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Nature-Based Solutions for water in cities

以自然為本的城市水資源解決方案

Cristina Calheiros

02/06/2020

Project: Nature-based solutions for a cleaner and safer Macao

以自然為本的解決方案建構更乾淨更安全的澳門

Aims to investigate ways to **enhance the water quality** of the city's coastal waters **through the use of native wetland plants**, especially mangroves, as natural purifiers for water pollution.

旨在研究如何通過利用原生濕地植物，尤其紅樹林樹種，來淨化及改善沿海城市的水質。

Talk:

Integration of Nature-Based Solution (NBS) in cities towards managing water resources, offset the rising challenges from water security to population growth and climate change.

結合城市水資源管理方案與NBS，以抵消從水安全，人口增長及氣候變化等帶來的日益嚴峻的挑戰。

Raise awareness of the benefits of Green Infrastructure solutions and NBS for water resources management.

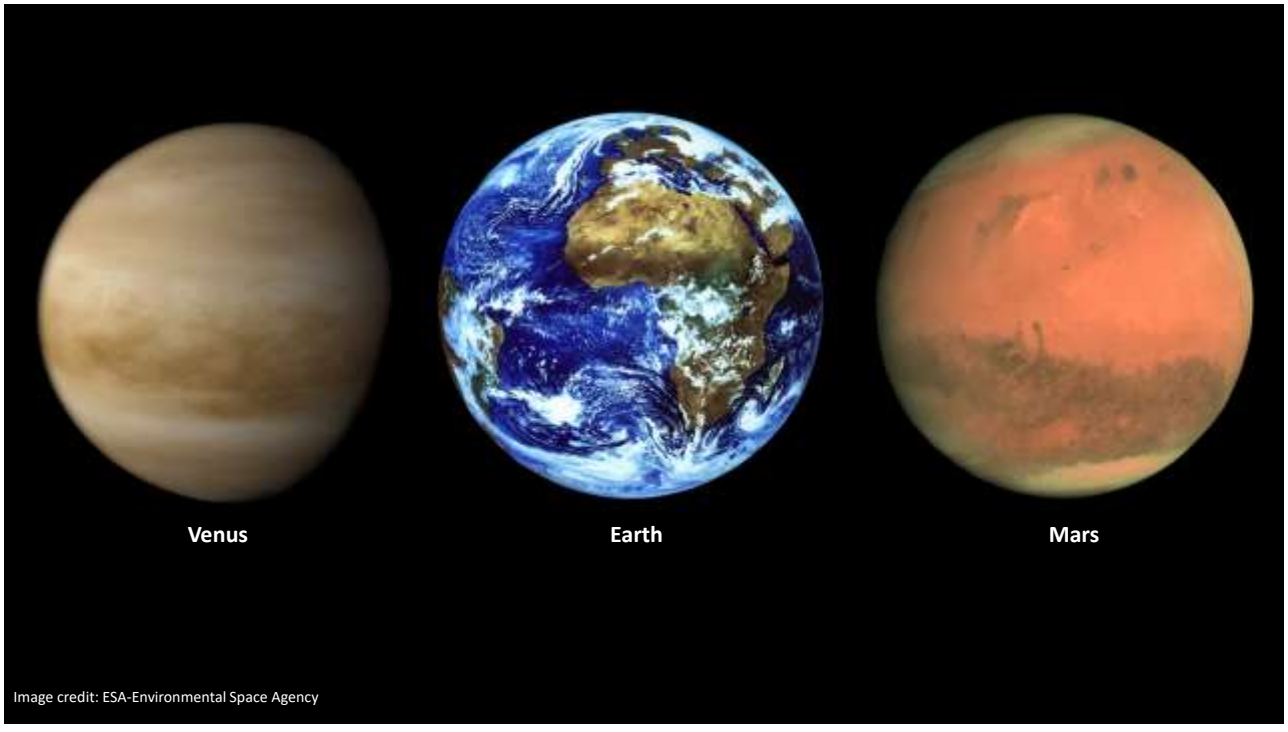
提高大眾對綠色基礎設施在水資源管理中的益處的認識。

Framework

Green Infrastructures
綠色基礎設施
and
和
Nature-Based Solutions
以自然為本的解決方案

Framework

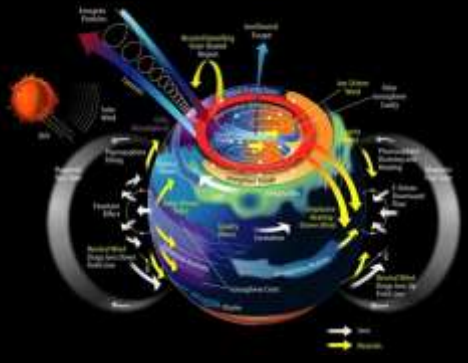

www.nasa.gov


Venus
Earth
Mars
Image credit: ESA-Environmental Space Agency

The Planet

http://blueturn.earth/

The System



J. Grebowsky/NASA GSFC

Hardware | 硬件

Tangible space, where territorial division is possible.

有形空間，可以進行地域劃分。

Software | 軟件

Functional and intangible space, with no specific territorial character.

功能性和無形空間，無特定的地域性。

Climate Change | 氣候變化

Urbanization | 城市化

↓

Resource demand | 資源需求

Impermeabilization | 水變得不能滲透

↓

Loss of green spaces | 失去綠地

IWA the international water association

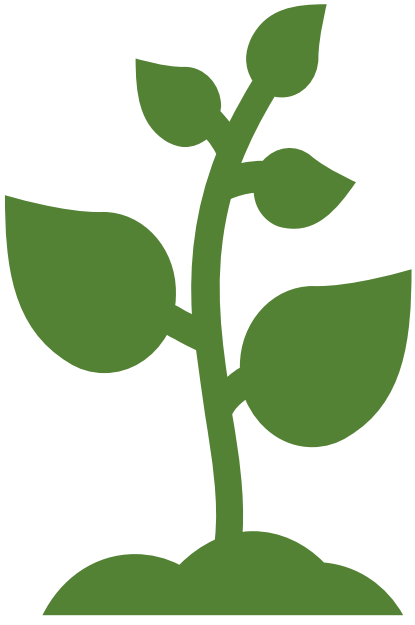
Climate change and water | 氣候變化與水

- **Water availability |** 可用水量
- **Water quality |** 水質
- **Sea level rise |** 海平面上升
- **Extreme events (floods and droughts) |** 極端事件（水災與乾災）

The United Nations General Assembly declared 2021 – 2030 the UN Decade on Ecosystem Restoration

