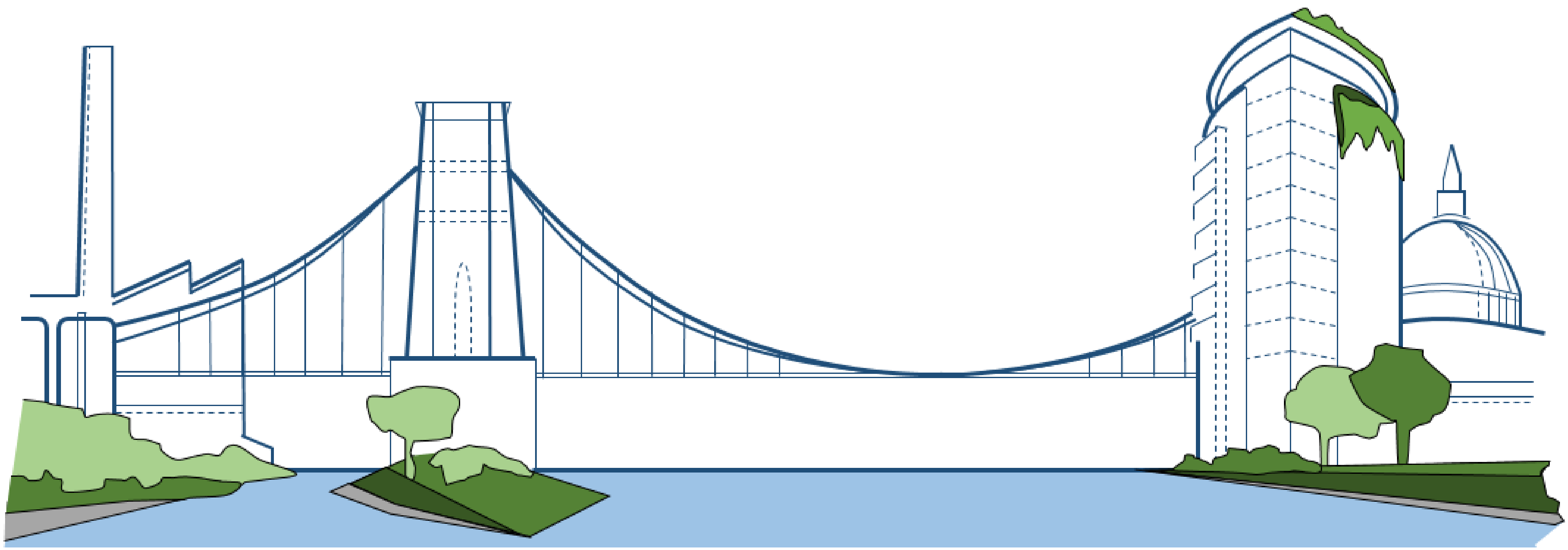
Achieving Urban Flood Resilience in an Uncertain Future



Aim

Make *urban flood resilience* achievable nationally, by making transformative change possible through adoption of the whole systems approach to urban flood and water management

Urban Flood Resilience

A city’s capacity to maintain future flood risk at acceptable levels by:

1. preventing deaths and injuries,
2. minimising damage and disruption during floods,
3. recovering quickly afterwards,
4. ensuring social equity,
5. protecting the city’s cultural identity and economic vitality

Urban Flood Resilience Research Themes

- **Engineering Design** of the integrated Blue/Green and Grey (**B/G+G)** treatment trains that support resilient management of both water quantity and quality

- **Planning** that puts UFRM at the heart of urban planning & focuses on interfaces between planners, developers, engineers and *beneficiary communities*

- **Development** of flood and water management assets that function inter-operably with other urban systems: inc. transport, energy, land-use and natural systems

Urban Flood Resilience Research Questions

1. How can we adapt flood and water quality treatment infrastructure to meet the challenges posed by changes in climate, governance, economic development and environmental values that are unavoidable, but uncertain?
2. How can flood models, infrastructure data and community exposure/vulnerability information be combined to support local, regional and national assessment of the potential for integrated B/G+G infrastructure to meet these challenges?
3. How can engineered flood and water systems be aligned with natural processes to:

(a) realise the resource potential of all forms of urban water
(b) become inter-operable with other urban systems?

