Blue and Green Cities

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The Role of Blue-Green Infrastructure in Managing Urban Water Resources

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List of Acronyms

ABC Waters	Active, Beautiful, Clean Waters
BCA	Building and Construction Authority
BGI	Blue-Green Infrastructure
CAP	Climate Adaptation Plan
CCRA	Climate Change Risk Assessment
CMP	Cloudburst Management Plan
COP	Code of Practice
CPI	City Parks Initiative
CRIAC	Clean Rivers Impervious Area Charge
CSIA	Combined Sewer Impervious Area
CSOs	Combined Sewer Overflows
DC Water	District of Columbia Water and Sewer Authority
DCP	Department of City Planning
DEC	Department of Environmental Conservation
DEP	Department of Environmental Protection
DOB	Department of Buildings
DOEE	Department of Energy and Environment
DOT	Department of Transportation
DPR	Department of Parks and Recreation
EAD	Expected Annual Damage
EDC	Economic Development Corporation
EPA	Environmental Protection Agency
ERU	Equivalent Residential Unit
GARP	Greened Acre Retrofit Program
GIS	Geographic Information Systems
GRTA	Green Roof Tax Abatement

GSDM	Green Streets Design Manual
GSI	Green Stormwater Infrastructure
HDB	Housing Development Board
IES	Institution of Engineers, Singapore
LEED	Leadership in Energy and Environmental Design
LTA	Land Transport Authority
LTCPs	Long Term Control Plans
MoU	Memorandum of Understanding
MS4	Municipal Separate Stormwater Sewer System
MTA	Metropolitan Transportation Authority
MWRD	Metropolitan Water Reclamation District of Greater Chicago
NParks	National Parks Board
NPDES	National Pollutant Discharge Elimination System
NUS	National University of Singapore
NYCHA	NYC Housing Authority
OGI	Office of Green Infrastructure
PEG	Prefabricated Extensive Greening
PPR	Philadelphia Parks and Recreation
PUB	Public Utilities Board
PWD	Philadelphia Water Department
RFI	Request for Information
RISA	Rain InfraStructure Adaptation
ROW	Rights of Way
SBI	Sites of Biological Importance
SCBA	Societal Cost Benefit Analysis
SDOT	Seattle Department of Transportation
SIA	Singapore Institute of Architects
SILA	Singapore Institute of Landscape Architects
SMIP	Stormwater Management Incentives Program
SPARC	Seattle Parks and Recreation
SPDs	Stormwater Planning Districts
SPU	Seattle Public Utilities
SRC	Stormwater Retention Credit
SWB	Sewerage and Water Board of New Orleans
TARP	Tunnel and Reservoir Plan
TPL	Trust for Public Land
UHI	Urban Heat Island
URA	Urban Risk Assessment
VA	Vulnerability Assessment
WEF	Water Environment Federation
WHG	Workforce Housing Group

WSUD	Water Sensitive Urban Design
WTD	Wastewater Treatment Division
WWTPs	Wastewater Treatment Plants

Imperial to Metric Conversion Table

For use with chapters 5, 6 and 9: conversions are rounded up to two decimal places

1 gallon = 4.55 litres
1 mile = 1.61 kilometres
1 acre = 0.40 hectare
1 foot = 0.30 metre
1 square foot = 0.09 square metre
1 cubic foot = 0.03 cubic metre
1 pound = 0.45 kilogram

INTRODUCTION

Cities are home to half the world's population and serve as global economic hubs, generating almost 80 percent of the world's GDP. With cities facing extreme weather events and rapid urban growth leading to the overuse of natural resources and creating environmental degradation, urban centres around the world need to become more resilient to climate change and reduce their ecological footprints.

Green Cities are concerned with how to design the whole city in a more sustainable, efficient, adaptive and resilient way. Green Cities recognise connections between different sectors and support development strategies that fulfil multiple functions and create multiple benefits for society and urban ecosystems. In the context of urban water resource management, a Blue-Green City calls for the holistic planning and management of water, wastewater and stormwater across the whole city to ensure that populations are resilient to climate change and extreme weather events while ensuring the health of aquatic ecosystems.

Traditionally, urban water managers have relied on grey infrastructural solutions, including dams and levees, to mitigate risks – with numerous environmental and economic consequences. For instance, traditional stormwater drainage systems, designed to prevent localised flooding, have created downstream flooding risks as well as stormwater overflows into waterways. At the same time, traditional systems have impacted the local hydrological cycle with less groundwater recharge and lower baseflows of waterways, impacting availability of water for humans and nature. In addition, traditional systems are inadequate to deal with climate change-related extreme weather events, with systems unable to cope with sudden

large volumes of precipitation. Traditional systems also impact water quality, with runoff washing pollutants into nearby waterways. Furthermore, runoff causes turbidity as well as thermal pollution which can impact drinking water quality. In addition to climate change impacting water quality and quantity, urbanisation is resulting in environmental degradation. Finally, cities are facing regulatory challenges in simultaneously managing floods while also restoring the health of waterways.

In a Blue-Green City, Blue-Green Infrastructure (BGI) involves the use of natural or man-made systems to enhance ecosystem services in the management of water resources and increase resilience to climate risks. BGI solutions can also be used to support the goals of multiple policy areas. For example, green spaces and restored lakes and wetlands can reduce flooding risks to neighbourhoods while simultaneously supporting urban agricultural production and wildlife, in addition to providing recreational and tourism benefits. In Blue-Green Cities, urban water managers also use a variety of innovative fiscal and non-fiscal tools to encourage the implementation of BGI on public and private property to sustainably manage water resources and increase resilience to climate risks.

