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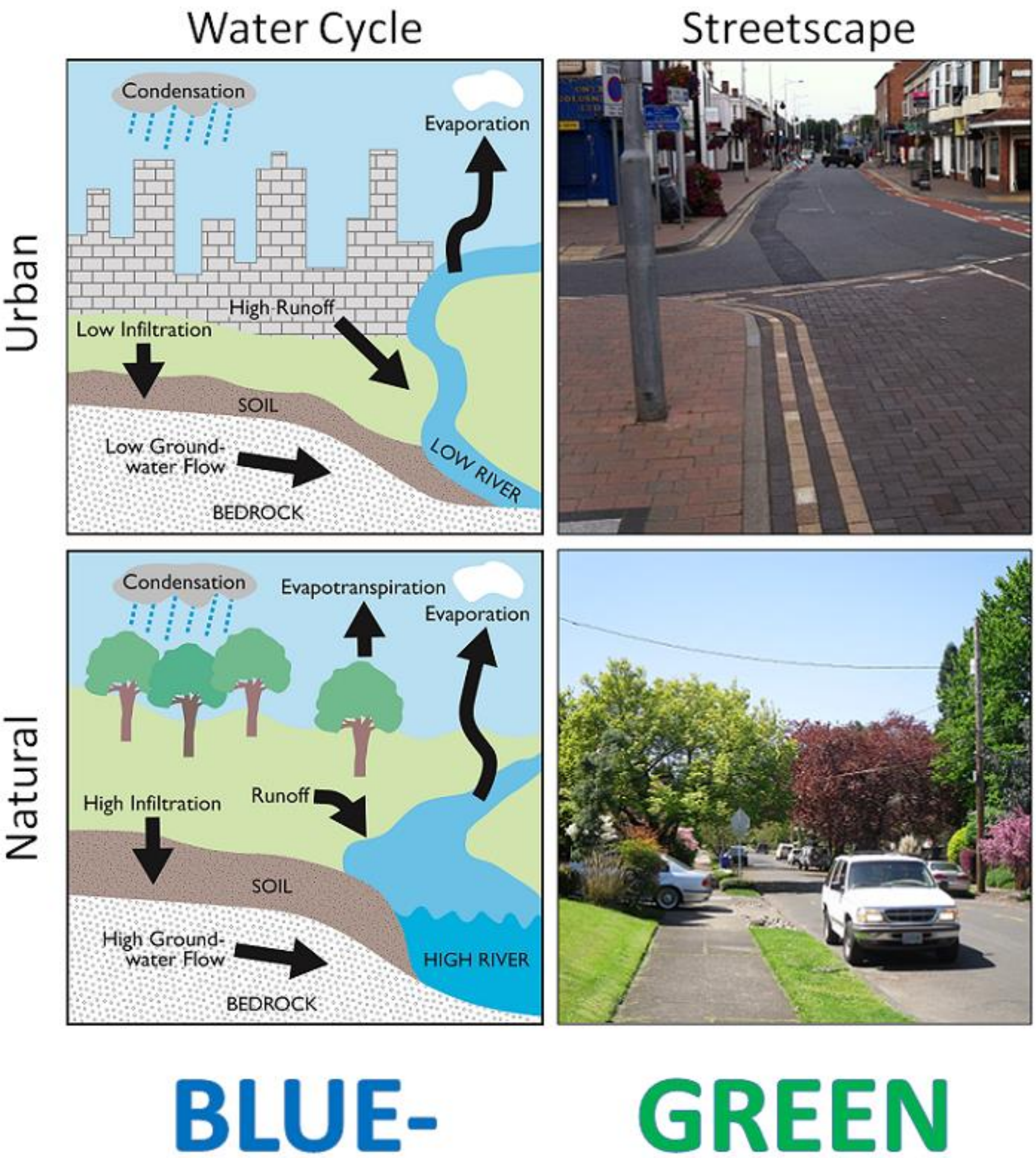
Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities

Key Project Outputs



EPSRC Project EP/K013661/1

February 2013 – February 2016

A Blue-Green City aims to recreate a naturally-oriented water cycle while contributing to the amenity of the city by bringing water management and green infrastructure together. This is achieved by combining and protecting the hydrological and ecological values of the urban landscape while providing resilient and adaptive measures to deal with flood events.

The Blue-Green Cities Research Consortium aimed to develop new strategies for managing urban flood risk as part of wider, integrated urban planning intended to achieve environmental enhancement and urban renewal in which multiple benefits of Blue-Green Cities are rigorously evaluated and understood.

The Consortium's objectives were to:

1. Put competent authorities, businesses and communities at the centre of the research by establishing feedback pathways between them and the urban flood risk management (FRM) modellers, planners and decision makers to ensure co-production of knowledge;
2. Model existing flood risks using coupled surface/sub-surface hydrodynamic models linked to semi-quantitative assessments of sediment/debris dynamics and habitats, using fieldwork where necessary to fill knowledge gaps in urban drainage network forms and functions;
3. Identify and assess candidate options for adaptive strategies combining hard and soft responses to flood risk that are capable of functioning as spatially-integrated, urban FRM systems;
4. Use fieldwork to identify and understand the behavioural responses of individual and institutional stakeholders to the candidate options for urban FRM;
5. Synthesise existing and novel performance measures to identify 'value added' at a range of scales and under flood/non-flood conditions, in an ensemble of possible flood futures;
6. Develop a framework to identify and characterise the uncertainties and barriers to Blue-Green infrastructure, and;
7. Develop a 'flood footprint' tool to calculate the economic impact of flood events.

This document presents the key outputs from the five main work packages.