Urban Flood Resilience Research Questions

4. How can engineering, scientific and local knowledges be co-produced and applied to design adaptive flood and water infrastructure that provides safe, healthy and attractive Blue-Green urban spaces that are intensively used and highly valued by citizens and communities?

5. How must interactions between responsible Authorities and Stakeholders (e.g. planners, developers, engineers and scientists) evolve to enable cities to achieve flood resilience and water security that is sustainable, reliable and enduring (i.e. future proof)?

Consortium Objectives - 1

1. Develop urban flood and water management system designs with the adaptive capacity essential to keep flood risk at acceptable levels however climate changes.

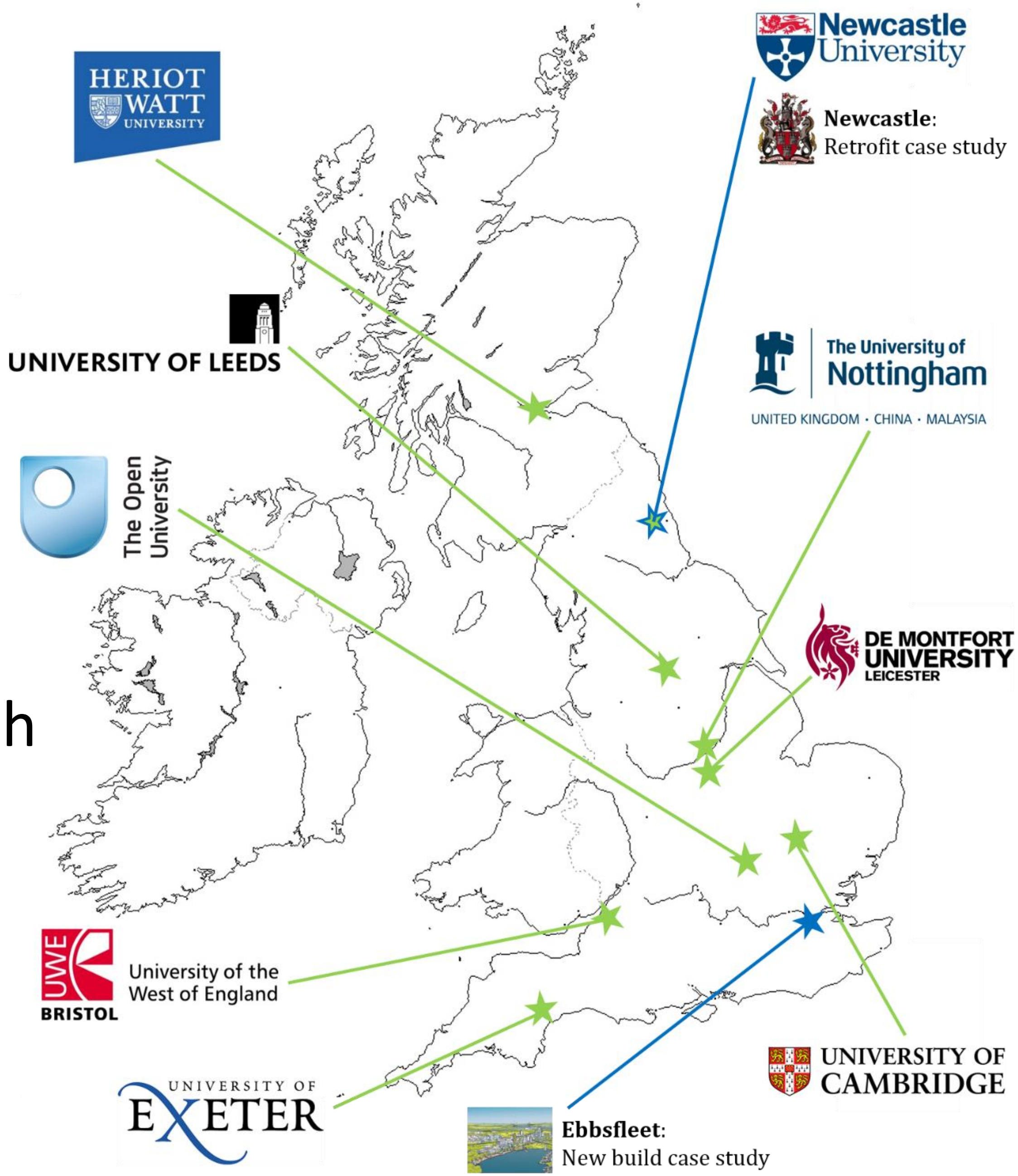
2. Produce a GIS-based tool to support comparative evaluation of the costs and benefits of alternative UFRM solutions and the potential for integrated B/G+G systems to deliver affordable urban flood resilience at the city, regional and national scales.

