to understand their impact on sustainable urban water management. Ascertainment identification of the trends in the precipitation is the key to understand the changes in climate variability. This study attempted to understand the temporal rainfall characteristics by detecting changes of the rainfall using the CUSUM lag, sequential MK test and Likelihood Ratio techniques. The wavelet analysis was carried over monthly precipitation anomalies to find the temporal rainfall variability across Scotland. The trend analyses shows four types of time series; a time series with a single step change, a partial step change and multiple changes in trends also the time series with no change in trend. The wavelet analysis shows both short and long-term periodicities in precipitation. These rainfall characteristics and periodicities are closely related to the North Atlantic Oscillation (NAO). The spatial pattern in rainfall variability was also sensitive to the Lamb weather types and changes in wind direction (easterly and westerly), as compared to the geographic pattern in rainfall. Finding of this study helps to find the impacts of rainfall characteristics and variability on sustainable urban water management across Scotland.
*Corresponding author:

5-2P: Predicting Infiltration and Pollutant Retention in Bioretention Sustainable Drainage Systems: Monitoring, Modelling and Design.

Alejandro Dussaillant,[1] Ruth Quinn[1]
[1]School of Engineering, University of Greenwich, Chatham, UK, ME4 4TB
Phone: +44 163 4883495 Email: A.DussaillantJones@gre.ac.uk

A major problem of increasing urbanization is the rise in pollution caused by runoff, affecting water quality directly and due to combined sewer overflows. Among alternative strategies, Sustainable Drainage Systems (SuDS) such as rain gardens and other bioretention facilities is becoming more widespread. Previous research has focused primarily on hydrologic design, including the degree to which groundwater is replenished by these systems, and models have been developed to quantify the extent of that enhanced focused recharge. However, there are few tools for their design that adequately consider pollutant retention. We have developed a numerical model that simulates infiltration into different area systems with porous media of up to three layers, and can simulate movement and accumulation of metals considering macropore flow. This model is here further validated using new laboratory column results (for matrix and macropore flow), and applied to the design of a rain garden system for a planned roundabout in Kent, U.K, considering climate change scenarios. Results using past and potential future climate series show levels of lead can build up in the upper layers of the system, but only constitute a health hazard after approximately 10 years (when a management intervention such as replacing the upper few cm of soil is required). Implications and future opportunities are discussed.

5-3P: Understanding pluvial flooding – coupling numerical and physical modelling techniques

D. Green[1], D. Yu[1], I. Pattison[2]
[1]Department of Geography, Centre for Ecological and Hydrological Sciences, Loughborough University, Leicestershire, UK, LE11 3TU

[2]Department of Civil and Building Engineering, Loughborough University, Leicestershire, UK, LE11 3TU
Phone: +447878 832247 Email: D.Green@lboro.ac.uk

Pluvial flooding occurs due to intense precipitation events where rainfall cannot infiltrate into the sub-surface or drain via storm water systems. The perceived risk appears to have increased in recent years with pluvial flood events seeming more severe and frequent within the UK. Pluvial flood risk currently accounts for one third of all UK flood risk, with approximately two million people living in urban areas being at risk of a 1 in 200 year flood event. Recent events include flooding in the cities of Glasgow (2002), Sheffield and Hull (2007). Pluvial flooding research is often focused on using 1D, 2D or 1D-2D coupled numerical modelling techniques to understand the extent, depth and severity of actual or hypothetical flood scenarios. Although much research has been conducted using numerical modelling, field data available for model calibration and validation is limited due to the complexities associated with data collection in pluvial flood conditions, resulting in the data which numerical models are based upon being erroneous and often inconclusive. Physical models offer an alternative and innovative environment to collect data within. A controlled and closed system allows independent variables to be altered individually to investigate cause and effect relationships. Despite this advantage, the physical modelling approach has not yet been explored in surface water flooding research. The aim of this research is to undertake detailed observation and measurement of pluvial flood variables within a scaled 'model city' environment in order to gain a better understanding of the mechanisms associated with pluvial flooding. Subsequently, this study will focus on evaluating the extent to which data collected can be used to inform and support current flood modelling strategies.

5-4P: Impacts of urban land-use and imperviousness upon hydrological response – observations from field monitoring in two urbanised catchments

J. Miller[1]
1. Centre for Ecology and Hydrology, Wallingford, UK, 0X10 8BB. Email: millj@ceh.ac.uk

Urbanisation results in a significant alteration of drainage pathways and loss of pervious surfaces that combine to cause increased runoff volumes, peak flows and a reduced catchment response time. Accounting for the impacts of different land-use types and level of impervious cover on the hydrological response of urban areas to storm events is however complicated due to the diversity of features within the urban environment that can alter the response to runoff, and by the scale being considered. Monitoring strategies require sampling of precipitation and runoff at strategic locations that capture contrasting areas of land use at various scales. Similarly the metrics used to contrast the resulting storm hydrograph must be suitable for the scale and differences in land use being considered.

High resolution monitoring of river and storm drain flows has been undertaken across 15 sub-catchments within two urban areas (Swindon and Bracknell) and provides a unique dataset for assessing the impacts of different land use types and urban layouts. Here we present a analysis of a number of events recorded during the period 2011 to 2014 using number of metrics to compare and contrast observed hydrographs from sub-catchments of different land-use and at different scales. Observations illustrate interesting differences in the hydrological response of different land-use types and demonstrate the importance of considering land-use, scale and antecedent conditions when choosing a hydrological metric to quantify and contrast the impacts of land-use on storm hydrographs – being particularly evident during the winter storms of 2013-2014.