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Editorial

Richard Fenner[1]

Engineering Departmenmt, Cambridge University, Trumpington Street, Cambridge UK

Great floods have flown from simple sources, and great seas have dried when miracles have by the greatest been denied
Oft expectation fails, and most oft there where most it promises.
William Shakespeare (Alls Well that Ends Well)

We are facing a climate emergency. As global temperatures rise and weather patterns become more intense and uncertain, a serious threat is the exposure of urban populations to catastrophic flood damage. Compounding the problem is the way cities are expanding with unregulated development and the creation of urban forms that expand hard impermeable surfaces, drastically changing the hydrological response of an area.

Flooding can pose an existential threat to some communities and cause nuisance and economic loss to many others. Building flood resistant urban infrastructure which is resilient to both future climate uncertainties and increasing urbanisation is one of the pressing challenges of this century. This issue brings together current UK and international work exploring recent developments in: understanding the changing drivers of flooding; system applications of flood modelling; pathways to multifunctional infrastructure that can provide multiple benefits; social, economic, and community interaction with flood management interventions, and the effectiveness of flood recovery responses. Several papers provide an international perspective on how countries are reacting to the need for achieving urban flood resilience. The issue argues for a paradigm shift which moves from merely managing the risks of draining water "away" to creating the opportunities of capturing stormwater locally and utilising it as a component of urban regeneration and urban greening and as a potential resource for water supply, local energy production, and environmental restoration.

The challenge of urban flood management is now seen as how to deal with stormwater at source through storage and infiltration systems which attempt to recreate the characteristics of pre-development hydrology across an urban landscape. A range of similar approaches are strongly advocated in many countries, ranging

*Author for correspondence (xxxx@yyyz.zz.zz).
†Present address: Department, Institution, Address, City, Code, Country

from Sustainable Drainage Systems (SuDS) in the UK, Low Impact Development (LID) in the Unites States, Sponge Cities in China and Water Sensitive Urban Design in Australia. All share the same principles and often use vegetative surfaces as part of Blue Green Infrastructure (BGI) which provide multiple benefits to urban environments. However the adoption of these solutions is not universal and in many cases has been resisted by developers.

This reflects the messy nature of urban flood risk management where parts of both the problem and potential solutions are owned by a diverse range of stakeholders ranging from water utility companies, regulators, planners, and property owners leading to complex and often fragmented responsibilities. Moreover for flood schemes to be resilient they have to be acceptable to the local communities in whose locale they are situated. Thus solving urban flooding is no longer a solely technical problem, where solutions are imposed by specialist engineers and scientists responsible for understanding the physical responses of the systems. Instead responses must be framed within a wide socio-technical system where many actors interact in often muddled ways. There is a need to understand how communities respond to new flood resilient solutions so systems can be designed to reflect their preferences and be appropriate in locally specific contexts, thus ensuring that their ownership, maintenance and use can be sustained into the future. Hence the papers included in this special edition attempt to deal with all these critical aspects of urban flood resilience ranging from modelling and evaluating the performance attributes of flood resilient solutions, to perspectives from planning, governance and even the social psychology of the public's awareness of the solutions available.

It is worth pausing at this point and recognising that the term "resilience" doesn't have a generally consensual definition, despite it being a term regularly used in relation to Flood Risk Management. One definition of resilience provided by Sayers et al [1] is:

" The ability of an individual, community, city or nation to resist, absorb or recover from a shock (such as an extreme flood) and /or successfully adapt to adversity or change in conditions (such as climate change or economic downturn) in a timely and efficient manner".

Nuancing this Birkland and Waterman [2] have suggested community resilience is based on damage prevention, speedy recovery and preservation of community functionality. In the Safe and SuRe Framework proposed by Butler et al [3] resilience is defined as "the degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional conditions". This is an example of engineering resilience where the key features are the resistance to disturbance and the speed of return to equilibrium. Other formulations refer to ecological resilience which sees resilience in a more dynamic way where the capacity to absorb the magnitude before changing its structure is the main feature [4]. Holling [5] stresses that engineering resilience focuses on efficiency, constancy and predictability while ecological resilience focuses on persistence, change and unpredictability. A good summary of Urban Flood Resilience, is provided by Miguez and Verol [6] suggesting three important aspects:

- The capacity of maintaining resistance over a period of time
- The capacity of the affected communities to recover from material losses, and
- The capacity of the drainage system to recover its functions and keep operating after the storm, guaranteeing basic conditions for urban services to return to normality.