The Blue-Green Cities project was led by Prof Colin Thorne (University of Nottingham) and lead research and project coordinator Dr Emily O'Donnell (University of Nottingham). The research team comprised nine UK Universities;

Cranfield University – Dr Jenny Mant, Dr Ian Holman, Dr Victoria Janes
De Montfort University – Prof Nigel Wright
Heriot-Watt University – Dr Scott Arthur, Dr Heather Haynes, Deonie Allen
Leeds University – Dr Sangaralingam Ahilan, Dr Andrew Sleigh
London School of Economics – Prof Leonard Smith
Newcastle University – Prof Chris Kilsby, Vassilis Glenis
University of Cambridge – Dr Dick Fenner, Dr Lan Hoang, Dr Malcolm Morgan
University of East Anglia – Prof Dabo Guan, David Mendoza-Tinoco
University of Nottingham – Prof Colin Thorne, Dr Emily O'Donnell, Shaun Maskrey, Lindsey Air, Dr Nick Mount, Dr Faith Chan (University of Nottingham Ningbo)
University of the West of England – Dr Jessica Lamond, Dr Glyn Everett

Please contact Emily O'Donnell (Emily.O'Donnell@nottingham.ac.uk) or Colin Thorne (Colin.Thorne@nottingham.ac.uk) for further information.

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WP1 Communications and Uncertainty

KEY OUTPUTS

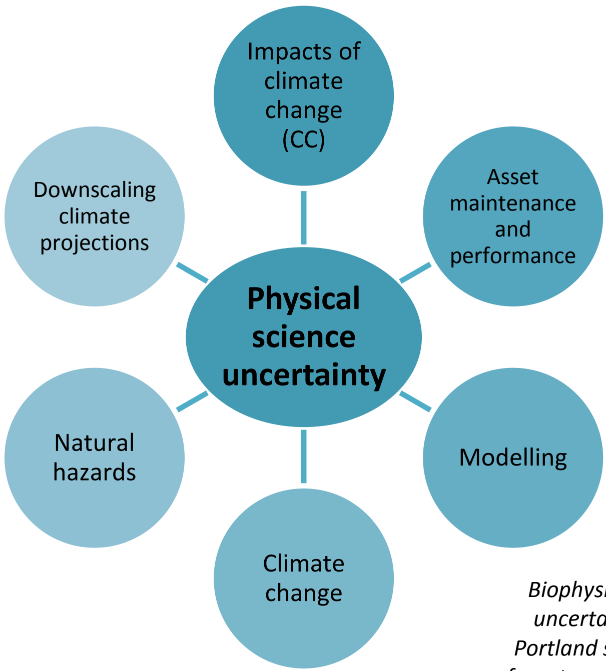
The aims of WP1 were twofold; 1) to **facilitate co-production of knowledge** and increase two-way communication between academics, consultants, practitioners and other technical specialists via a **Learning and Action Alliance**, and 2) develop and test a framework for **identifying the key uncertainties and barriers** to delivering Blue-Green infrastructure.

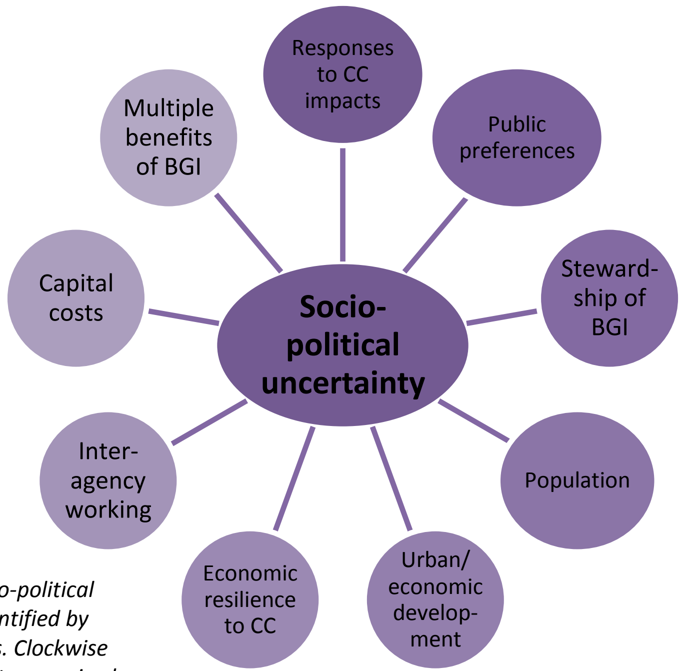
Newcastle Learning and Action Alliance (LAA) – see http://goo.gl/G5tjtr

The Newcastle LAA was established in February 2014 and brings together Newcastle stakeholders (local authority, EA, Northumbrian Water, major landowners, academics, local interest groups) to create a **joint understanding of flood and water management problems** and possible solutions based on **rational criticism** and discussion. The LAA has met 13 times and **facilitated innovative thinking** to solve complex problems outside of the constraints of existing formal institutional settings. These ideas are then presented in inter-organisational decision-making processes to generate impact. The success of the LAA has led to **opportunities for Newcastle that may not have occurred otherwise**, particularly discussions around using Blue-Green infrastructure to meet multiple objectives for different organisations and departments, e.g. to manage surface water while creating biodiversity corridors, improving health and wellbeing, air and water quality and city aesthetics. The LAA has also **opened communication channels** with those not typically involved in flood risk management, strengthened existing relationships between stakeholders, and created **opportunities for collaborative working to achieve common goals** and potential for joint funding. The LAA framework is **transferable to other cities** and can be **scaled up to a whole catchment approach** (sharing risk to enable greater progress).

Uncertainties, barriers and overcoming barriers to Blue-Green infrastructure

Research in Portland, Oregon USA, has identified two types of uncertainty that limit the implementation of Blue-Green infrastructure; **scientific uncertainty** related to physical processes that affect future infrastructure performance and service provision, and; **socio-political uncertainty** stemming from lack of confidence in the social structures, public preferences and political support. Research in Newcastle, UK, investigated strategies to overcome these uncertainties; most interview respondents thought that promoting multifunctional space, assessing (monetising) the multiple benefits, improving education and awareness, and **greater partnership working would be key to overcome the barriers**.





Biophysical and socio-political uncertainties as identified by Portland stakeholders. Clockwise from top: most to least recognised

For further information see Thorne, C., et al. (2015) Overcoming uncertainty and barriers to adoption of Blue-Green infrastructure for urban flood risk management, *Journal of Flood Risk Management,* DOI: 10.1111/jfr3.12218.

