Understanding and overcoming uncertainties and barriers to wide adoption of blue-green infrastructure for urban flood risk management

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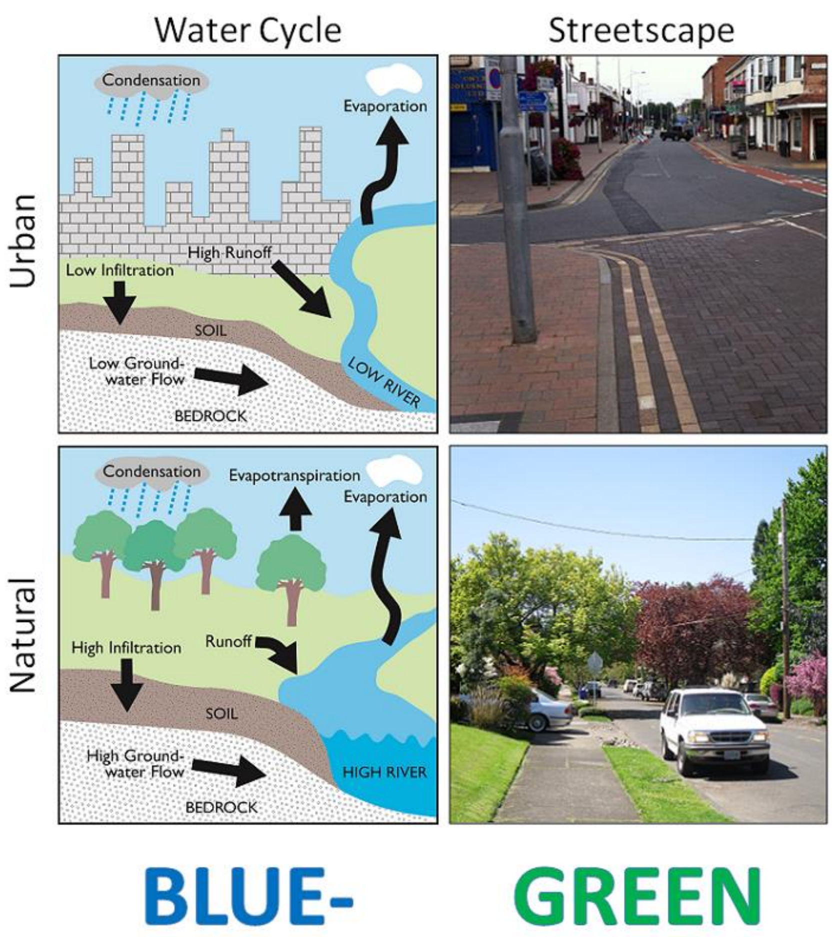
Blue-Green Infrastructure, Best Management Practices (BMPs) and Sustainable Drainage Systems (SuDS) are increasingly recognised as vital components of urban flood risk management systems. However, scientific uncertainty regarding their hydrologic performance and lack of confidence concerning their public and political acceptability create concerns and challenges that limit widespread adoption. We explore the biophysical and socio-political uncertainties that can act as barriers to the implementation of Blue-Green infrastructure in Portland, Oregon USA, and suggest how these may be addressed and overcome. We find that socio-political uncertainties are often the greatest barrier to Blue-Green decision making.

1. What is Blue-Green infrastructure?

Blue-Green infrastructure 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. Key functions include restoring natural drainage channels, mimicking pre-development hydrology and improving water quality, reducing imperviousness, and increasing infiltration, surface storage and the use of water retentive plants. The Blue-Green approach is more than a stormwater management strategy aimed at improving water quality and providing flood risk benefits. It can **also provide important ecosystem services**, **socio-cultural benefits** and adaptability to future (uncertain) changes in climate and landuse.



Comparison of the hydrologic (water cycle) and environmental (streetscape) attributes in conventional (upper) and Blue-Green Cities

2. Barriers to Blue-Green infrastructure

Implementation of Blue-Green strategies for urban flood risk management are currently limited due to scientific uncertainties in hydrological and biophysical processes that impact on service delivery, maintenance requirements and asset performance. **These uncertainties are generally perceived to be greater for Blue-Green compared to the equivalent grey infrastructure.** Decision makers and planners also question the appetites of beneficiary communities and their elected representatives for increasing a city or neighbourhoods' reliance on Blue-Green infrastructure, and there is often little confidence that all stakeholders will value, understand, and be willing to pay for the additional benefits (to society, the environment and the economy) of using Blue-Green in combination with grey infrastructure.

3. Methods: classifying uncertainties

We used the outcomes of **twelve semi-structured interviews** to identify key concerns and challenges faced by a range of **institutional stakeholders** working in different governmental departments and bureaus in the City of Portland.

We classified the uncertainties, determined if they were reducible or irreducible and then ranked them (based on frequency of mention).

Biophysical uncertainties = uncertainty in the physical processes that affect infrastructure performance and service provision, such as modelling asset performance and maintenance requirements, natural hazards and downscaling climate projections for model scenarios.