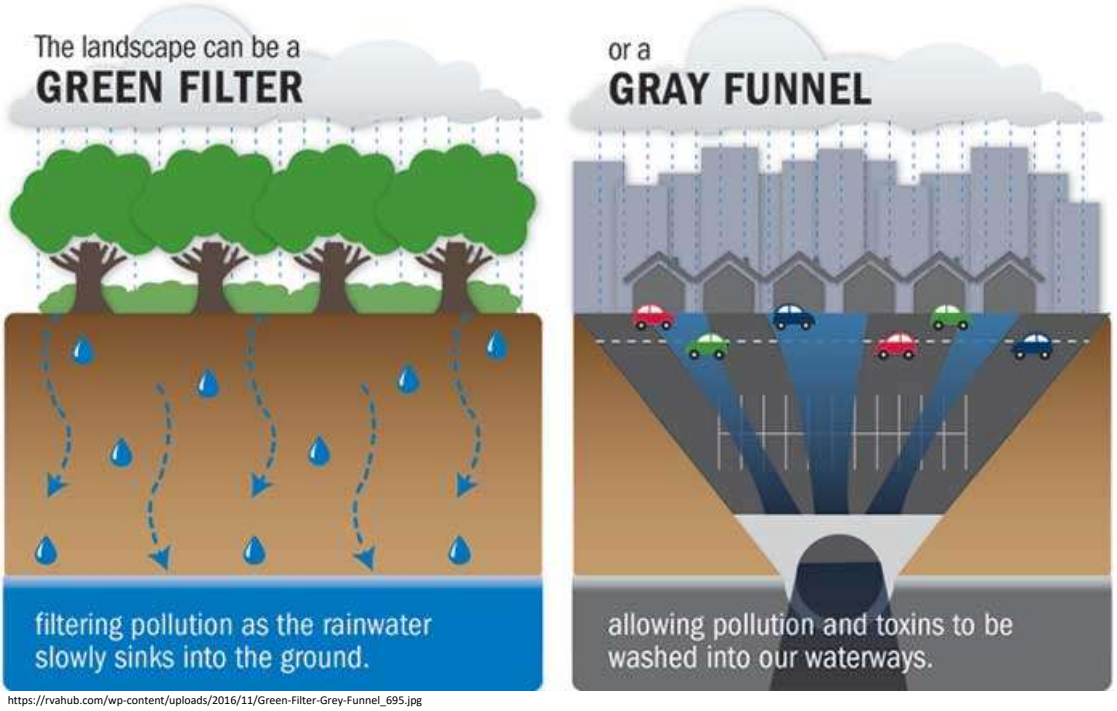
Bringing nature into the city will help to support regeneration of overexploited ecosystems, and offer the opportunity for **job creation, food security and addressing climate change**

將自然帶回城市將有助支持被過度開發的生態系統的再生，**創造就業機會，保障糧食的持續供應和應對氣候變化**



Think green...
綠色意識

What can Nature do for us?
大自然能為我們做什麼？



https://rvahub.com/wp-content/uploads/2016/11/Green-Filter-Grey-Funnel_695.jpg

Green infrastructures|綠色基礎設施

and |和

Nature-Based Solutions |

以自然為本的解決方案

...vegetation does not need the Humans...

Pripyat - Ucrânia

...植物並不需要人類...

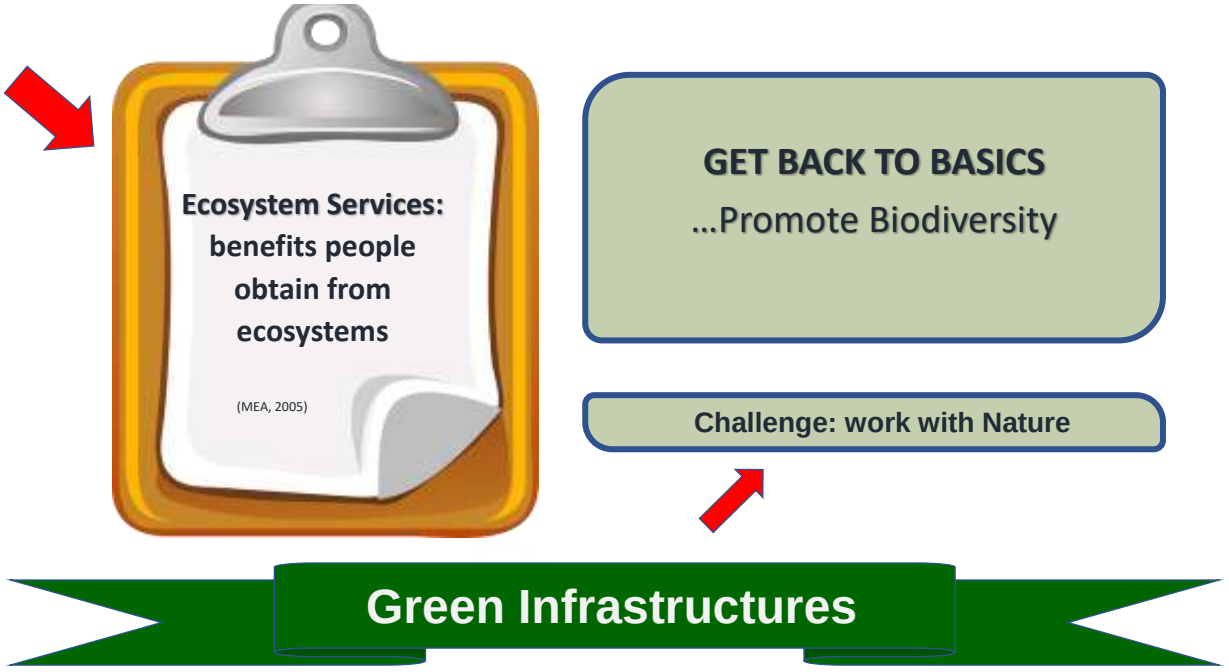
Carolina do Norte - EUA

19

...but we need to share our space with vegetation...

...但是我們需要與植物共享空間...

Fukuoka, Japão - Project: ACROS Fukuoka Prefectural International Hall



Cities providing Ecosystem Services through Nature
城市通過太自然來提供生態系統服務

 # Water quality improvement **|** 改善水質

 # Water management: stormwater, grey/blackwater as resources **|** 水資源管理：以雨水，灰水/黑水等污水作資源

 # Buffering aquatic ecosystems: effects of catchment urbanization and climate change **|** 水生生態系統緩沖帶：集水區城市化的影響和氣候變化

Cities providing Ecosystem Services through Nature
城市通過太自然來提供生態系統服務

 # Flood mitigation: infiltration; detention; harvesting and safe passage of flood water **|** 防洪： 入滲；滯洪 ; 收集和安全引導洪水

Influencing urban **micro-climates / mitigation of urban heat Island |** 影響城市中微氣候/緩解城市熱島效應

Enhancing urban **ecology and biodiversity |** 增強城市生態和生物多樣性

The United Nations World Water Development Report
聯合國世界水發展報告

Green infrastructure (GI)
綠色基礎設施

"Green infrastructure (for water) uses natural or semi-natural systems such as NBS to provide water resources management options with benefits that are equivalent or similar to conventional grey (built/physical) water infrastructure."

Nature-Based Solutions (NBS)
以自然為本的解決方案

"Nature-based solutions (NBS) are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water. "

Fonte: https://unesdoc.unesco.org/ark:/48223/pf0000261594_por

"**NBS** offer a vital means of moving beyond business-as-usual to address many of the world's water challenges while simultaneously delivering additional benefits vital to all aspects of sustainable development"

"**Upscaling NBS** will be central to achieving the **2030 Agenda for Sustainable Development**. "

NBS的進一步發展將是實現《2030年可持續發展議程》的關鍵。

"The current situation, with ageing, inappropriate or insufficient **grey infrastructure** worldwide, creates opportunities for **NBS** …"

當前，全球灰色基礎設施的老化，不適當或不足，為NBS創造了機會……

Combining green and grey infrastructure approaches can lead to cost savings and greatly improve overall risk reduction

結合綠色和灰色基礎設施的架構方法能節省成本並大大降低總體風險

Green infrastructure can:

• **Improve connectivity**, between existing nature areas in order to counter fragmentation and increase their ecological coherence.
改善現有自然區域之間的連通性，以應對細碎化並增強其生態連貫性

• **Enhance landscape permeability** and allow species dispersal, migration and movement.
增強景觀的通透性，以幫助物種的擴散，遷徙和移動

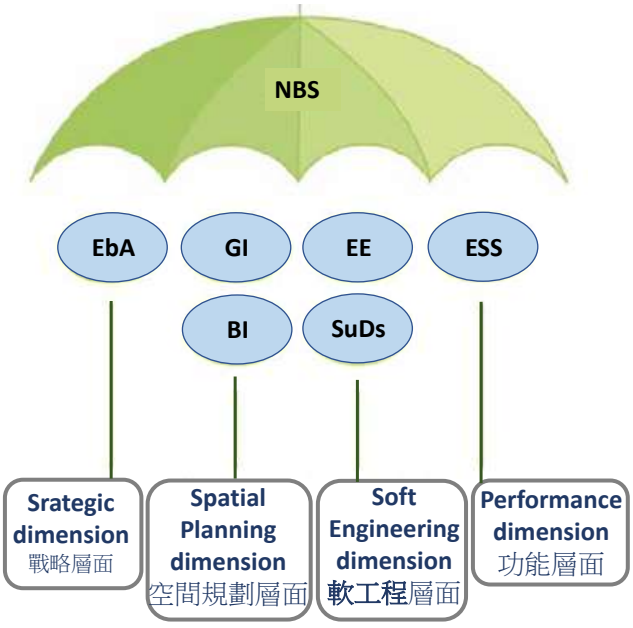
• Provide **multifunctional zones**.
識別多功能區域

NBS have to be:
- replicated
- amplified

to get the real effect!