WP2a Inundation Modelling

KEY OUTPUTS

The aims of WP2a were: 1) to **develop the CityCAT hydrodynamic model** to better represent urban areas, 2) to **fully couple the surface flow model with a storm sewer network model**, 3) **represent key Blue-Green infrastructure** (e.g. blue-green roofs, permeable areas, swales, water butts) in the model, and 4) carry out an ensemble of simulations addressing the uncertainty and variability in the characteristics of present and future extreme rain storms.

Main Outputs

A new storm sewer network model has been developed which can handle the flashy and pressurised flows found in sewers. **For the first time, the link between the gullies/drains and the sewer pipes is included in the model** which is **fully coupled** with the surface to model both inflows and outflows.

New features have been added to represent key Blue-Green infrastructure such as permeable pavements and surfaces, green and blue roofs, swales and water butts to allow for **application in an innovative and flood resilient city environment.**

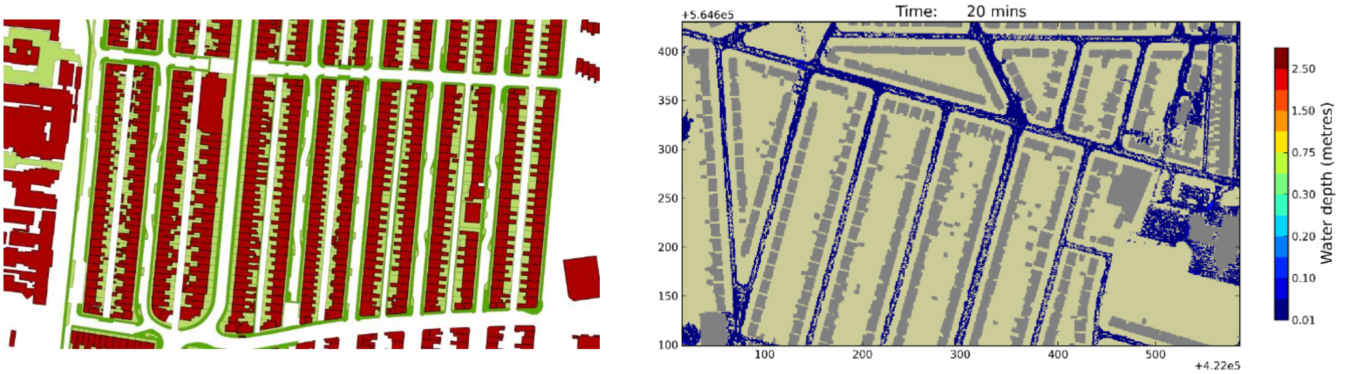


Figure 1. Modelling blue-green features in the Wingrove area of Newcastle

The model has been applied to the Newcastle case study sites to simulate the effects of a combination of new blue-green features:

1) Green areas, permeable pavements and water butts in the Wingrove area of Newcastle (Fig 1)
2) St. James Boulevard – a swale carrying flood flows towards the River Tyne (Fig 2)
3) Green areas and green roofs in the urban core

Key Findings

1. CityCAT successfully reproduces observed depths of flooding, and flows in the sewer network, associated with storm events such as the Toon Monsoon of 2012;
2. The effect of Blue-Green features on flows and flood depths can be assessed across the whole city;
3. A swale on St James Boulevard has far-reaching benefits across the urban core;
4. Lesser, but worthwhile, benefits can be incrementally achieved by widespread implementation of features, particularly in areas upstream of *at risk* locations.

Figure 2. Modelling St James' Boulevard swale

For more information contact ***Vassilis Glenis*** or ***Chris Kilsby*** at ***Newcastle University***.

WP2a Influences of SuDS on flow and sediment dynamics

KEY OUTPUTS

Research aim: to investigate the impact of SuDS on **water flow, sediment dynamics** and **flood risk** in **fluvial systems**.

Case Study 1: Wortley Beck catchment, Leeds, UK

The first case study explores potential flood resilience approaches for the highly urbanised Wortley Beck river basin, south west of the City of Leeds. Integrated 1D and 2D hydrodynamic modelling, using ISIS and TUFLOW, has been utilised to explore potential impact of SuDS on the flood hazard for three (15 year, 50 year and 100 year) flood events. A direct rainfall runoff modelling approach has been employed to implicitly incorporate SuDS feature within the case study region. Results indicate that **SuDS reduce the flood hazard downstream for all three (15 year, 50 year and 100 year) simulated flood events**, with the effect more pronounced for the lowest rainfall (15 year) event.

Case study 2: Johnson Creek, Portland, USA

This study investigated sedimentation dynamics on a recently restored floodplain in the East Lents area of the Johnson Creek catchment. This study used a 2D hydro-morphodynamic model for the prediction of flow and suspended sediment dynamics in downstream Johnson Creek, the East Lents reach, where the bank of the river has been reconfigured to reconnect to a restored floodplain on a 0.28 km^2 (28-ha) site. The simulation scenarios included event-based (10, 50, 100, and 500 year floods) deposition modelling of flood events and long-term modelling using 64 historical flood events between 1941 and 2014. Simulation results showed that the **restored floodplain attenuates the upstream flood peak by up to 25%**. Results also indicated that **20-30% of sediment transported from further upstream** is deposited on the East Lents floodplain. This research demonstrates the spatial distribution and amount of short and long-term sediment deposition on the floodplain, and the resulting potential loss of the flood storage capacity.

Case study 3: Ouseburn catchment, Newcastle, UK

The third case study explores the influence of the Newcastle Great Park (NGP) SuDS ponds on the flow and sediment dynamics in the Ouseburn, a tributary of the River Tyne that runs through the NGP development. A TUFLOW hydrodynamic model was used to investigate how the SuDS ponds influenced three simulated flood inundation events; non-flood condition (5 year event); sewer design condition (30 year event); and flood condition (100 year event). 'With' and 'without' SuDS ponds scenarios were considered for the three events in order to assess the relative impact of the ponds. **The simulation results show that the SuDS ponds attenuate and delay the flood peaks for all three events, and that effects are more pronounced for higher magnitude events (e.g. 100 year).** A layer based hydro-morphodynamic model was also used to assess the impact of the SUDS ponds on sediment dynamics for the three flood events. **The SuDS ponds are shown to trap sediment during all three simulated flood events,** thus meeting their design criteria.