Socio-political uncertainties = associated with forecasting future social conditions, public preferences, funding schemes and governance around Blue-Green, and challenges related to the lack of confidence that beneficiary communities recognise, value, and are willing to pay for the additional benefits of using Blue-Green infrastructure.

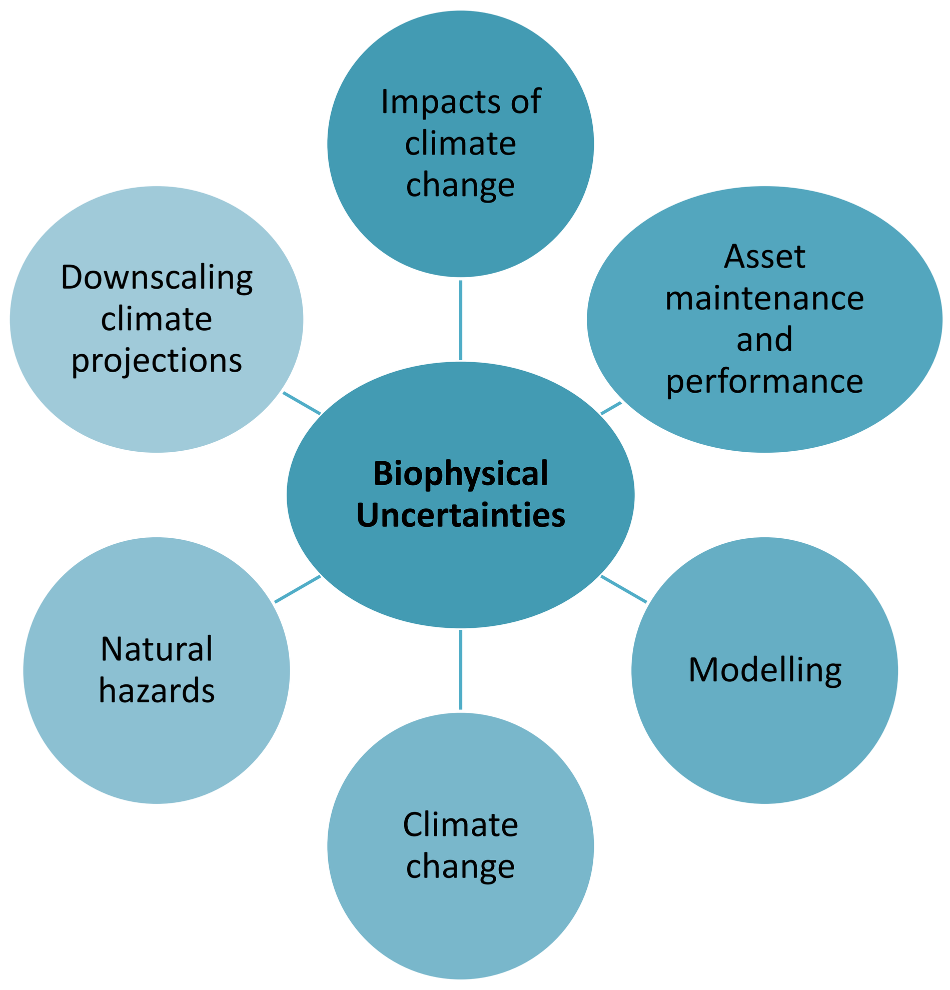
4. Case Study: Portland, Oregon USA

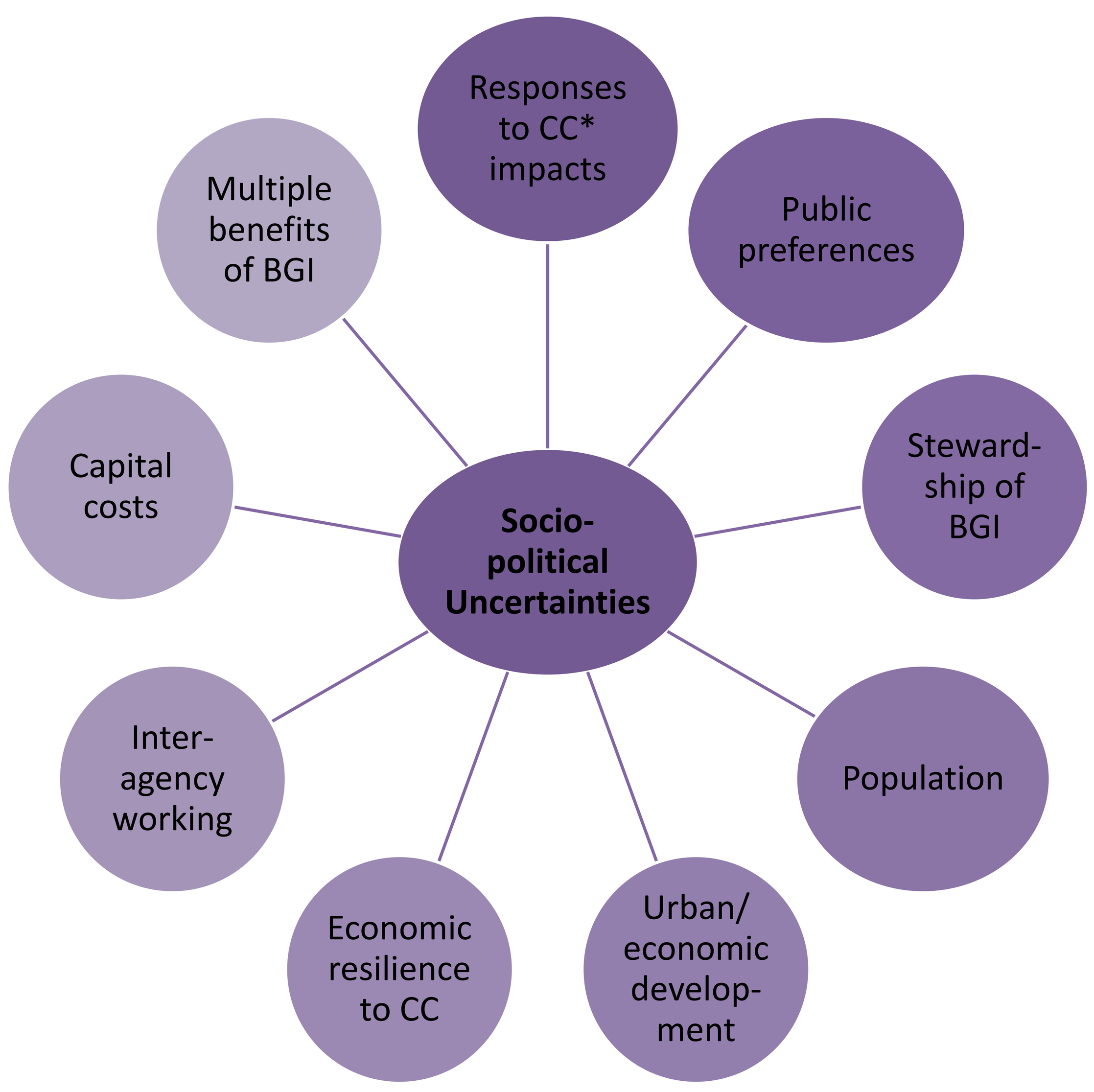
Blue-Green infrastructure has long featured in urban water management in Portland and expanded during the 1990s to help reduce the frequency of Combined Sewer Overflows (CSOs) into the Willamette River. In addition to a major investment ($1.2 billion) in grey infrastructure, **the City also invested in green infrastructure projects to manage the stormwater** (quantity and water quality) and provide a range of biophysical, ecological and social benefits. For instance, the **'Grey to Green' initiative** ($55 million) which ran from 2008-2013, successfully planted street trees, and constructed green street planters and eco-roofs throughout the city. The initiative also included culvert removal and land acquisition for creation of green assets, reintroduced natural vegetation and restored sections of the river and floodplain. Similarly, downspout disconnections aimed to reduce the amount of surface water going into the combined sewer system and 26,000 downspouts have been disconnected since the project began in 1993.

5. Biophysical and socio-political uncertainties

We identified 15 uncertainties: 6 biophysical and 9 socio-political.

The socio-political uncertainties, notably public preferences, stewardship and equitable delivery of Blue-Green infrastructure assets, appear to **have a greater impact on decision making in Portland than their hydrological and biophysical counterparts**.





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