Source:Climate-KIC

Nature-Based Solutions relations to existing key concepts (graphic: ILPÖ)
NBS與現有之關鍵概念（圖形：ILPÖ）



EbA- Ecosystem-based adaptation
基於生態系統的適應

GI- Green Infrastructure
綠色基礎設施

BI- Blue Infrastructure
藍色基礎設施

EE- Ecological Engineering
生態工程

SuDs- Sustainable urban drainage systems
可持續的城市排水系統

ESS- Ecosystem Services
生態系統服務

Choosing NBS |選擇NBS：

- **Based on Societal Challenges |** 基於社會挑戰
- **Based on Ecosystem Services |** 基於生態系統服務
- **Based on mitigation and adaptation to Climate Change**
  |基於緩解和適應氣候變化

From: **Enhancing the circular economy with nature-based solutions in the built urban environment: green building materials, systems and sites** . Published online December 03, 2019.46-72 doi:10.2166/bgs.2019.928

Three scales of **NBS** implementation in the built environment:

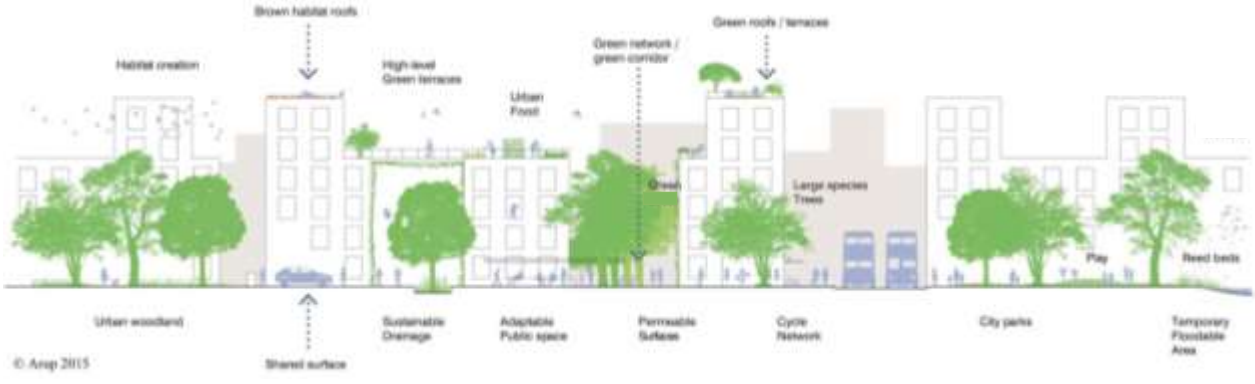
"Green building materials are raw and processed nature-based materials used in the construction of the built environment..."

"**Green building systems** systems for the greening of buildings…"

Green building sites may be open spaces directly adjacent to buildings…are spaces for establishing nature in Cities … providing opportunities for biophilic design …"

Green infrastructures: Integration /multifunctional /multilayer

綠色基礎設施：整合/多功能/多層

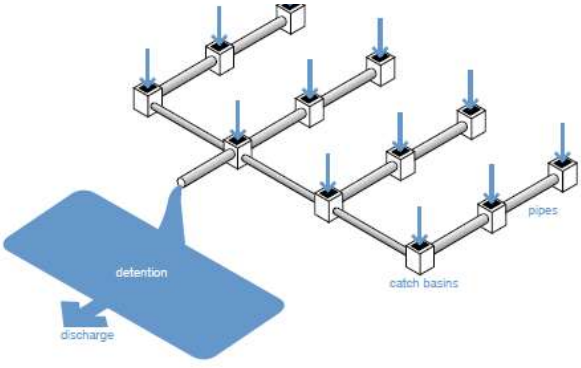


© Arup/ UK Green Buildings Council (2015)

Blue and green solutions |藍與綠的解決方案

Hard engineering …transfers pollution to another site

硬工程…把污染轉移到另一個站點



conventional management: "pipe-and-pond" infrastructure
drain, direct, dispatch

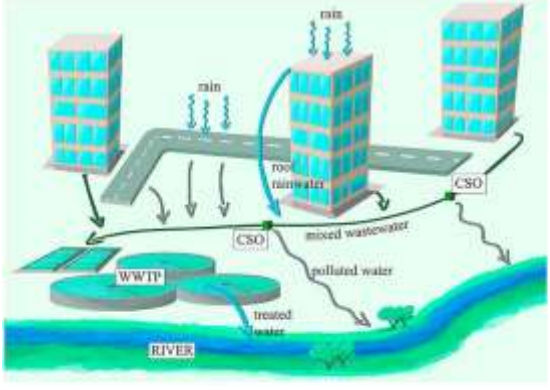
Soft engineering …metabolizes pollutants on site…not pipes!

軟工程…在現場代謝污染物……無管道！

low impact management: watershed approach
slow, spread, soak

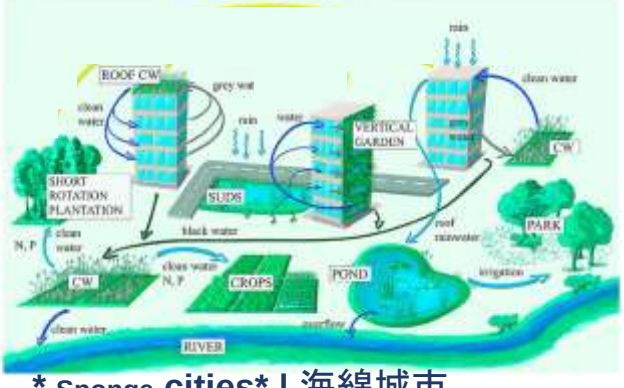
Source: Low Impact Development: A Design Manual for Urban Areas, 2010

Conventional | 常規



NBS towards water management and circular economy

| NBS 有助於水資源管理與循環經濟



*** Sponge cities* | 海綿城市**

Current centralised vs. future decentralised and NBS based concepts for urban sanitation.
當前集中式的城市衛生概念 vs. 未來以NBS為基礎的分散式城市衛生概念。

Source: F.Masi, A.Rizzo, M.Regelsberger (2018). The role of constructed wetlands in a new circular economy, resource oriented, and ecosystem services paradigm. Journal of Environmental Management.

