



# UNIVERSITÀ DEGLI STUDI DI MILANO

Dipartimento di Scienze Agrarie e Ambientali

## Il ruolo del verde urbano

*Giulio Senes*

SEMINARIO DI APPROFONDIMENTO

### PROGETTARE PER L'INVARIANZA

REGOLAMENTO REGIONALE N. 7 DEL 23.11.2017:

CRITERI E METODI PER IL RISPETTO DEL PRINCIPIO DELL'INVARIANZA IDRAULICA E IDROLOGICA

AI SENSI DELL'ART. 58 BIS DELLA L.R. 12/2017



COMUNE DI  
MONZA



PROVINCIA  
MONZA BRIANZA



INU Lombardia  
Istituto Nazionale di Urbanistica

ordine degli architetti  
pianificatori, paesaggisti  
e conservatori della provincia  
di monza e della Brianza

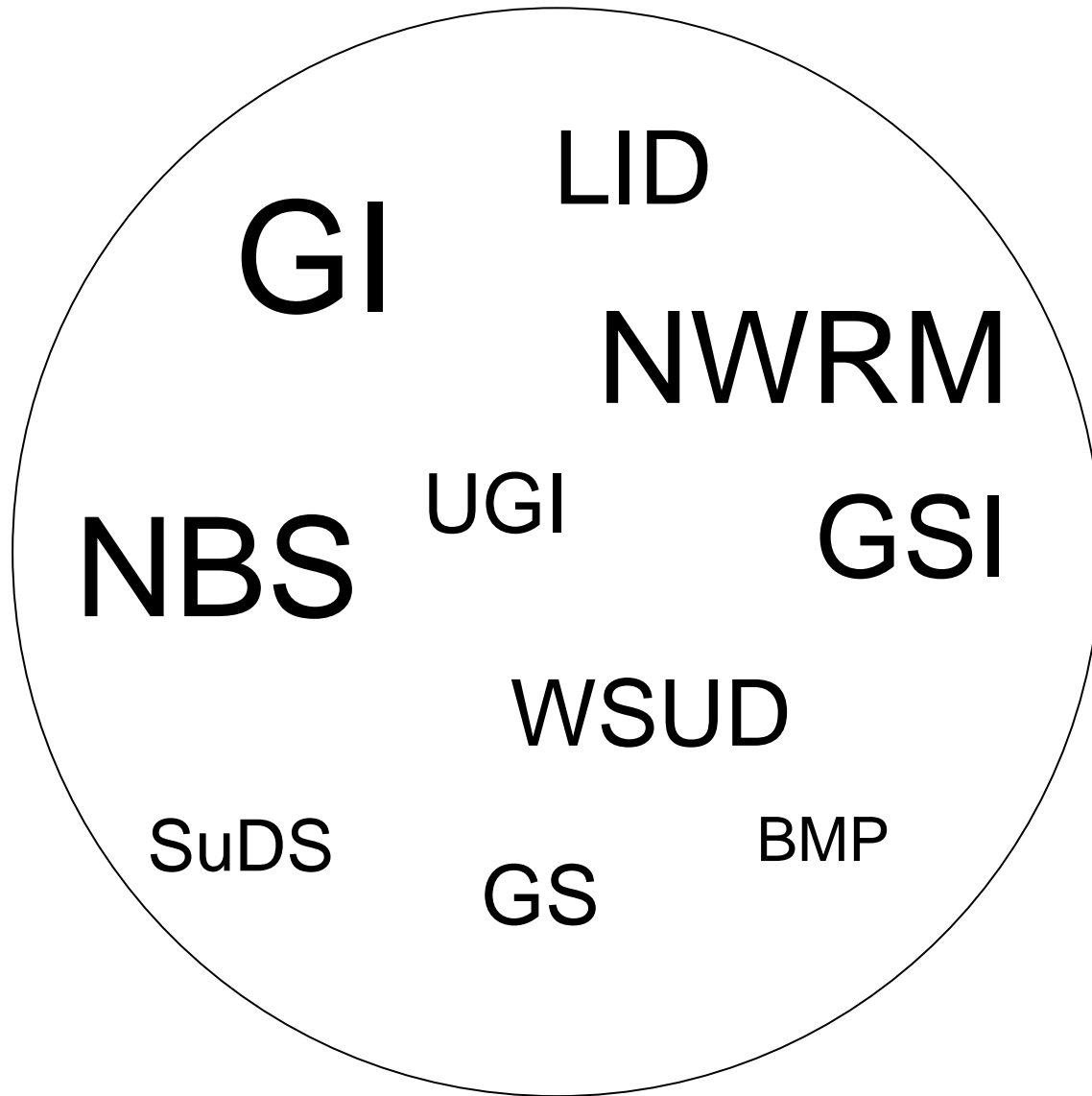


Collegio Provinciale  
Geometri e Geometri Laureati  
di Monza e Brianza



11 Aprile 2018 - Sala Congressi Assolombarda - Confindustria Milano Monza e Brianza, via Petrarca 10 - Monza