3. Design stormwater treatment trains capable of enhancing service provision, improving asset performance and delivering ecosystem services through integrated management of water quantity and quality that treats stormwater as both a hazard and an asset .

Objectives - 2

4. Enhance inter-operability of UFRM assets with other systems (e.g. transport, energy, land-use) to expand the capacity of integrated systems of B/G+G infrastructure to contribute to wider urban resilience to climate change.
5. Make the objectives of multi-objective planning policies deliverable in practice by bringing together engineers, stakeholders and Local Authorities in partnership working.
6. Create connectivity in urban flood and water planning and management to support multiple functions while balancing trade-offs and facilitating positive interactions between: engineered assets; advances in water technology; natural processes in restored streams and drainage systems; and the preferences and behaviours of the citizens and communities that benefit from systems of B/G+G infrastructure.

UK Urban Flood Resilience Research Consortium



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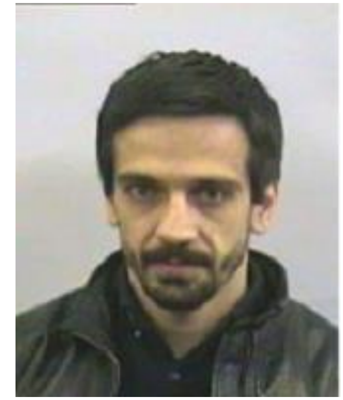

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Project Scope, Methods and Models

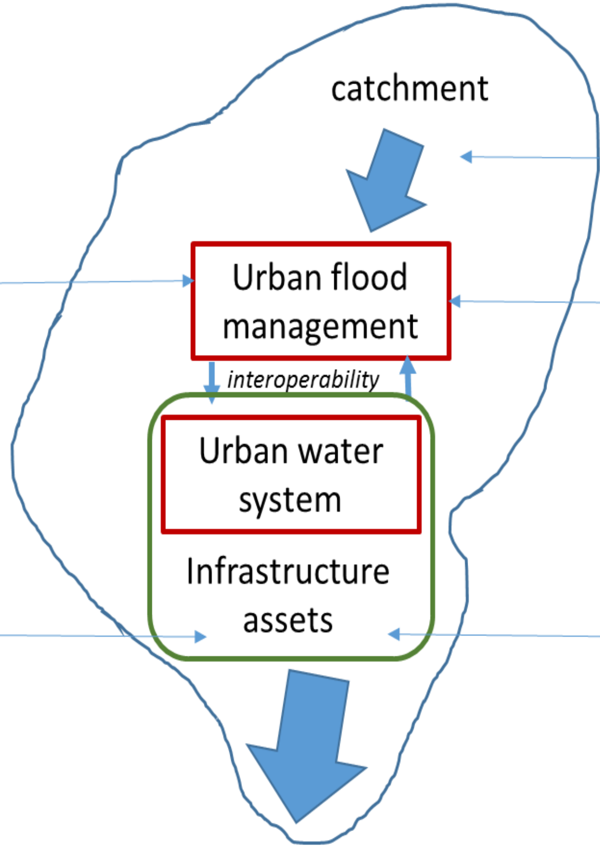
Stakeholder actions and system evaluations:

Participatory Action Research and **Social Practice Theory** to examine relationships between researchers, UFRM practitioners and communities, based on **Local Action Alliances** in locations such as Newcastle and Ebbsfleet. *This will explore tacit knowledge, behaviours and citizen's attitudes with respect to diverse flood mitigation measures and link the desirability of specific asset interventions with wider urban planning.*

Real Options analysis will find the most synergistic mix of B-G and G assets, with new objective functions for option isolation based around maximising multiple benefits and service delivery. *This will apply methods for evaluating the benefits of SUDS-GI developed in the Blue Green Cities project. Optimisation will include Totex (including maintenance liabilities) and monetised benefits (generated using CIRIA's BeST tool).*

System interdependencies will examine interactions with other components of urban fabric including open spaces, highways and buildings. *This will evaluate systemic resilience and the uncertainties arising from climate and socio economic futures to be accounted for in infrastructure planning and decision making.*