Blue-Green infrastructure in Portland. Rain gardens (bioswales) and downspout disconnections

6. Overcoming uncertainties

The identification and management of both biophysical and socio-political uncertainties are thus essential to broadening implementation of the Blue-Green infrastructure necessary to deliver sustainable urban flood risk management solutions that are practical, resilient, scientifically sound, and supported by local stakeholders.

A key different between socio-political and biophysical uncertainties is that ***people can influence social-political uncertainties***, especially at the local level. Through interventions such as education, open discussion and social learning opportunities, people can change the dominant understandings that create the culture of the future. Informing residents of the benefits of Blue-Green infrastructure can make them more inclined to support Blue-Green projects and take ownership of local initiatives.

Community involvement in a Portland rain garden creation (image source: Oregon Department of Environmental Quality 2010)

7. Portland's decision making under uncertainty

Portland has successfully championed a series of Blue-Green city-wide strategies that demonstrate decision making in spite of the hydrological/biophysical and socio-political uncertainties. For instance, over 32,200 new street trees, 867 green street planters and 398 ecoroofs have been built as part of the 'Grey to Green' initiative. Portland's Bureau of Environmental Services continues to champion Blue-Green schemes and reduce physical science uncertainties by further monitoring and detailed modelling of infrastructure assets, and addresses socio-political uncertainties by greater community engagement and outreach.

For further information see: Thorne 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.

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