UNEP

GREEN INFRASTRUCTURE

GUIDE FOR WATER MANAGEMENT

Ecosystem-based management approaches for water-related infrastructure projects

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Principal authors:
UNEP-DHI Partnership: Maija Bertule, Gareth James Lloyd and Louise Korsgaard
IUCN: James Dalton, Rebecca Welling, Stefano Barchiesi and Mark Smith
TNC: Jeff Opperman
WRI: Erin Gray and Todd Gartner (Chapter 4*)
Green Community Ventures: James Mulligan (Chapter 4*)
U.S. Army Corps of Engineers: Dr Richard Cole (Subchapter 3.11 and 3.12)
**The views in this chapter represent the personal views of the authors and do not necessarily represent the views of the author's employer.*

Contributors and reviewers:
The authors of the guide would like to thank the following for their valuable contributions: Thomas Chiramba (UNEP DEPI), Nicolas Bertrand (UNEP TEEB), Aruwa Bendsen (UNEP DEPI), Niels Riegels (DHI), Peter Koefoed Bjørnsen (UNEP-DHI), David Coates (CBD), Llorenç Mila J Canals (UNEP International Resource Panel) and Maite Aldaya (UNEP DTIE).

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BCA	Benefit-cost analysis
CBD	Convention on Biological Diversity
CEA	Cost-effectiveness analysis
EPA	U.S. Environmental Protection Agency
GGA	Green-Grey Analysis
IUCN	International Union for Conservation of Nature
NPV	Net Present Value
O&M	Operation and Management
MCA	Multi-criteria analysis
PWD	Portland Water District
TNC	The Nature Conservancy
UNEP	United Nations Environment Programme
USD	U.S. Dollars
WRI	World Resources Institute
WWF	World Wide Fund for Nature/World Wildlife Fund

EXECUTIVE SUMMARY

Green Infrastructure (GI)[1] is becoming increasingly recognized as an important opportunity for addressing the complex challenges of water management. The GI approach refers to the natural or semi-natural systems that provide services for water resources management with equivalent or similar benefits to conventional (built) "grey" water infrastructure.

Typically, GI solutions involve a deliberate and conscious effort to utilize the provision of ecosystem services to provide primary water management benefits, as well as a wide range of secondary co-benefits using a more holistic approach. As a result, GI solutions can be used to support goals in multiple policy areas. For example, floodplains can reduce flood risk and simultaneously improve water quality, recharge groundwater, support fish and wildlife and provide recreational and tourism benefits. While the value and function of grey infrastructure can be expected to depreciate over time, many GI solutions can appreciate in value and function over time as soils and vegetation generate or regenerate.

Green Infrastructure solutions for water management are also at the heart of Ecosystem-based Adaptation – defined as [using] "… *biodiversity and ecosystem services*[2] *as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels*" (UNEP 2010). The capacity of GI to build resilience to climate shocks and variability has already proven to be effective in a multitude of cases around the globe – from conserving mangroves that provide shoreline protection against coastal erosion and storms, to restoring natural floodplains that recharge groundwater and reduce the risk of severe flooding.

The growing interest in GI is being driven by a combination of factors, including the need to improve water management, owing to a growing demand for and a scarcity of freshwater, and the increasing impact of climate change, including extreme events such as floods and droughts. Moreover, spatial planners, engineers and decision-makers are eager to identify and utilize cost effective, long term and environmentally appropriate infrastructure solutions.

This guide addresses one of the main barriers to widespread adoption of GI solutions: a general lack of awareness of the solutions and associated cost-benefits. The illustrative case studies in this guide provide examples of GI options that address water management challenges, while delivering a number of significant co-benefits. These include reafforestation and afforestation (abbreviated in the tables as Re/afforestation), wetland conservation and construction, levee setbacks, flood bypasses and coastal protection, as well as a number of urban oriented options such as green roofs and permeable pavements.

Table 1 provides an overview of GI solutions that are relevant for water resources management and are discussed in this guide. Solutions marked with '*' consist of built or "grey" elements that interact with natural features and seek to enhance their water-related ecosystem services. These are included in this guide to provide an overview of the wide spectrum of GI solutions for water management.

1 For the purposes of this publication, the terminology of Green Infrastructure is adopted, while it is acknowledged that the terms *ecological and natural* infrastructure are often used to describe similar approaches.

2 See more on the definition of ecosystem services on page 10.

Table 1 Green Infrastructure solutions for water resources management

Water management issue (Primary service to be provided)		Green Infrastructure solution	Location				Corresponding Grey Infrastructure solution (at the primary service level)
			Watershed	Floodplain	Urban	Coastal	
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	■				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Water harvesting*	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
Water quality regulation	Water purification	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
	Erosion control	Re/afforestation and forest conservation	■				Reinforcement of slopes
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
	Biological control	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
	Water temperature control	Re/afforestation and forest conservation	■				Dams
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (shading of water ways)			■		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	■				Dams and levees
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Establishing flood bypasses		■			
	Urban stormwater runoff	Green roofs			■		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			■		
		Water harvesting*	■	■	■		
		Permeable pavements*			■		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				■	Sea walls
		Protecting/restoring reefs (coral/oyster)				■	

The guide also includes an outline methodology for water management options assessment comprised of a number of steps relating to definition of development objectives, specification of investment portfolios, modelling of environmental outcomes and economic evaluation, cost-benefit analysis, as well as risk and uncertainty analysis.

While in some cases planners may directly compare the advantages of "green versus grey" water infrastructure solutions, this guide places greater emphasis on understanding how green solutions can be integrated within an overall system of water management, composed of appropriately sited and designed elements of both green and grey water infrastructure. The methodology, therefore, provides meaningful evaluation of water infrastructure *options* – consisting of green and grey alternatives, or mutually supportive green and grey elements.

Mainstreaming GI solutions as equally relevant water management approaches remains a challenging task, as the economic analysis of GI is relatively new with a lack of historical cost and benefit. On the other hand, there is a wealth of historical cost and benefit data for grey infrastructure. This increases the perceived risk (i.e. uncertainty) associated with GI, and such projects may have to pass a higher threshold in order to be considered. As a result of this uncertainty, GI valuation studies often employ conservative assumptions and produce wide ranges of estimated benefits. Conservative assumptions and the omission of ancillary benefits can lead to the *underestimation* of the value of a GI investment. Even with these limitations, GI can still be demonstrated to be a cost-effective infrastructure alternative in many cases. In time, efforts by economists in this area of research and the benefit of hindsight will lend additional understanding of the real returns provided by GI over time (Schmidt and Mulligan 2013). Also, greater emphasis on the quantification of environmental (and, to the extent possible, social) impacts over the life cycle of water management systems will be necessary to ensure that unintended trade-offs are not created (UNEP 2004a; 2011a; 2012).

The response to water challenges can benefit from a combination of green and grey infrastructure that involves retrofitting GI solutions to grey infrastructure systems in order to improve efficiency. Thus, this guide takes a pragmatic approach to water management and shows that GI not only provides significant water management benefits and co-benefits in a stand-alone manner, but also as a supporting element to existing grey water infrastructure. The most efficient and cost-effective approach can only be found by evaluating all available options, grey and green, based on their suitability to local hydrology, resource availability, climatic conditions and other variables, on a case-by-case basis.

1 INTRODUCTION

Green Infrastructure refers to natural or semi-natural ecosystems that provide water utility services that complement, augment or replace those provided by grey infrastructure.[3] This Green Infrastructure guide shows that viable and cost-effective alternatives to grey infrastructure in management of water resources can result from an increased effort to work with GI.