GIS visualisation of the flood mitigation performance of potential of Blue-Green & Grey assets and their multifunctional benefits. *This will consolidate the model outputs for use locally to guide development and be up-scaled regionally/nationally to inform policy, and form the basis for a National Assessment of flood resilience.*



Stormwater Hazard + Resource potentials

Urban flood risk
Non-potable use
Irrigation of Blue Green infrastructure
Groundwater and soil moisture recharge
Micro-hydropower
Maintaining urban green spaces and ecosystem services

Physical Models:

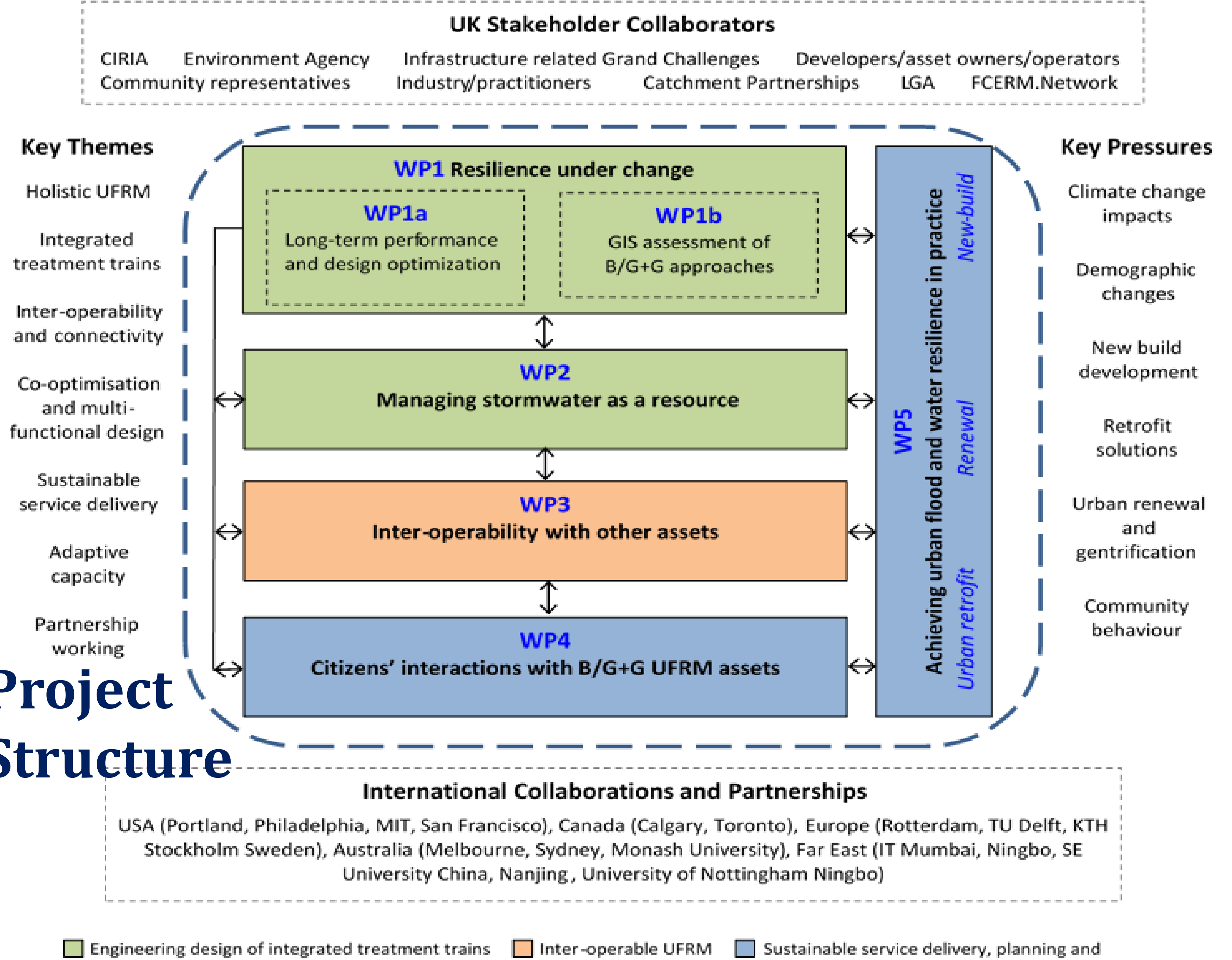
SHETRAN handles water, flow multi-fraction sediment transport and multiple, reactive solute transport within a river basin model. *This will couple catchment hydrology and sediment/contaminant inputs to urban systems (simulated using CityCAT and WaterMet2).*