Summary of some of the benefits provided by green infrastructure (GI) (reported by O'Neil, 2014)

Dimension	Contribution of green infrastructure to sustainable development
Economic	−50% of capital costs in relation to traditional drainage solutions
	4.5 °C of temperature regulation using green roofs and walls
	£2.3M of annual contribution of trees through air purification
	+40% commercial trading within town centers including green infrastructure
Environmental	9.1% of suspended particles removed by urban vegetation
	3.16 kg of carbon stored in $1m^2$ of green space
	3 dB reduction due to the use of grass instead of built-up surfaces
	Up to 8 °C decrease in urban temperature from vegetated cover
	17–20% reduction in runoff using green roofs in residential areas
	+50% species transfer when habitats are connected by green areas
Social	People happier when living in urban areas covered by large amounts of green space
	83% of respondents believe green areas provide focal points for communities
	24% of people more likely to be physically active if have access to green space
	−40% less chances to be obese if living in a highly green urban area

Source: Jato-Espino et al, 2018

NBS Examples

. **Constructed Wetlands & Floating Wetlands | 人工濕地 & 浮動濕地**

. **Tree Trenchs |樹溝**

. **Rain Gardens | 雨水花園**

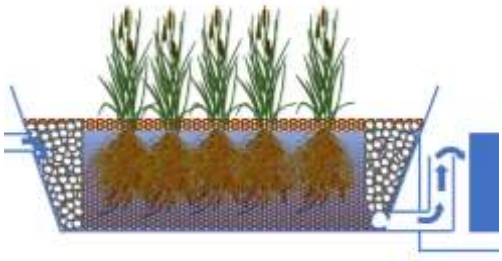
. **Bioswales | 生態草溝－ 一種景觀設計**

. **Mangroves | 紅樹林**

. **Green Roofs & Green Walls | 綠色屋頂與綠牆**

Constructed Wetlands & Floating Wetlands

人工濕地 & 浮動濕地



CONSTRUCTED and **FLOATING WETLANDS** are treatment systems that use natural processes involving wetland **vegetation, substrate/platform**, and their associated **microbial assemblages** to improve water quality. They intent to mimic the biogeochemical processes occurring in natural wetlands.

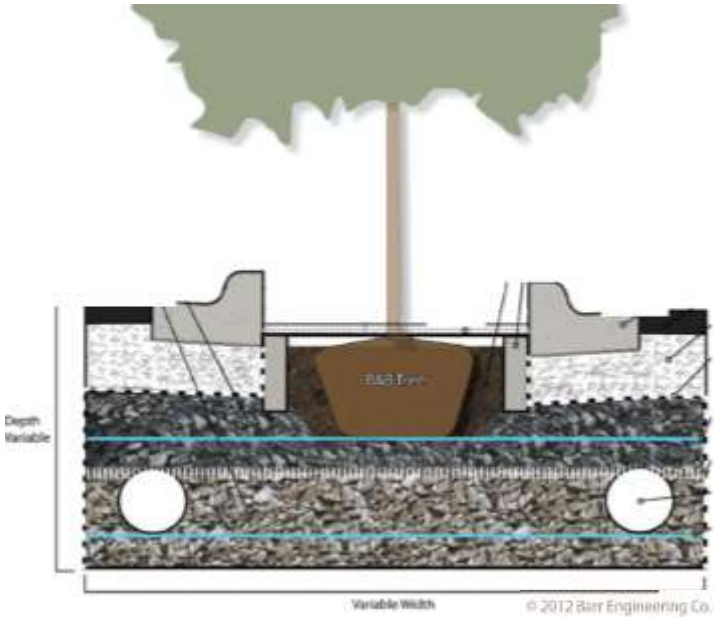
https://iwa-network.org/projects/nature-for-water-and-sanitation/

H. Brix et al. / Ecological Engineering *37 (2011) 729–735*

Vymazal and Kröpfelová, 2008

Headley and Tanner, 2006

Tree Trench
樹溝

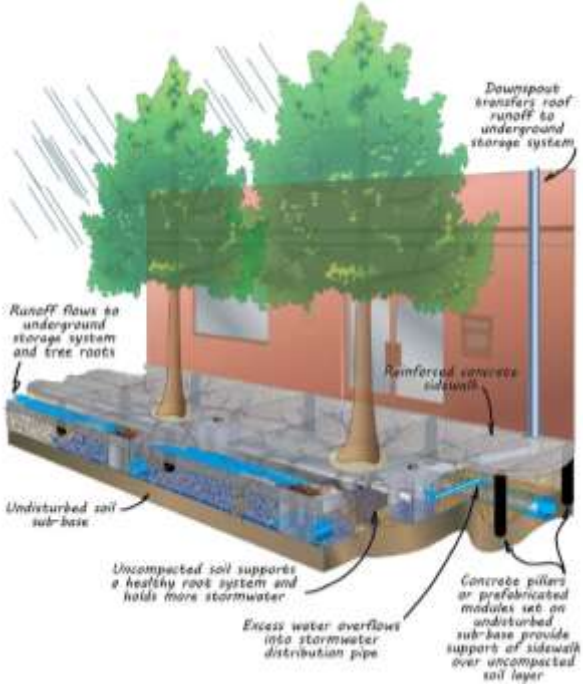


https://www.epa.gov/sites/production/files/2016-11/documents/final_stormwater_trees_technical_memo_508.pdf

Source: https://www.phila.gov/media/20160504172218/Green-Streets-Design-Manual-2014.pdf

Photos courtesy of Deep Root Partners, L.P.

Source: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf



Source: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

Rain gardens
雨水花園

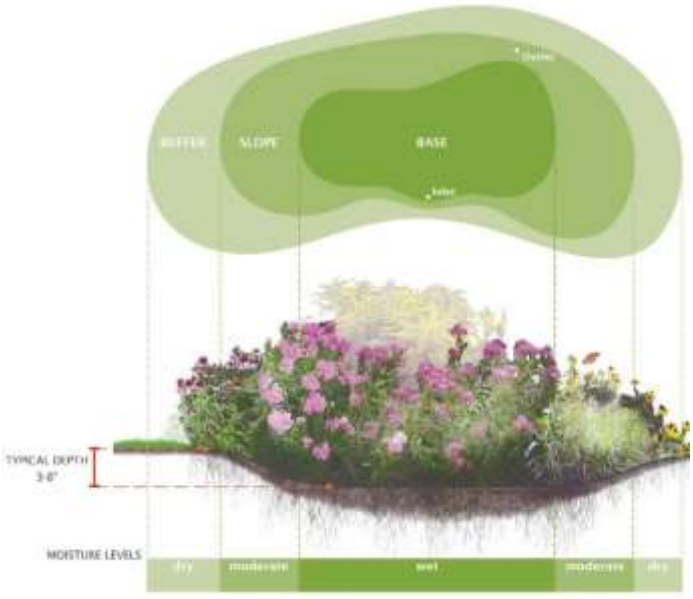


Diagram of Rain Garden (Rutgers University)

Much moore than a pretty garden…

Source: The SuDS Manual (C753F)

Shepard Recreation Center Corner Bump-out

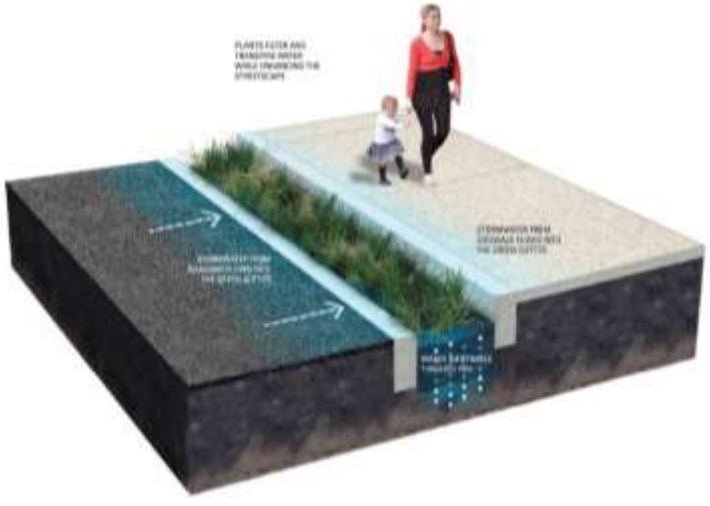
Mid-block Stormwater Bump-out

Corner Stormwater Bump-out

Source: https://www.phila.gov/media/20160504172218/Green-Streets-Design-Manual-2014.pdf