Ring Road, Wortley Beck

East Lents restored floodplain

SuDS pond, Ouseburn catchment

For further information contact: Prof Nigel Wright (nigel.wright@dmu.ac.uk)

See Ahilan, S., et al. The Influences of Floodplain Restoration on Sediment Dynamics in an Urban River, Journal of Flood Risk Management, (under review)

WP2b Sediment, Debris and Ecosystems

KEY OUTPUTS

The aim of WP2b was to unravel the impact of Blue-Green infrastructure on sediment transport, particularly during multiple rainfall-runoff events, to ultimately determine the long term efficiencies of SuDS. Research investigated:

- The trapping, transport and release of fine sediment from the urban environment
- The transport and flood risk impact of small woody debris on small urban watercourses
- The urban pollution treatment provided for urban stormwater runoff by Blue-Green infrastructure, and
- The identification and quantification of possible macro-invertebrate, biotic diversity and water quality benefits

Main Outputs

1. A detailed understanding of how Blue-Green infrastructure treats fine sediment and key urban pollutants during multiple rainfall-runoff events
2. A record of SuDS pollution levels and trends based on extensive fieldwork
3. Evidence of the quantity of fine sediment being temporarily deposited within SuDS assets, which is necessary for SuDS maintenance and quantification of long term flood storage loss, and
4. Identification of the ecosystem service benefits provided by SuDS assets and Blue-Green networks

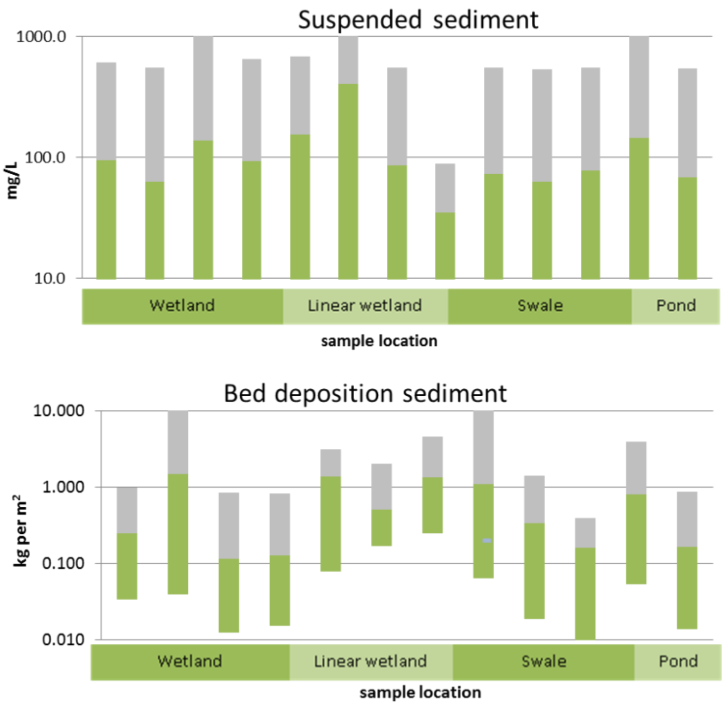


Figure 1: Fine sediment detention of SuDS assets

Key Messages

- SuDS/Blue-Green assets provide sediment detention, but not necessarily in the way, or to the level, that existing manuals suggest
- SuDS/Blue-Green assets provide water quality improvement, with differing levels of benefits provided by different types of assets
- SuDS/Blue-Green assets can change the particle size distribution in stormwater by removing the larger sediment, but again each asset acts differently
- Field data shows the benefits of individual SuDS/Blue-Green assets: ***this is a step towards detention and pollutant remediation ranking of studied SuDS***
- Research has illustrated the ***benefit of SuDS/Blue-Green networks***, and that the ***composition of the network is more important than the number of assets in the network***

This research has been drafted into new CIRIA guidance on SuDS Asset Performance, as well as helping inform the 2015 SuDS Manual.

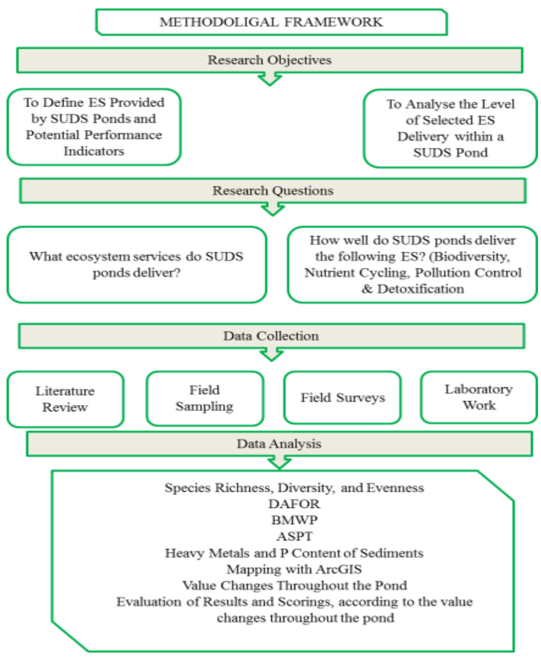


Figure 2: Ecosystem service benefits

Further information

Allen, D., et al. (2015) Multiple rainfall event pollution transport by Sustainable Drainage Systems: the fate of fine sediment pollution, International Journal of Environmental Science and Technology, *in review*

Allen, D., et al. (2015) Urban sediment transport through an established vegetated scale: Long term treatment efficiencies and deposition, Water, 7, 1046-1067, doi: 10.3390/w7031046

WP2b Blue-Green Infrastructure in the Context of Natural Flood Management and Habitat Gain

KEY OUTPUTS

This research investigated whether natural flood management (NFM) schemes that include habitat creation in the channel and on the floodplain have additional benefits on the removal of sediment-bound contaminants.