CityCAT models urban flooding to assess pluvial and fluvial flood risk and flood alleviation measures with simulations driven by rainfall, flow and/or water depth time series. Maps of water depths and velocities at different times are combined to animate the flood propagation. *This central tool will simulate how stormwater cascades through urban systems, show where capture and re-use is possible and where its resource potential is constrained.*

WaterMet2 is an urban water system performance model providing flows/fluxes in 4 subsystems: water supply, sub-catchment, wastewater and water resource recovery. *This will be coupled with CityCAT to explore the interconnections between all forms of urban water.*

Eco-hydrological modelling links plant physiology within SuDS to water availability, using a water balance model linking the total water in the rooting zone with rates of rainfall, interception, runoff, evapotranspiration and leakage (in mm/d). *This will apply time series data from CityCAT and WaterMet2 to determine the resilience of vegetation in Blue-Green infrastructure and SuDS systems.*

Project Structure



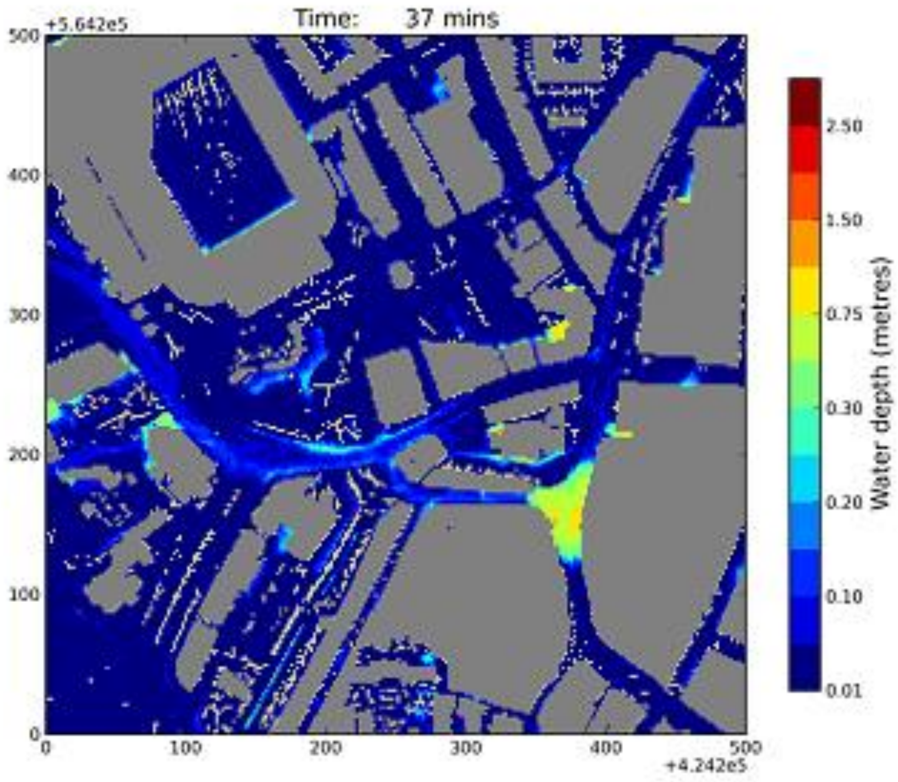
Project Time Chart

Activity/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Project Start-up Meeting (including Strategic Advisory Board)	1																																			
WP1- Resilience under change																																				
WP1a- Long-term performance and design optimization																																				
WP1b- GIS-tool for national assessment of B/G+G approaches																																				
WP2- Managing stormwater as a resource																																				
WP3- Inter-operability with other assets and systems																																				
WP4- Citizens interactions with B/G+G UFRM assests																																				
WP5- Achieving urban flood and water resilience in practice																																				
Quaterly Progress Meetings			1			2			3			4			5			6			7			8			9			10			11			12
Strategic Advisory Board Meetings						1						2						3						4						5						6
Dissemination Activities																																				

WP1a. Long-term performance and design optimization

Aim: Optimise B/G+G and SuDS system performance under Flood Foresight-style future scenarios for climate change and socio-economic development