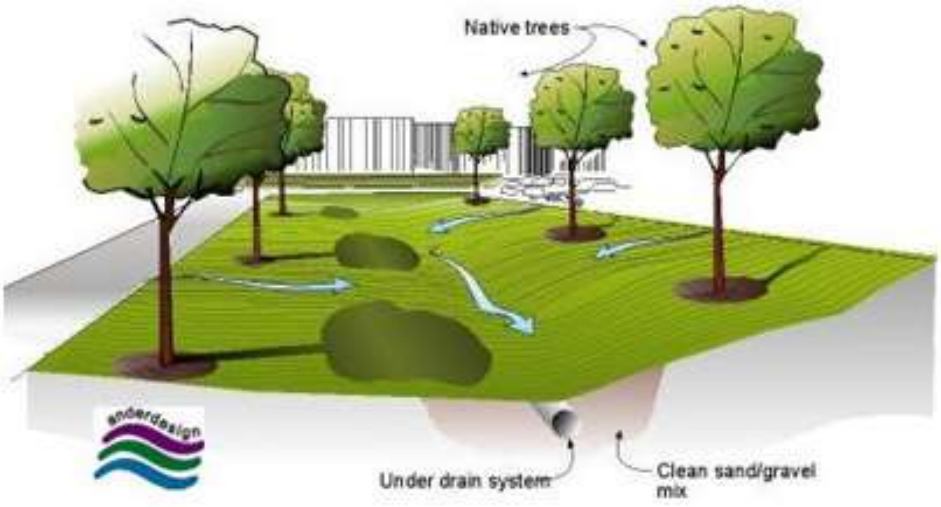
Portland, OR precedent

Green gutter |綠色水槽



Source: https://www.phila.gov/media/20160504172218/Green-Streets-Design-Manual-2014.pdf

Bioswale |生態草溝－ 一種景觀設計



The SuDS Manual (C753F)

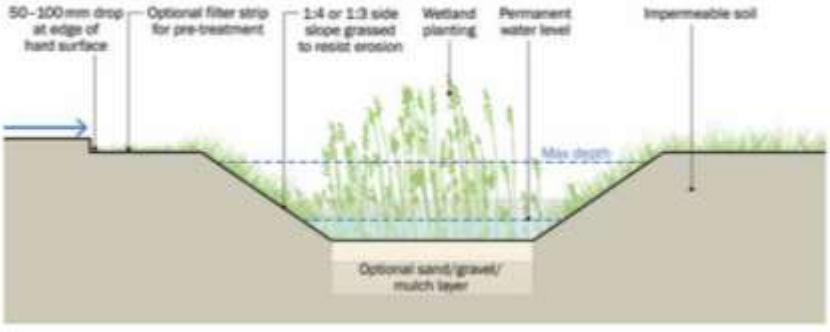


Figure 17.3 Typical wet swale

Mangroves | 紅樹林

Mangrove forests make up one of the most productive and biologically diverse ecosystems on the planet.

Protecting/restoring mangroves, marshes or dunes	
Water management benefits	**Co-benefits**
• Coastal flood/ storm protection	• Biodiversity benefits (habitats preservation, breeding and nursery for birds, fish, shellfish and mammals)
• Shoreline stabilization, erosion and sediment control	
• Reduced saltwater intrusion	• Climate change mitigation and adaptation (carbon storage, storm protection)
	• Income opportunities (fisheries, raw materials, tourism)
	• Recreational, aesthetic value

2014 United Nations Environment Programme. Publication: Green Infrastructure Guide for Water Management: Ecosystem-based management approaches for water-related infrastructure projects
ISBN: 978-92-807-3404-1

Green Roofs and Green Walls

綠色屋頂與綠牆

Green roofs comprise a layer of vegetation planted over a waterproofing system that is installed on top of a building slab above or at ground level.

Green walls refers to all systems which enable greening a vertical surface (e.g., facades, walls, etc.) with a selection of plant species, including all the solutions with the purpose of growing plants on, up or within the wall of a building.

Passeio dos Clérigos–Porto (Portugal): green roof, shopping, underground parking

USJ – Macau | 澳門聖若瑟大學

Hong kong
香港

Roof top farming
屋頂農場

Fu Shan Estate

https://www.sempergreen.com/en/references/fu-shan-estate

Sheffield Bus Shelter-UK

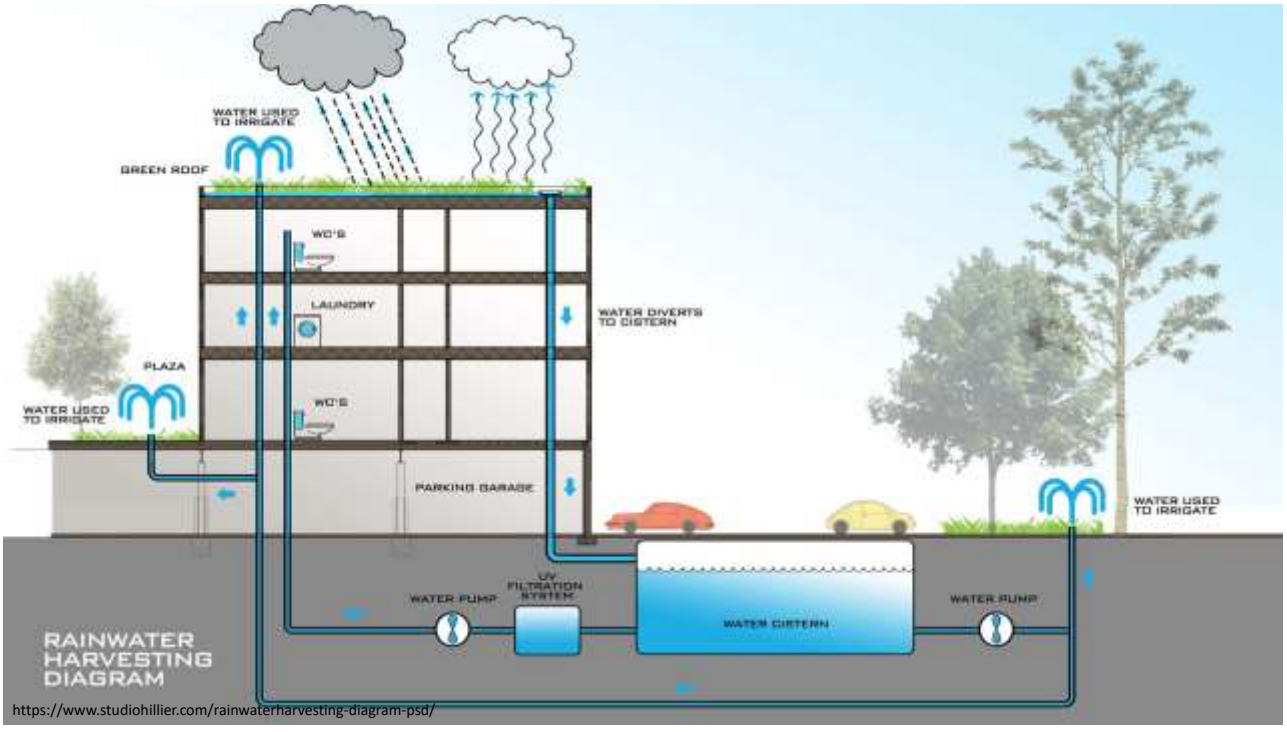
https://www.greenroofs.com/projects/sheffield-bus-shelter/

Barcelona-Spain

https://www.urbangardensweb.com/2013/07/24/phyto-kinetic-green-roofs-for-city-buses-and-improved-urban-ecosystem/

Bus Roots-NY-USA

https://inhabitat.com



https://www.studiohillier.com/rainwaterharvesting-diagram-psd/

Green Walls 綠牆


Continuous living wall system, Caixa Forum, Madrid, June 2013.