Specifically the objectives were:

- To **quantify sediment quality within the Johnson Creek channel network** (Oregon, USA) upstream, at and downstream of stormwater outfalls to assess the impact of outfall type (set-back vs. direct) and level of channel restoration on contaminant deposition.
- To **conduct standard River Habitat Survey** (RHS) downstream of the outfalls to assess the reach condition (i.e. level of restoration/naturalness)
- Compare several habitat and river modification scores generated from the RHS field assessment, to establish **if NFM had a positive benefit in terms of reducing chemical contamination** within water courses.

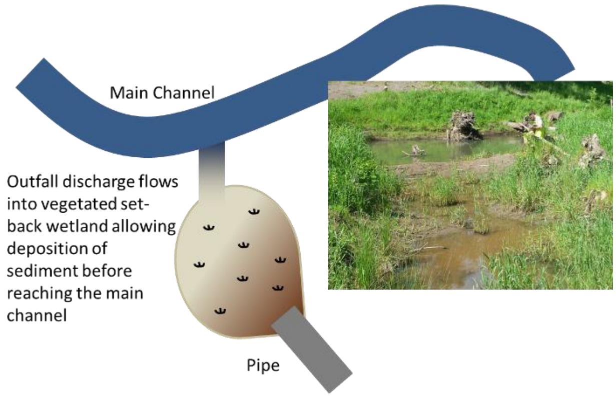


Figure 1: Example of a setback outfall (Johnson Creek, Portland, Oregon: the study site)

Main methodological outputs

1. A range of common, less common and potentially natural **contaminants** were analysed by Herriot-Watt University (see other WP 2b) from samples taken at the outfalls, and up and down stream.
2. Outfalls assessed comprised both those that directly discharged into river reaches and those that were set back (see figure 1).
3. **Habitat, modification, unnaturalness and contamination removal efficiency (RE) indices** were established for each reach (figure 2).

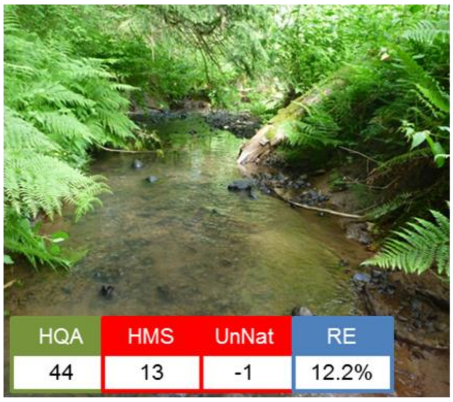


Figure 2: Example of outputs on habitat assessment

Key Messages

- The results indicate that **setback outfalls have significantly higher levels of sediment contamination** than the background levels in the channel for several key pollutants (Cu, Ni, Mg, Cd, P, K, Ca) indicating contaminants are settling out prior to reaching the rivers.
- **Sediment contamination in the channel increased more at direct outfalls than setback outfalls** compared to background levels upstream, providing additional support for the removal of pollutants in set-back outfalls.
- The derived indices from each reach when compared to contamination levels showed a **general beneficial trend in sections with higher habitat quality and removal efficiency scores**.
- Not all contaminants show the same correlation to habitat scores (also found by other researchers).
- The use of the **RHS method in this context has helped to provide an index against which to assess NFM benefit**.
- This research however, is based on a snap shot in time (i.e. one field work period) so the impact over time or for a range of storm events could not be assessed. Results however, do show some relative variation between different types of reaches.

Going Forward

- The research had indicated that there are **multiple benefits that can be associated with NFM approaches.**
- A more detailed paper on this subject is in preparation and will shortly be available.

***For more information contact**:* V.j.janes@cranfield.ac.uk or Jenny.mant@ricardo.com

WP2c Behavioural Responses of Publics

KEY OUTPUTS

Research Questions

1. How do **people's perceptions and understanding** of Blue-Green Infrastructure (BGI) facilities **affect their preferences** and levels of support for them?
2. Do understandings, perceptions and **behaviours around BGI develop over time** and with experience?

Main Messages and Outputs

- People generally **feel positively towards BGI facilities** for the **aesthetic improvements** they offer and the **amenity** they provide, from ponds through to permeable paving.
- **Appreciation depends on the detail of the design** in each instance. There are no objective measures for amenity, and so we need to understand local preferences in looking to deliver multiple benefits.
- **Members of the public value having a voice** in the development of facilities. This can help to increase 'buy-in', in the sense of adopting appropriate behaviour and willingness to help with maintenance.
- **Understanding of wider BGI functions and service requirements is frequently lacking**; this can become more problematic in the absence of long term engagement. Willingness to help maintain facilities is variable and depends on multiple factors including understanding, ease of maintenance and perceived "ownership" of the facility.
- **People are willing to have local BGI installations that can reduce flood risk downstream**, even when they themselves are not at risk.

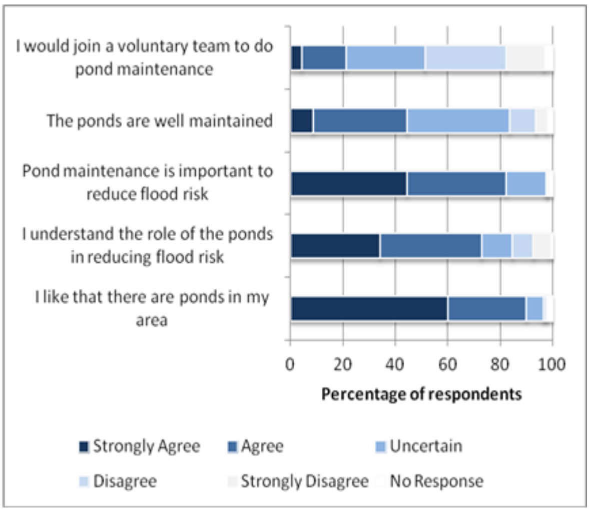


Figure 1. Newcastle Great Park pond preferences

'Good to know they protect us from floods … We like the herons and swans on the ponds … Visual appeal enabling mindful moments … Relaxing and tranquil, a great place to forget the troubles of the day.'