Bertilsson et al [4] point out that information about the spatial distribution of resilience is particularly valuable since well-targeted projects can enhance the surrounding areas considerably. Abdulkareem and Elkadi provide a thorough discussion of the different forms of resilience [7] contrasting the engineering fail-safe approach with the ecological safe-to-fail response, noting that the challenge for flood management is to find more environmentally sound materials and technologies, whilst in the long term recognising the necessity to change our habits and life style. In reality, achieving urban flood resilience requires co-ordination across multiple levels of government. Examining the institutional, economic, geographical and cultural mechanisms that facilitate such co-ordination in six European cities, Dieperink et al [8] conclude that multiple flood risk management strategies will be required - co-ordinated across multiple governance layers - achieved by proactive policy entrepreuners, bridging concepts, clear rules, and the provision of the necessary resources.

The current EPSRC Urban Flood Resilience Research Consortium funded by EPSRC (2016-2020) recognises these subtleties and has been working on the challenges described above and provides a core of papers here around which these themes are developed and supplemented with contributions from other leading international researchers in the field. The focus is on encouraging the practical implementation of SuDs and other related techniques by practitioners and which have the potential for transformative change in planning, design and implementation of urban water systems.

The first paper by **O'Donnell and Thorne** reassess the current drivers of urban flood risk, first established by the UK Flood Foresight Project over ten years ago. They suggest 5 drivers have strengthened and they introduce two new drivers relating to loss of floodable urban spaces, and indirect economic impacts. This reappraisal frames the overall problem in the light of recent advances in flood risk science, technology and practice. As such, this forms the basis by which social, economic, agricultural, planning and environmental polices can be evaluated in the context of future flood risk management. A second introductory paper by **Zevenbergen, Gersonius and Radhakrishan** examines the varying frameworks for "resilience" and explores how a shift from a traditional to a resilient approach in flood risk management can be achieved and quantified. Through a series of case studies they contrast the concepts of engineering resilience with ecological and socioecological resilience and conclude that translating these concepts into practice is challenging but with the latter effective in building future capacity which embraces flood protection, prevention and preparedness. The paper by **Rogers et al** provides an example from Melbourne, Australia where many of these challenges come together and are dealt with through an interdisciplinary and catchment based approach. Drawing on methods from environmental engineering, social science and urban design, a set of measures for the suburb of Elwood are presented and, crucially, how these have been operationalised in practice is explained.

The next two papers deal with different modelling approaches to examining aspects of urban flood resilience. **Ferguson and Fenner** use a novel coupled model linking DynamicTOPMPODEL, HEC-RAS and Infoworks ICM to explore the effect of Natural Flood Management (NFM) interventions in the Asker catchment (Dorset UK). Their paper investigates if moderating water levels in the urban receiving watercourse can be achieved by NFM to allow free drainage at frequently submerged drainage outlets, in this case from a housing estate in Bridport. A parallel systems approach is taken by **Dawson, Vercruysse and Wright.** They combine hydrodynamic modelling with spatial information on infrastructure systems to explore how flood management interventions can be inter-operably connected. Applied to the urban catchment of Newcastle upon Tyne, their findings illustrate the benefits of combining data sources in a systematic and spatial way highlighting the interactions between flood source areas (where most intervention are required) and flood benefit areas (where most of the reduction in flooding is achieved).

Two papers follow which examine the planning and performance of Blue-Green Infrastructure and SuDS systems. **Kapetas and Fenner** present an adaptive pathways approach to answer the question: what is the most suitable mix of grey and blue green solutions to urban flooding at any given location and at any future time. A methodological framework is applied to a small sub-catchment in south London using a Storm Water Management Model (SWMM), a SuDS opportunity selection tool, and an adaptation pathways generator. The CIRIA B£ST tool is then used to monetise and compare the multiple benefits of the alternative pathways generated (using combinations of grey pipe expansion, bioretention cells, permeable pavements and storage ponds). **Krivstov, Birkinshaw et al** report the performance of a historic pond in the Royal Botanic Garden Edinburgh which regulates surface runoff, using the CityCAT hydrodynamic model and the Shetran hydrological model as well as assessing the ecology and biodiversity of the pond and adjacent area, giving insights into the benefits such a facility can provide .