Modular living wall system, Natura Towers, Lisbon, August 2012.


Fig. 2. Direct green facade, private house, Colegã, Portugal.


Fig. 3. Indirect green facade.

M. Manso, J. Castro-Gomes / Renewable and Sustainable Energy Reviews 41 (2015) 863–871

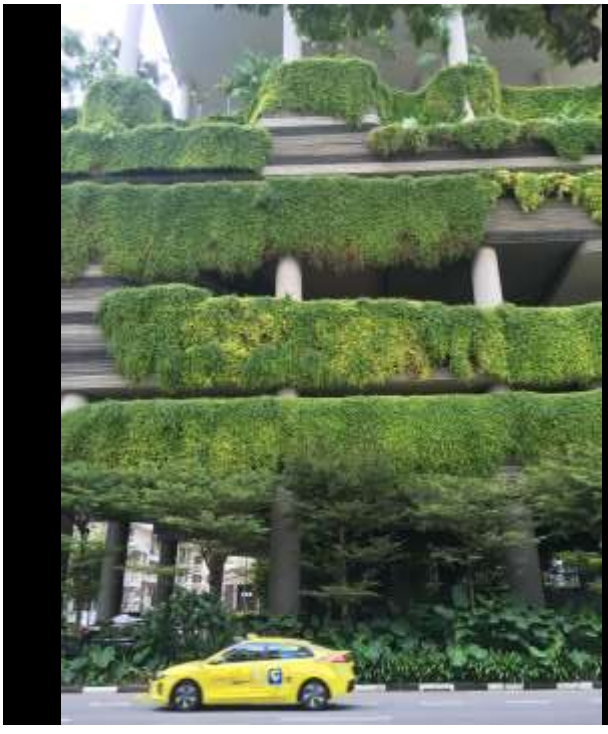
Solutions at the level of the buildings and territoires

建築物與其周邊土地的解決方案

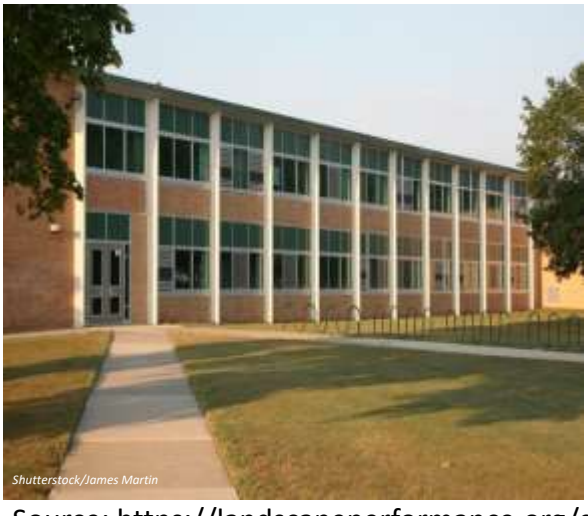
Skypark at Marina Bay Sands

濱海灣金沙的空中花園

(Author: Dr. Tan Puay Yok, National Universtity of Singapore)

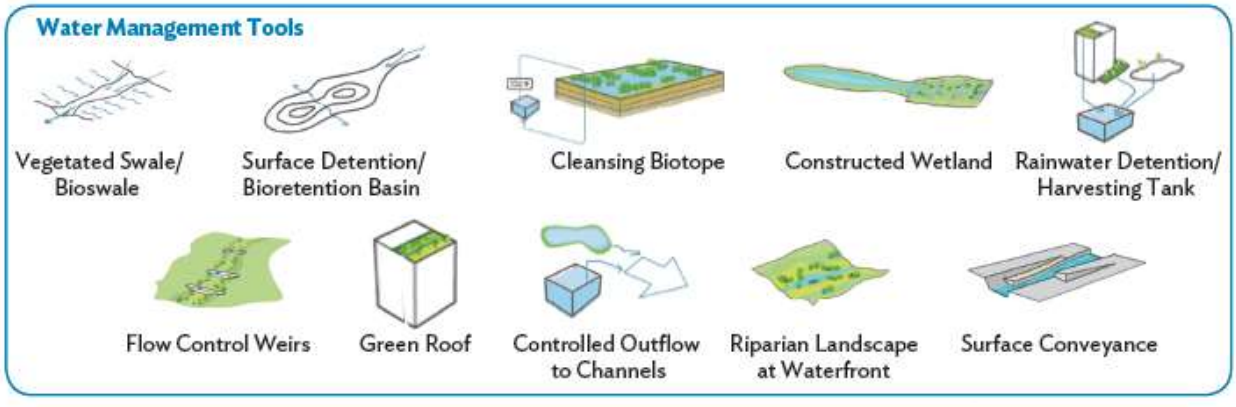


Sidwell Friends Middle School - USA



Source: https://landscapeperformance.org/case-study-briefs/sidwell-friends-middle-school

Fonte: https://www.adb.org/sites/default/files/publication/535016/nature-based-solutions-cities-viet-nam.pdf

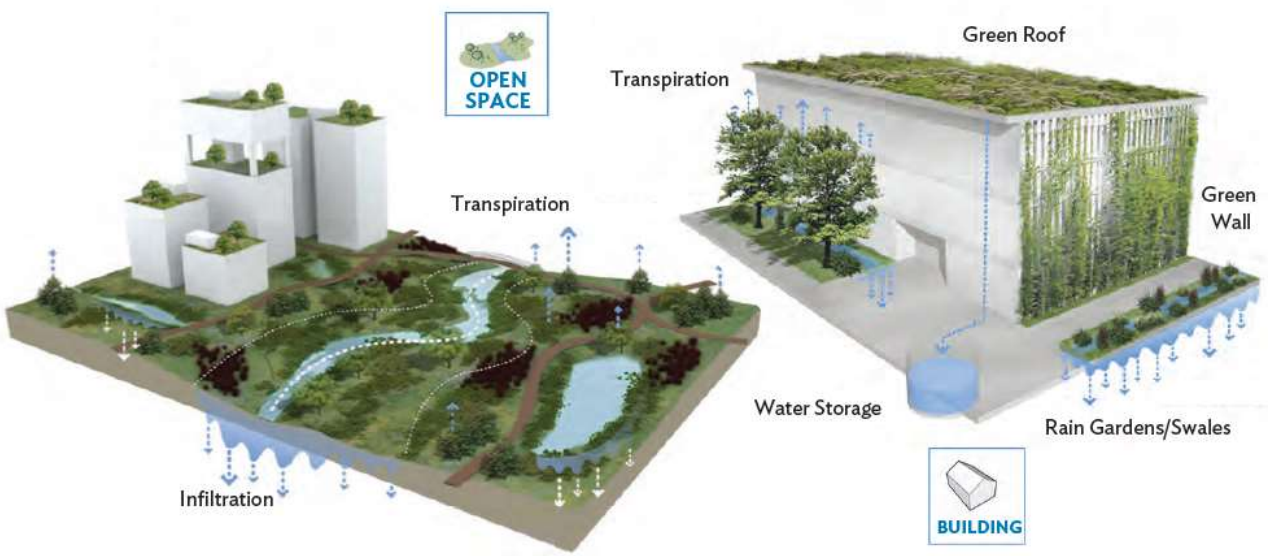


Source: A. Hoban and T.H.F. Wong. 2006. *WSUD Resilience to Climate Change*. Paper presented at the first Australian National Hydropolis Conference. Perth. 8–11 October.