Recommendations

- **Longer-term social engagement** is advised for all BGI installations; this can help improve understanding and so appreciation and behaviour.
- Publics have **local knowledge** that can inform proposals and local preferences that will affect appreciation of selected designs.
- Solutions will be more effective and more sustainable if they are **co-developed in conversation** with those who will live alongside them.
- Creative efforts at **longer-term engagement and awareness-raising** need to be ongoing; populations change over time and people forget, so **outreach will always be beneficial**.

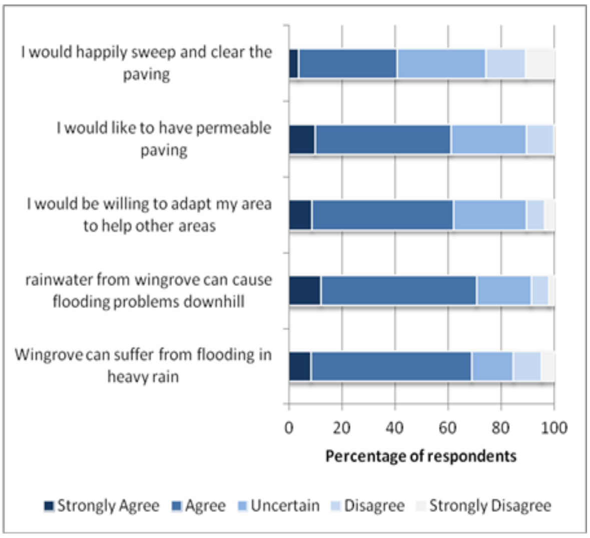


Figure 2. Wingrove survey preferences

For further information, see Everett, G. et al. (2015) 'Delivering green streets: an exploration of changing perceptions and behaviours over time around bioswales in Portland, Oregon', *Journal of Flood Risk Management*, http://dx.doi.org/10.1111/jfr3.12225.

WP3 Systems of Systems

KEY OUTPUTS

This aspect of the Blue-Green Cities project asked the **following questions:**

- How do different elements of blue-green drainage infrastructure interact with the wider urban system?
- What are the critical inter-dependencies under both flood and non-flood conditions?
- What combination of conditions promotes or impedes a range of multiple benefits from blue-green infrastructure incorporated into SuDS systems (SuDS/GI) from being simultaneously realised?

Main outputs

A series of interdependencies between stormwater management components and the wider urban landscape were identified. These were classified as **Physical interdependency** when one infrastructure installation is dependent on the material output of the other; **Cyber interdependency** when one component needs information from another system; **Geographic interdependency** when critical infrastructures are located at the same site and can be impacted by the same event; and, **Logical interdependency** between the states of services between two systems, with a prior event or action determining subsequent levels of performance.

Based on the range of hydrological, ecological and built environment functions which SuDS/GI can provide, the physical interactions between technical systems were identified *(functional complexity*) where installations:

i) operate within their design capacity (non-flood condition) and

ii) during exceedance conditions of controlled and uncontrolled surface water flooding.

The effects of wider urban features on the performance of SuDS/GI were identified, as well as how SuDS/GI might impact on other aspects of the urban environment. Similarly the *relational complexity* between a range of actors, organisations and responsible authorities were explored - again under flood and non-flood conditions. The work also showed that for specific installations such as **green roofs** different **benefits can prevail under different conditions**, with the main determining factors being temperature and water budget of the roof. This highlights the need to design systems in ways that co-optimised the preferred dominant benefits.

Key findings

Organisational complexity between responsible bodies has not reflected new interdependencies created by SuDS/GI solutions

Responsibilities for SuDS and GI are largely separated by different groups responsible for their design and maintenance

There is a state of policy disconnection which acts as a key barrier towards the effective adoption of SuDS/GI relating to physical barriers, perception/ information barriers and organisational barriers

Optimising around one function of SuDS/GI can reduce other functions thus creating conflicts amongst disparate stakeholder groups

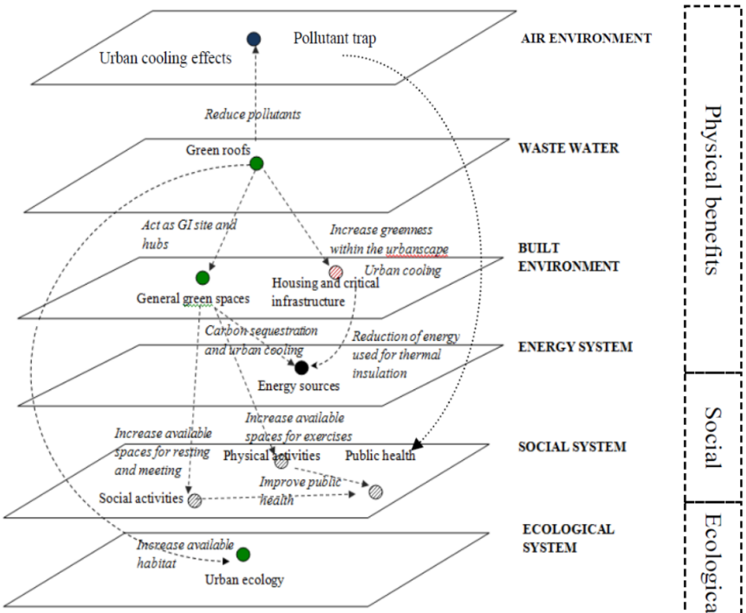


Figure 1 The inter-related impacts of green roofs across the urban system

Further Information:

- Hoang L, Fenner R.A. (2015) System interactions of flood risk strategies using Sustainable Urban Drainage Systems and Green Infrastructure. Urban Water Journal 27 May 2015 DOI: 10.1080/1573062X.2015.1036083
- Hoang L, Fenner R.A. (2014) Systems interactions of green roofs in blue green cities. 13th International Conference on Urban Drainage, Sarawak, Malaysia, 8-12 September 2014

WP3 Flood Footprint Assessment

KEY OUTPUTS

Research questions:

- How do flood damages spread through socio-economic sectors (i.e. indirect damage)?
- Which are the most vulnerable economic sectors after a flood event?
- What is the total economic benefit of Blue-Green infrastructure?