- Replace ‘design flood’ with ‘whole systems approach’ that coordinates management of the ‘stormwater cascade’
- Quantify performance of B/G+G systems in terms of flows, debris, sediments and pollutants
- Optimise design solutions for future flood resilience using ‘Real Options’ approach to build the maximum adaptive capacity



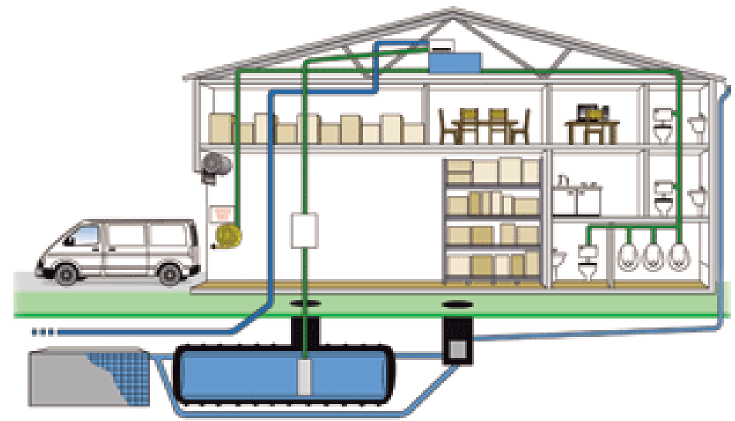
WP1b. GIS assessment of B/G+G approaches

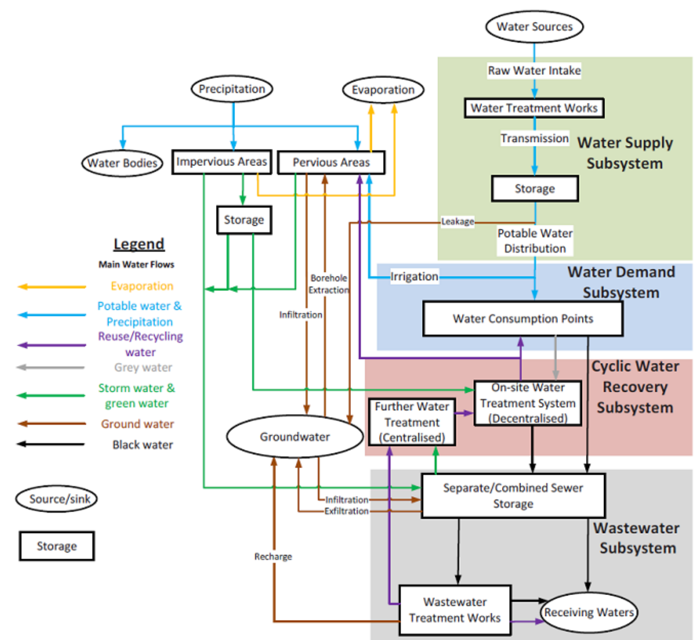
Aim: build a GIS-toolbox to evaluate the costs and multiple co-benefits of sustainable UFRM and urban water management solutions

- GIS-toolbox will integrate maps of flood risk reduction (costs avoided) with wider co-benefits to evaluate who benefits.
- Use Future scenarios for climate change, socio-economic development and damage & disruption reductions to establish benefits of improving inter-operability between flood, water and other urban systems.

WP2. Managing stormwater as a resource

- Probabilistic rainwater harvesting under climate change
- Use the Urban Water Metabolism model (WaterMet2) to calculate the B/G+G & SuDS stormwater development balance and long-term resource potential
- Simulate surface, piped and soil water systems to assess surface hydrology and flood risk
- Assess how stormwater retention supports growth of diverse vegetation within streams, green spaces & corridors
- Investigate cumulative effects of B/G+G and SuDS treatment trains on stream channel forms, processes and stability (SHETRAN)





WP3. Inter-operability with other assets

Aims: investigate the potential for employing inter-operable B-G/G infrastructure design solutions to increase flood resilience across urban infrastructure systems

- Identify and evaluate propagation of flood impacts across multiple infrastructure sectors (e.g. water, transport, land-use and energy)

- Identify specific interdependencies and develop flood impact profiles for case study cities
- Use ‘Systems of Provision’ approach to evaluate system-wide resilience of multiple, inter-operable B/G+G infrastructure design solutions