# Introduzione





# Introduzione



## Green Stormwater Infrastructure in Seattle Implementation Strategy 2015-2020



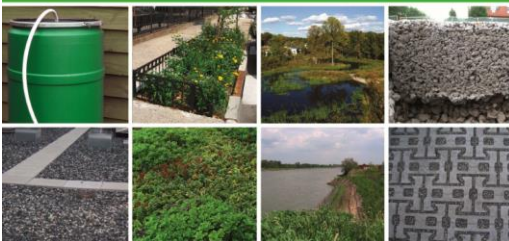
## GREEN INFRASTRUCTURE CASE STUDIES: Municipal Policies for Managing Stormwater with Green Infrastructure



## NYC GREEN INFRASTRUCTURE PLAN

A SUSTAINABLE STRATEGY FOR CLEAN WATERWAYS

Michael R. Bloomberg, Mayor  
Cruz Hobbaway, Commissioner

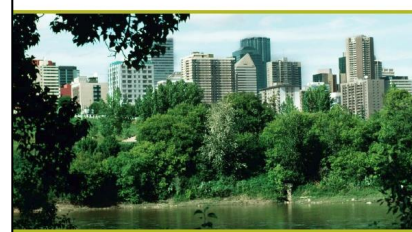


## Integrating Green Infrastructure



## Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities

Final Report of the Horizon 2020  
Expert Group on 'Nature-Based Solutions  
and Re-Naturing Cities'

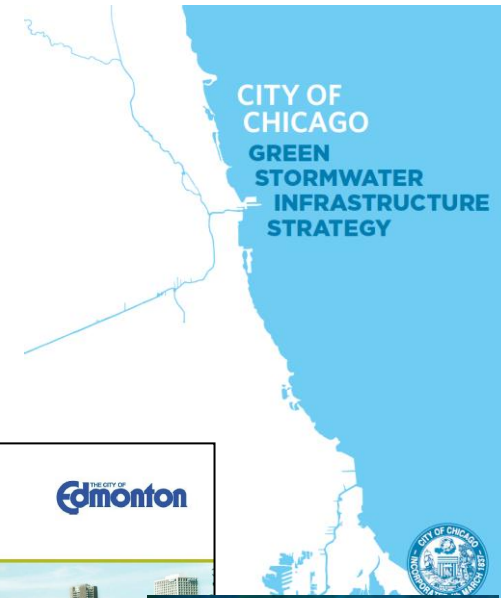


## Low Impact Development Best Management Practices Design Guide Edition 1.1

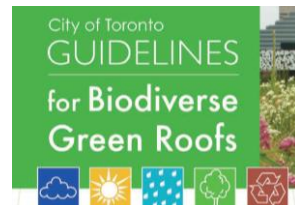
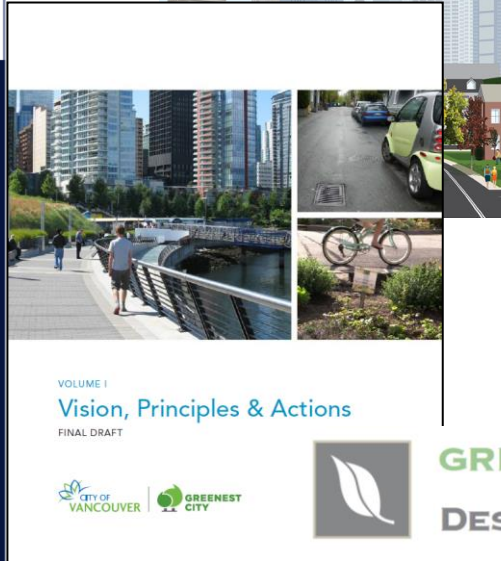
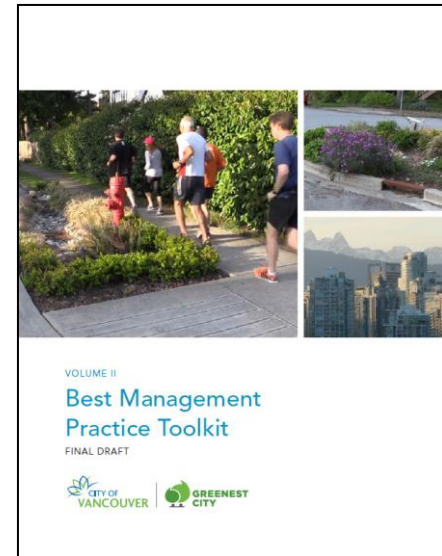
December



## Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits



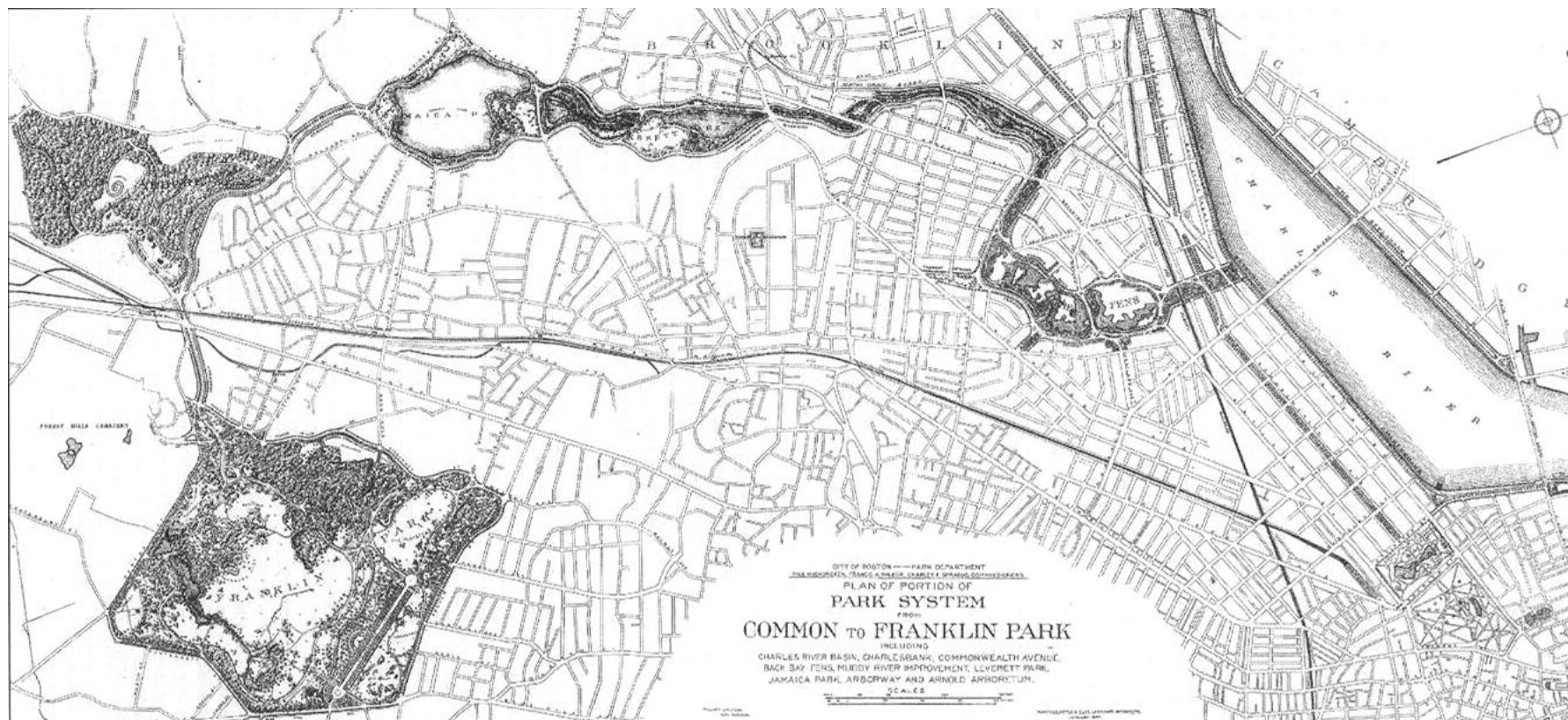
# Introduzione







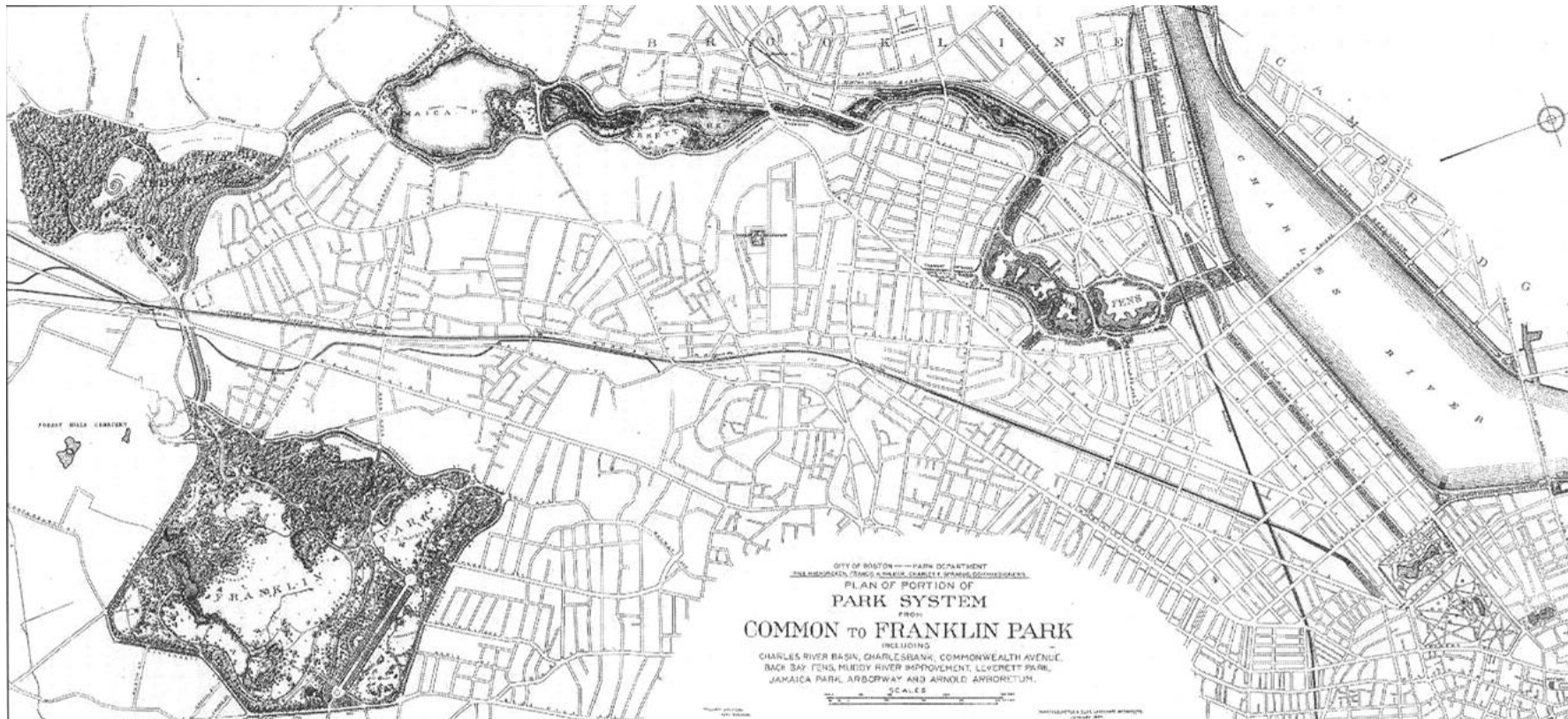