Flood Footprint framework

The Flood Footprint is a new concept that provides a **damage accounting framework** to measure the **total socio-economic impact that is directly and indirectly caused by a flood event** to the economic systems and social networks in the wider area. Traditionally, impact assessments of floods have mainly focused on direct damages to physical assets and people. However, the intricate links that bind together the economy can result in impacts rippling to other economic sectors, even far beyond the physical location of the event and can lead to substantial indirect damage through supply chains. Risk management frameworks and impact assessments have traditionally failed to account for the total economic impact of flooding largely because they fail to incorporate these indirect damages.

Flood Footprint for 2012 summer flooding in Newcastle

2012 summer flooding in the UK is used as a case study to show the applicability of the Flood Footprint framework. The Environment Agency estimate direct damages from the event to be £600m nationwide. Using information from Newcastle City Council, we estimate that the **direct damages to Newcastle were £34m**. These direct damages have economic consequences on the rest of the economy in a knock-on effect. Using the Flood Footprint tool, we estimate that the **indirect damages were £44m** (Figure 1).

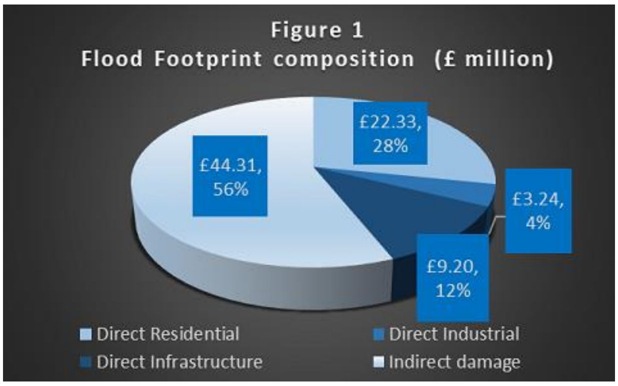


Figure 1
Flood Footprint composition (£ million)

One of the main outputs of the Flood Footprint framework is the sectoral analysis, which allows for **identification of vulnerable sectors in the economy**. Figure 2 presents an overview of the damage distribution among industrial sectors in Newcastle, where Manufacturing, Utilities and Financial Services sectors are the most affected, accounting for 60% of the indirect damage. The ratio of indirect to direct damage is 1.27; **the indirect damage is 27% bigger than direct damage**.

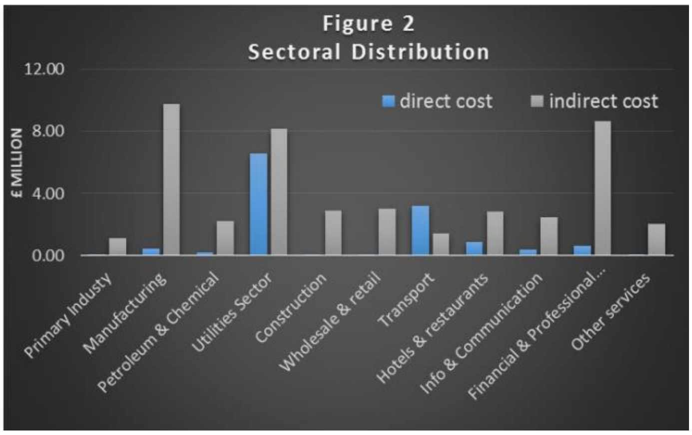


Figure 2
Sectoral Distribution

Maximising risk management options

The Flood Footprint framework can be used to optimise investment in Blue-Green infrastructure by **identifying the blind-spots in critical infrastructure and vulnerable sectors** in economic supply chains and social networks. This supports adaptation measures, e.g. Blue-Green infrastructure, for the affected regions to reduce the level of damage from future events. The benefits of adaptation investment in Blue-Green infrastructure is not limited to the flooded area, it also extends to entire socio-economic networks and this must be considered in order to maximise the magnitude and probability of cascading benefits of Blue-Green infrastructure.

For further information please contact Professor Dabo Guan (dabo.guan@uea.ac.uk) or David Mendoza-Tinoco (d.mendoza-tinoco@uea.ac.uk), School of International Development, University of East Anglia.

WP4 Multiple Benefit Evaluation

KEY OUTPUTS

This aspect of the Blue-Green Cities project asked the **following questions:**

- How can multiple benefits from blue-green infrastructure incorporated into SuDS systems (SuDS/GI) be locally contextualised to assess the specific uplift an area receives in each benefit category?
- What is the spatial extent of each SuDs/GI benefit and where and to whom does the aggregate benefit accrue?
- How is the overall benefit distribution modified by the value and preferences of community stakeholders?

Figure: Multiple Benefit intensity, Newcastle urban core

Main Outputs

New protocols to help practitioners understand the **relevant dominant benefits for a SuDS/GI scheme** to complement existing monetisation techniques (e.g. CIRIA BeST tool) through the following new concepts:

- **Benefit profile** – using normalised benefit values against a defined initial condition state
- **Benefit intensity** – the spatial distribution of cumulative benefits
- **Benefit dependency** – the interrelationships between benefit categories and their response to a set of site specific controlling variables

PLUS **A Blue-Green Cities Multiple Benefits Toolbox**

This is a set of **benefit evaluation tools for ArcGIS 10.X**, from which the above parameters can be calculated. The tools are designed to work using OS data commonly available in UK cities. The tool box consists of three main parts:

1. simple models that (to date) predict the spatial distribution of six benefit categories (with opportunity to add more, as required), including:
    - Flood damage mitigation
    - Carbon sequestration
    - Access to greenspace
    - Habitat size
    - Air pollution mitigation
    - Noise pollution attenuation
2. tools to evaluate and normalise benefits so that they can be directly compared and used to produce benefit intensity maps
3. tools to combine the outputs of each single benefit tool to produce multiple benefit intensity maps

Key Findings

Spatial distribution of multiple **benefit intensity** from SuDS/GI can usefully inform aspects of urban planning

The wider benefit performance of SuDS/GI installations is dependent on the initial condition of each site location

Tradeoffs may occur between different benefits categories for a range of installation types, and the benefits and dis-benefits are context specific

Many benefits are incremental and need to be assessed in relation to the rate they develop over time, so the **benefit profile** also distinguishes between realised and potential benefits in each category

Further information:

Hoang L., Fenner R.A., Skenderian M. (2016) Towards A New Approach For Evaluating The Multiple Benefits Of Urban Flooding Management Practice. Submitted to Journal of Flood Risk Management (under review).