Nonetheless, our understanding of the role urban water managers have in implementing BGI to mitigate climate risks while reducing environmental degradation lags significantly behind engineering knowledge on water resource management. As such, little has been written on the actual implementation of policy innovations at the urban level that promote the application of BGI projects that not only reduce climate risk but also restore ecosystems and the numerous services they provide. In addition, because the application of BGI requires holistic planning, little has been written on how innovative policies have been developed to ensure BGI water projects fulfil multiple functions and policy goals and create multiple benefits for society and urban ecosystems.

This book provides new research on urban policy innovations that promote the application of BGI in managing water resources sustainably. In particular, the book contains case studies that illustrate how cities, of differing climates, lifestyles and income levels, have implemented policy innovations that promote the application of BGI in managing water, wastewater and stormwater sustainably to enhance resilience to climate change and reduce environmental degradation. The six case studies review leading cities that have implemented a variety of fiscal and non-fiscal policy tools to encourage the implementation of BGI on both public and private property to reduce stormwater runoff volumes, enhance the health of

waterways, enhance resilience to climate change and meet regulatory requirements. Data for each case study have been collected from interviews conducted with, and primary materials provided by each city's respective department or utility in charge of implementing BGI. The six cities are Copenhagen, New York City, Philadelphia, Rotterdam, Singapore and Washington D.C., each of which are considered leaders in terms of their approach to sustainability, environmental and water resource management according to various sustainability indexes. The latter include Arcadis' Sustainability Index, which ranks cities on three pillars of sustainability: people, planet and profit, as well as the Siemens Green City Index, a research project conducted by the Economist Intelligence Unit and sponsored by Siemens. Copenhagen has been selected because it is a pioneer in showing that adaptation, in addition to managing excess stormwater, also provides significant social, environmental and economic benefits to the city. Meanwhile New York City is leading the way in combining BGI with traditional grey infrastructure to reduce combined sewer overflows. Philadelphia is implementing BGI to meet regulatory requirements and while doing so is ensuring that it creates a legacy for future generations to enjoy. Rotterdam is implementing a variety of BGI measures to help it become climateproof. Singapore, facing space constraints in developing grey infrastructure, is integrating green and blue spaces while mitigating the impacts of climate change. Finally, Washington is implementing BGI to improve the health of the city's waterways while reducing stormwater volumes that are predicted to increase with climate change. The book also contains a series of mini case studies of various cities around the world in the planning or implementation stage of initiating BGI to meet various challenges to their traditional grey infrastructure.

The book will introduce readers to the adaptive management framework that guides cities in their implementation of BGI in order to increase resilience to climate change and reduce environmental degradation. In the context of climate change, adaptive management is a process where decision-makers take action in the face of uncertainty. It is through this process of quantifying and acknowledging uncertainty that a society can decide how best to manage climate risk. Adaptive management also seeks to improve scientific knowledge and develop management practices that consider a range of future possibilities and even take advantage of unanticipated climatic events. In the context of natural resource management, adaptive management is the process of hypothesising how ecosystems

work and modifying management decisions to achieve environmental objectives through improved understanding. Adaptive management can be used to restore or enhance ecosystems damaged by the impacts of urbanisation as the framework recognises that resource systems are only partially understood and that there is value in tracking responses of natural resources to management decisions. In Blue-Green Cities, adaptive management relies on monitoring, investigating and researching to build knowledge on waterways and understand the outcomes of management decisions on the environment and the effects of climate change.

In the operationalisation of BGI, the adaptive management decision-making framework involves the planning, designing, implementing and monitoring of BGI to achieve the multiple benefits it provides. Blue-Green Cities use a variety of fiscal tools to encourage the implementation of BGI practices on both public and private property, including new and existing developments. Fiscal tools are easy to implement and provide decision-makers with the flexibility and creativity to meet specific priorities as well as provide the opportunity to pilot new incentives before citywide application. Meanwhile, non-fiscal tools encourage the implementation of BGI on both public and private property and allow policy-makers to test and refine BGI programmes that could one day become mandatory requirements.

The book's chapter synopsis is as follows:

Chapter 1 provides an introduction to traditional grey infrastructure stormwater systems; this is followed by a review of the impacts of traditional grey infrastructure on water quantity and water quality before discussing the challenges posed by climate change, rapid urbanisation and meeting regulatory requirements. The chapter then introduces readers to BGI and its multiple benefits before finally discussing the barriers to its implementation.

Chapter 2 discusses two types of BGI: natural and man-made water features, both of which provide numerous multifunctional benefits in addition to managing water quantity and quality.

Chapter 3 defines urban resilience and reviews the measures that can be taken to increase it. It then introduces the concept of adaptive management and how BGI can be operationalised using an adaptive management framework. Finally, the chapter discusses how cities can use a variety of fiscal and non-fiscal tools to encourage the development of BGI.

Chapters 4–9 comprise case studies on the implementation of BGI, as part of the process of becoming a Blue-Green City, in the following cities: Copenhagen (Chapter 4), New York City (Chapter 5), Philadelphia (Chapter 6), Rotterdam (Chapter 7), Singapore (Chapter 8) and Washington (Chapter 9).

Chapter 10 includes a series of mini case studies of other cities in the implementation stage of initiating BGI to become Blue-Green Cities.

Chapter 11 includes a summary of best practices from the selected case studies for other cities planning to implement BGI in an attempt to become Blue-Green Cities.