The next set of papers provide necessary diverse insights on the impacts of urban flood resilience measures from planning, community stakeholder, recovery, governance, regulatory and economic perspectives. **Potter and Vilcan** examine how resilience thinking can be implemented despite the realities of English planning procedures. They find three institutional factors constraining the implementation of SuDS, namely the lack of institutional backing, the power of private commercial interests and the severe lack of resources in local authorities which if not addressed will ensure resilience approaches remain largely aspirational. A novel application of the Implicit Association Test is used by **O'Donnell, Maskrey, Everett and Lamond** to investigate unconscious perceptions of SuDs by flood affected communities, which can help inform future SuDS design to increase their public acceptance. Drawing on their experience in New Zealand, **Trowsdale and Boyle** provide a stimulating and engaging piece to challenge engineering pre-conceptions about the value of stormwate re-use infrastructure, whilst **Coates et al** apply flood modelling and agent based simulation within a modelled geographic environment to study the time taken for post flood recovery of micro-SMEs following the 2007 flood in Tewkesbury. A historic comparison of the response to serious flooding in the UK in 2007 and in Germany in 2013 is provided by **Platt et al**, mapping the changes in both countries that were stimulated by these events and assessing whether they have been effective. Also dealing with the consequences of flooding, **Zhao and Guan** assess the indirect economic impacts using a flood footprint approach based on Input-Output theory. They show that the total economic footprint of multiple flood events within a region is larger than the sum of the footprint from individual flooding events, providing evidence on how to manage the recovery phase post flooding.

In addition to the examples provided in the above contributions from the UK, Australia, New Zealand, the Netherlands, and Germany the international perspective on achieving urban flood resilience is further reinforced by **Gupta** who reports measures to achieve stormwater control in India , and **Griffiths and Chan** who describe the application of sponge city guidelines in China.

The final closing paper by **Ashley, Gersonius and Horton** draws together the themes developed earlier**,** arguing that striving for sustainability in the water domain is now effectively over, "with simpler subordinate concepts such as resistance, resilience and adaptability being used to assess how best to provide water infrastructure that will be able to cope with the many future changing drivers" of flood risk. Echoing Shakespeare at the start of this editorial, they remind us that people expect to be completely safe from flooding, and often see the expert–led promise of hard engineered solutions to offer the most tangible and safe solutions to their own local exposure to flood risk. Yet this expected level of protection often fails. The change that is required "is frequently restrained by the lock-in to the existence of large scalevaluable assets for delivering and drawing water away and also by a locked-in attitude on the part of risk averse developers and professionals".

Provision of traditional flood control measures follow a logical progression starting with hydrological studies, selection of a design storm of a suitable return period, and the design and subsequent implementation of an engineered system to convey the flow generated. However there will always be the risk of the system being overwhelmed by a hydrological event which exceeds the design storm considered as well as eventually the physical failure of the assets. Disregarding these residual risks can lead to a false sense of security and create increased exposure to hazard in urban environments These traditional, inflexible, often centralised and increasingly deteriorating assets are failing more frequently as climate and other drivers of flood risk rapidly strengthen , whilst responsibilities are complex, convoluted and opaque. Echoing the keys themes of this special edition **Ashley, Gersonius and Horton** call for a new paradigm in which “an integrated approach to managing the water cycle begins by seeing potential opportunities, exploiting resources, adding to the quality of urban areas and preferring nature-based approaches, seeking multi- value and multi-functional infrastructure”. To do otherwise may be seen as a transgression from the inevitably of natural laws, attempting to hold back the tide - if you will. But achieving urban flood resilience is about overcoming messy problems and many contradictory paradoxes, summed up in this often cited anonymous quote:

All good men are for flood control and against sin. But how to control floods and what is sin—aye, there’s the rub *Anon*

Additional Information

Information on the following should be included wherever relevant.

Ethics
Insert ethics statement here is applicable

Data Accessibility
No data is cited

Competing Interests
The author declares that he has no competing interests”.

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