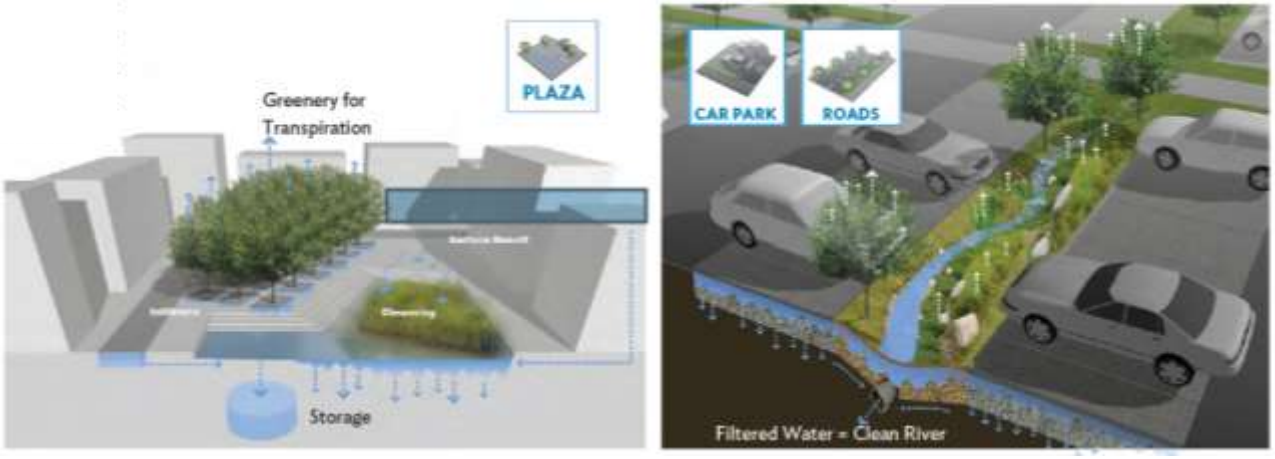
Fonte: https://www.adb.org/sites/default/files/publication/535016/nature-based-solutions-cities-viet-nam.pdf

Applications

role in storing, treating, and conveying water for various purposes: flood mitigation, runoff harvesting and reuse, heat mitigation, and recreational use with added ecological value.



Fonte: https://www.adb.org/sites/default/files/publication/535016/nature-based-solutions-cities-viet-nam.pdf



Fonte: https://www.adb.org/sites/default/files/publication/535016/nature-based-solutions-cities-viet-nam.pdf

CHINA'S 'SPONGE CITY' CONCEPT | 中國的"海綿城市"概念

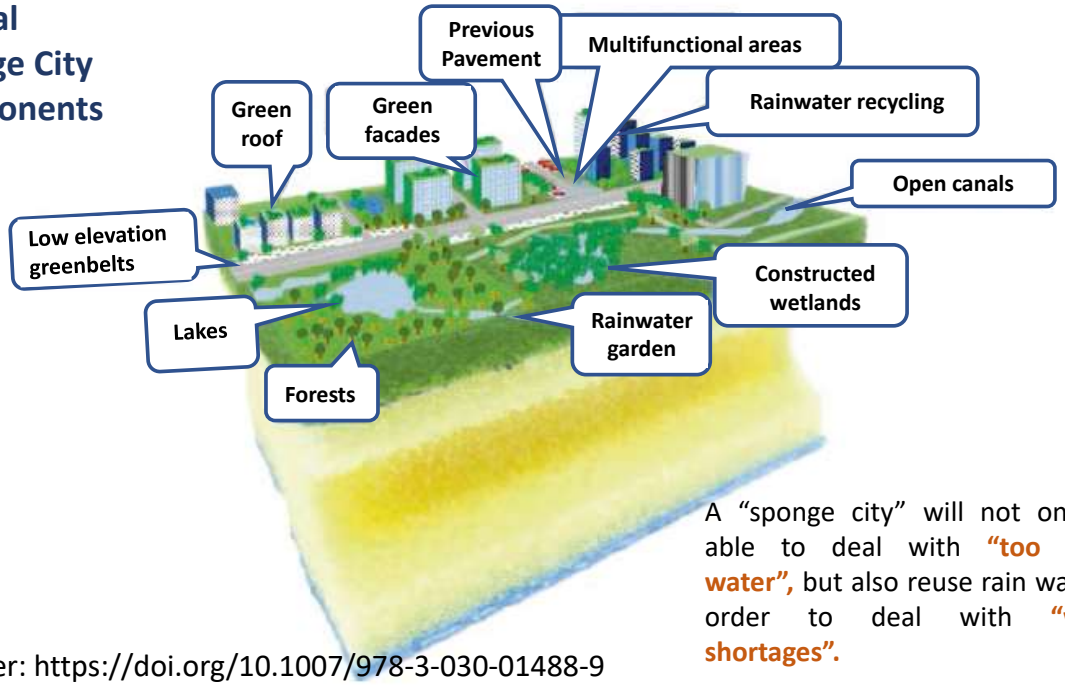
Many cities in China face severe challenges of **water scarcity, pollution, flooding and inadequate infrastructure.**

In 2013, the Chinese government declared its intention to convert Chinese cities into "Sponge Cities"

The general objectives of the concept entail **"restoring" the city's** capacity to **absorb, infiltrate, store, purify, drain, and manage rainwater** and "**regulating" the water cycle** as much as possible to mimic the natural hydrological cycle.

Springer: https://doi.org/10.1007/978-3-030-01488-9

Typical Sponge City components



A "sponge city" will not only be able to deal with **"too much water",** but also reuse rain water in order to deal with **"water shortages".**

Springer: https://doi.org/10.1007/978-3-030-01488-9

Sponge Cities | 海綿城市

Decentralized treatments and integrated urban catchment / green infrastructure

分散處理和綜合城市集水區／綠色基礎設施

It is supported by:

MOHURD -Ministry of Housing and Urban-Rural Development "Sponge Cities Guidelines"
MWR-Ministry of Water Resources "Water Ecological City Construction Evaluation Guidelines