- Develop methodology to integrate and evaluate water and UFRM decision-making as part of wider decision-making on urban infrastructure

WP4. Citizen’s interactions with B/G+G infrastructure

Aim: investigate transformative changes needed to achieve urban flood resilience in an uncertain future

- Develop new mechanisms for engaging communities, improving flood awareness and communicating B/G+G benefits
- Demonstrate how citizens’ priorities and lifestyles, affect their understanding of/support for B/G+G
- Participatory Action Research to support deep exchange of knowledge/beliefs
- Use on-line communications to study changing attitudes, perceptions and opinions, and potentially shift citizens’ & professionals’ attitudes and behaviours with respect to B/G+G

WP5. Achieving urban flood and water resilience in practice

Aim: inform and apply research in WPs 1-4 to establish how resilient UFRM service delivery can be put at the heart of urban planning and how barriers to innovation can be overcome

- Learning and Action Alliances in case study cities
- Investigation of barriers to innovation through interviews and participatory observation in meetings of planning authorities
- Participatory Knowledge Mapping and Cognitive Modelling to identify information needs for enhanced decision making as a focus for innovative data analytics, meta-learning and data mining

Case Study Cities

Newcastle

Retrofit, urban renewal and urban growth

Ebbsfleet

New build in a 'Garden City'

Deliverables

Engineering design to enhance service delivery

- **Next generation flood and water management models** that bridge the interfaces between urban/rural and engineered/natural hydrological systems: simulating urban floods, droughts and water cycles within their catchment and metropolitan contexts to deliver acceptable service provision 365 days a year (WP1a)

- **Steps necessary to design, implement and operate B/G+G stormwater treatment trains** through development of adaptation designs and pathways appropriate to their location, community and scale (WP1a)

- **GIS toolbox for a National Assessment** identifying appropriate location specific B/G+G combinations, considering catchment and urban water resources and their variability, flood risk, sewer condition and capacity, and stormwater resource potential under present and future climates(WP1b)

Engineering Development for resource use across drought – flood spectrum

- **Enhanced design methods** that co-optimise management of urban runoff both to mitigate flood hazards and capture the benefits of treating stormwater as a valuable, though under-utilised, resource leading to practical solutions for stormwater recovery, recycling and reuse. (WP2)

- **Improved integration of UFRM and water, energy and transport infrastructure** and expanded inter-operability of urban systems-of-systems. (WP3)

UFRM at the heart of urban planning, at multiple scales

- **Characterisation of citizen's behaviours and decision making** concerning flooding and urban water use, and means of informing those decisions through improved appreciation of flood risk and water literacy (WP4)

- **New protocols for placing flood and water management decision making at the heart of urban planning** as recommended by Pitt (2008) and legislated for in the 2010 Flood and Water Management Act (WP5)

- **Case studies** demonstrating Blue-Green approaches to flood and water management that are innovative, inclusive, resilient and suitable for retrofit, urban renewal, new build/new town applications (WP5)

Research Impact

- This project has the potential to enable a step change in protecting UK cities and the national economy against risks due to increased storminess caused by climate change, without constraining urban renewal and development.
- It can do so by envisioning and making deliverable a different water future: one based on resilient cities where flood and water management is planned, developed, designed and operated in ways that are truly sustainable.

Research Impact

Knowledge, insights and understanding of urban flood resilience will be useful to:

- organisations and practitioners responsible for urban flood risk management,
- people living and working in cities throughout the UK and beyond, including
  - City councillors,
  - Voters who elect them,
  - Council Tax payers who fund urban flood risk management,
  - Citizens and Communities at risk of urban flooding.

Social Impacts

Civic society and governance

- Enhanced planning policy
- Sustainable urban growth and development
- Improved public health and well-being
- Wider stakeholder engagement in city
- Planning and governance

Citizens and communities

- Urban renewal
- Reduced flood anxiety
- Neighbourhood uplift
- Higher flood and water literacy
- Flood and water citizenship
- Enriched quality of life

Economic and Environmental Impacts

Urban economies

- Reduced flood losses and business disruption
- Multiple BGI benefits between floods Increased water security
- More productive workforce
- Competitive edge over rival cities that are not flood resilient

Urban environments

- More urban green spaces and corridors
- Managed flooding during extreme events that exceed capacity of drainage systems
- Improved water, soil and air quality
- Reduced urban heat island effects
- Higher resilience to drought