Fenner R.A., Morgan M., Hoang L., (2016) Visualising multiple benefits from Sustainable Drainage Systems in CIRIA Report: Blue Green Infrastructure–Perspectives on Planning, Evaluation and Performance.

WP5 Demonstration Case Study
Newcastle upon Tyne

KEY OUTPUTS

In 2015, the Blue-Green Cities team transferred their research to Newcastle upon Tyne. Through discussion with the Newcastle Learning and Action Alliance (see WP1 outputs) two areas were selected for detailed study; the **middle Ouseburn and Newcastle Great Park**, and the **urban core and adjoining residential area of Wingrove**.

Middle Ouseburn and Newcastle Great Park

SuDS pond, Newcastle Great Park

Key findings:

Flood inundation modelling showed that the Newcastle Great Park **SuDS ponds reduce flood risk** in the local area

Hydrodynamic sediment modelling showed that the SuDS ponds can trap large quantities of sediment washed in from further up catchment, reducing sediment input into the Ouseburn watercourse

54% of **suspended sediment** transported into a sampled SuDS pond is retained; this demonstrates that sediment entering SuDS assets is not stationary once deposited but is resuspended over multiple rainfall events (this differs to design standards that assume ~80% deposition)

As designed, the sampled SuDS pond is **actively retaining heavy metals** (cadmium, zinc and lead)

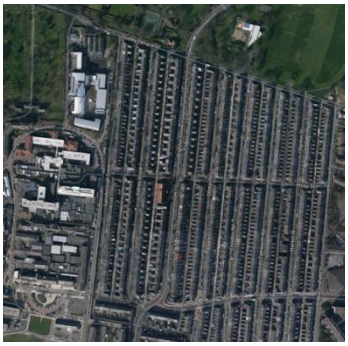
The sampled SuDS pond provides **beneficial ecosystem improvement** by supporting increasing macroinvertebrate species richness (which increases from the inlet to outlet)

90% of **residents' surveyed** (299 total responses) like the SuDS ponds and 61% understand the role of the ponds in reducing flood risk; opinions on the aesthetic appeal varied (from 'softens landscape' to 'scruffy')

In the non-flood condition the SuDS ponds **provide benefits** to carbon sequestration and habitats, and reduce air pollution, noise and flood risk

Opportunities for **natural flood management** in the Ouseburn catchment would further reduce flood risk, improve water quality and biodiversity

Newcastle Urban Core and Wingrove



Arthurs' Hill, Wingrove and Blue-Green model simulation

Key findings:

Flood inundation simulations (using the coupled surface-subsurface CityCAT model) showed that the inclusion of Blue-Green infrastructure (e.g. green roofs, permeable paving, a large swale along St James' Boulevard, green space and water butts) reduced flood risk under a range of event scenarios

When interviewed, institutional stakeholders suggested that **key barriers to the implementation of Blue-Green infrastructure** in the urban core include a reluctance to support novel (new) approaches and change practices, lack of knowledge, and funding constraints. Ideas to **overcome these barriers** focus on promoting multifunctional space and improving understanding of non-technical stakeholders, including decision makers

Multiple benefits evaluation shows that hypothetical Blue-Green infrastructure in **Wingrove** would reduce noise and air pollution, increase carbon sequestration and habitats, and improve access to greenspace for residents

Multiple benefit evaluation **suggests adding Blue-Green infrastructure to the urban core** would provide additional carbon sequestration, increase access to greenspace (and provide a network of Blue-Green space through the city), increase habitats and reduce air pollution and noise

The **flood footprint** (direct plus indirect damages) of the 2012 'Toon monsoon' is estimated at causing **£78 million damage to the local economy** (£34 m direct and £44 m indirect damages).

EPSRC Studentship

Building a community understanding of flood risk using participatory modelling

KEY OUTPUTS

Running alongside the Blue-Green Cities work packages is an EPSRC studentship held by Shaun Maskrey and supervised by Nick Mount and Colin Thorne at the University of Nottingham. The studentship is investigating the potential of different **participatory modelling tools** to more **actively involve local stakeholders** in the modelling of flood risk. It has the following five objectives:

1. Elicit what participation aims to deliver at different stages of the flood risk modelling process
2. Identify the strengths and limitations of **different participatory modelling tools**
3. Develop a **methodological approach** through which participatory modelling can be delivered
4. Trial and evaluate different participatory tools in local flood risk contexts
5. Develop an **evaluation framework** to use with a range of participatory tools

Case study application of participatory techniques (objectives 1-4)

The participatory approach has been trialled in two UK case studies. The first saw **Bayesian networks** used to identify interventions for managing flood risk in Hebden Bridge, West Yorkshire. Over the course of six workshops in 2013/14, participants built a Bayesian network model around the achievement of nine catchment objectives. Use of backwards propagation and other **sensitivity testing techniques** allowed stakeholders to identify those interventions they felt would have the greatest effect on achieving each objective, and thus merited further exploration.

A second case study used elements of **system dynamics** to model perceived risks in Southwell, Nottinghamshire. During the workshop programme, participants used water depths from the 2013 event to model how different receptors were exposed and/or vulnerable to risk at eight locations around the town. The model brought together local knowledge to form a clearer map of where the community should be focussing its **flood risk resilience** efforts.

Development of an evaluation framework (objectives 4-5)

Throughout the study, evaluation has been a key focus. A **holistic evaluation** is achieved by assessing four elements of participation: context, process, substantive outcomes and social outcomes. This advances evaluation beyond previous studies which have tended to focus solely on the process; and highlights the **importance of evaluation at every stage in the participatory cycle**. Specific **evaluation criteria** have been developed for each of these elements in collaboration with both residents and flood risk management practitioners, which are transferable to future studies.



Stakeholder activities from left to right: discussing the participatory process; identifying variables; mapping risk hotspots.

For further information see http://www.bluegreencities.ac.uk/bluegreencities/research/epsrcstudentship.aspx