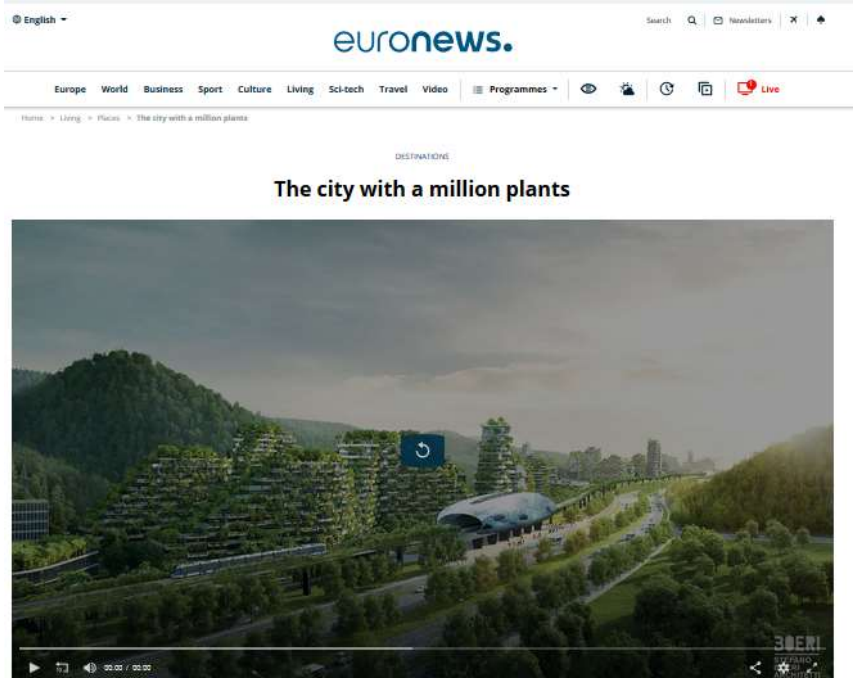
Ref. Ares(2018)4142480 - 07/08/2018

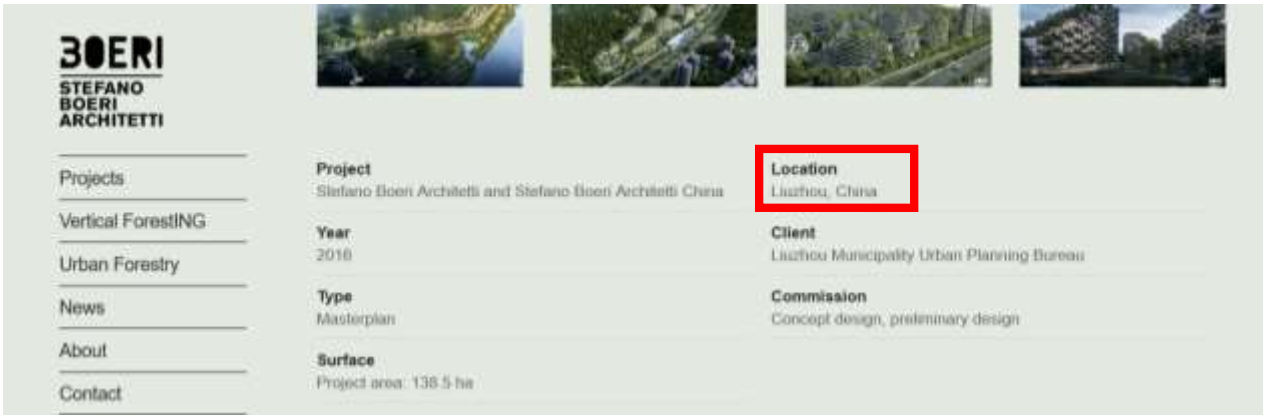
Sponge City component "Sunken Greenbelt" in Jiaxing (September 2016)

Rain garden under construction in the first round Sponge City Jiaxing (September 2016)

Springer: https://doi.org/10.1007/978-3-030-01488-9

https://www.euronews.com/2018/10/31/the-city-with-a-million-plants





High Line - NY

https://dspo2150a.wordpress.com/2014/11/07/the-new-york-high-line-an-urban-reclamation-project-by-citizens-for-citizens/

https://macaulay.cuny.edu/eportfolios/nycpublicspaces/files/2015/05/article-2139899-12EF2F80000005DC-992_964x1437.jpg

Restoring Cheonggytecheon-South Korea

Figure 3. Before and ater Cheonggytecheon Development (http://egloos.com [24]).

Sustainability **2016**, 8, 1178

https://urban-regeneration.worldbank.org/Seoul

Fonte: https://www.phila.gov/media/20160504172218/Green-Streets-Design-Manual-2014.pdf

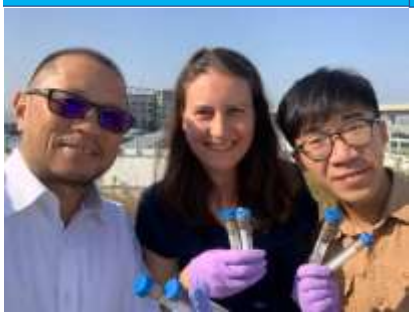
- Multidisciplinary teams
- Definition of priorities/aims
- Design and dimensioning –guidelines
- Right/proper plants
- Adequate materials (circular economy)
- Raise awareness

聖若瑟大學 USJ Institute of Science and Environment

* Green roofs |綠色屋頂
* Constructed wetlands |人工濕地
* Mangroves |紅樹林

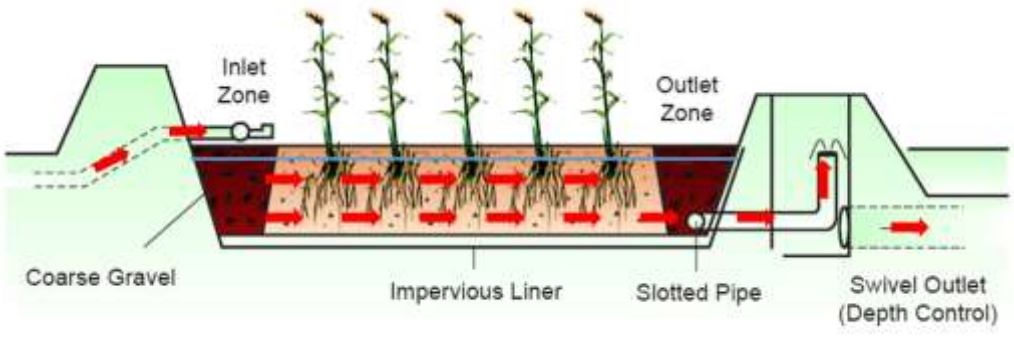
PhD Thesis By Lei Man Sao

"Towards Climate Change Resilient Cities, Macao SAR as a case-study"



Master Thesis By Micaela Lei

"Constructed wetlands for wastewater treatment in densely urban settlements"



(Adaptado de Kadlec and Knight, 1996)

Bringing Science to Schools in Macao - FDCT Project

Ecosystems component: Mangroves education

Prof. Karen Tagulao

Environmental Education

Field trips/activities at the mangroves sites (primary, secondary, university students)
Mangroves planting/restoration activity (secondary and university students)





Scientific research projects - FDCT/117/2014

"The role of mangroves on the bioaccumulation and citogenotoxic effects of metals and pesticides on the food web of a tropical coastal system"




Scientific research projects - Clean the World/ Las Vegas Sands project

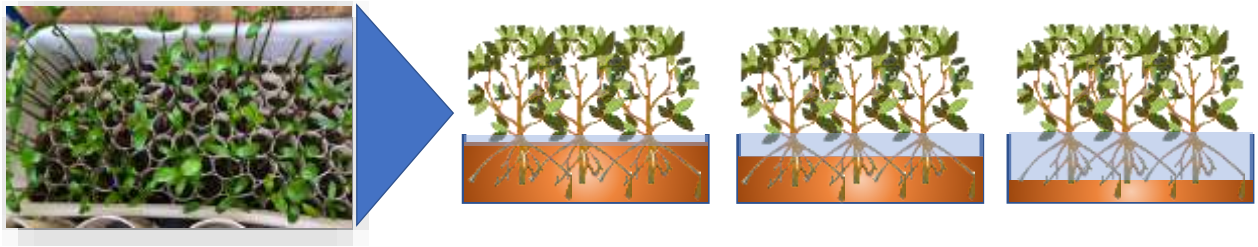
THE DROP4DROP PROJECT Sands SANDS ECO·360

"Nature-Based Solutions for a Cleaner and Safer Macao"



THE DROP4DROP PROJECT Sands SANDS ECO·360

On-going Scientific experiments | 進行的科學實驗



Planned activities | 實驗計劃 :

. Educational resources
. Biodiversity Exhibition
. Workshop: Nature-Based Solutions for water
. Campaign in schools
. Community awareness campaign


Imagine…
87


Imagine…


Present
Future

Thank You

謝謝

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ccalheiros@ciimar.up.pt

Nature-based solutions for water in cities

以自然為本的城市水資源解決方案