# Introduzione



# Introduzione

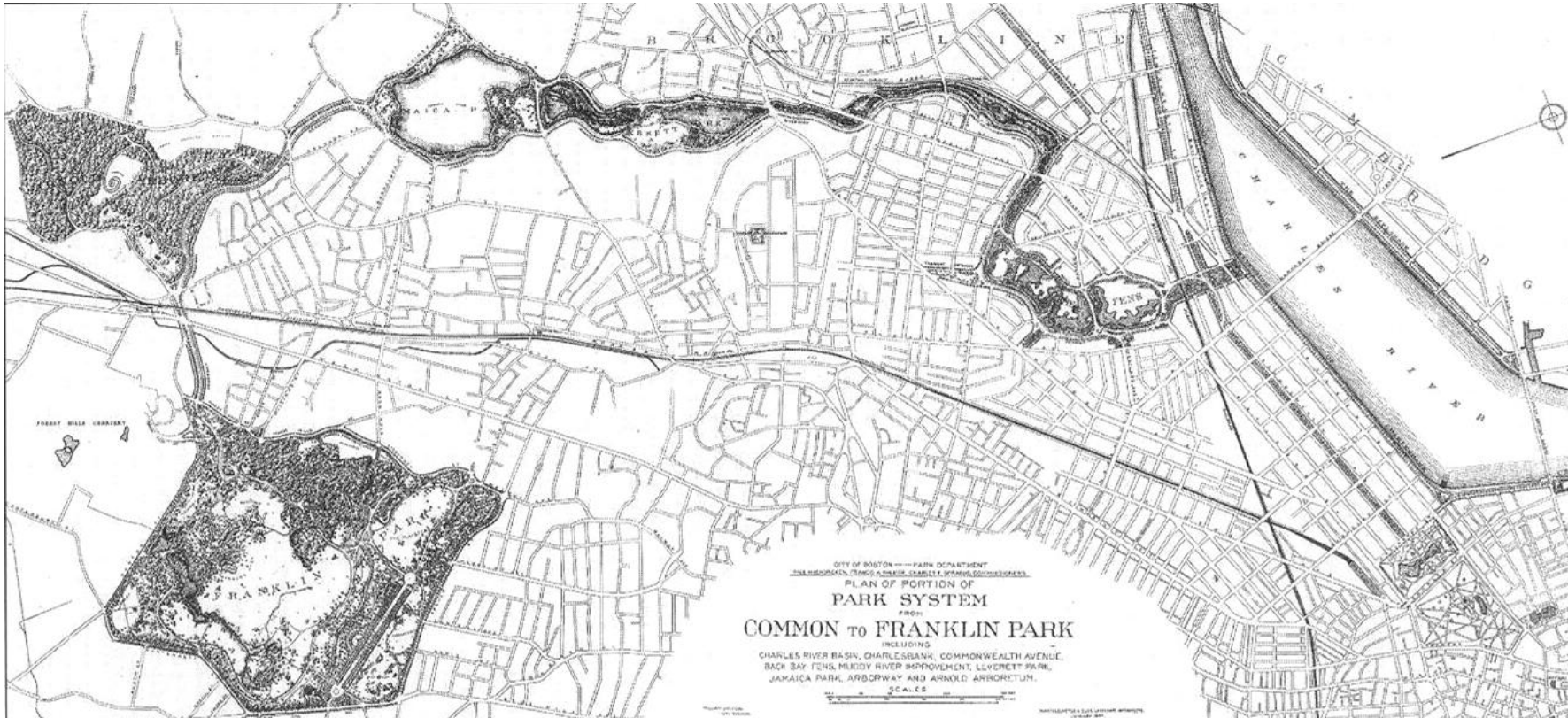
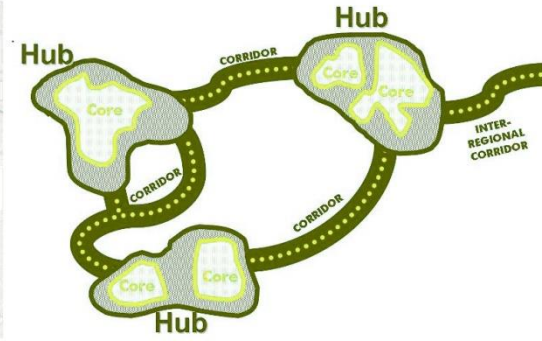
## Sistema di “parkways”\* per la città di Boston (“Emerald Necklace Park”). Frederick Law Olmsted (1878 – 1890)

\***Parkway**: percorsi colleganti le aree verdi con l’obiettivo di estenderne i benefici anche alle aree urbane e suburbane circostanti





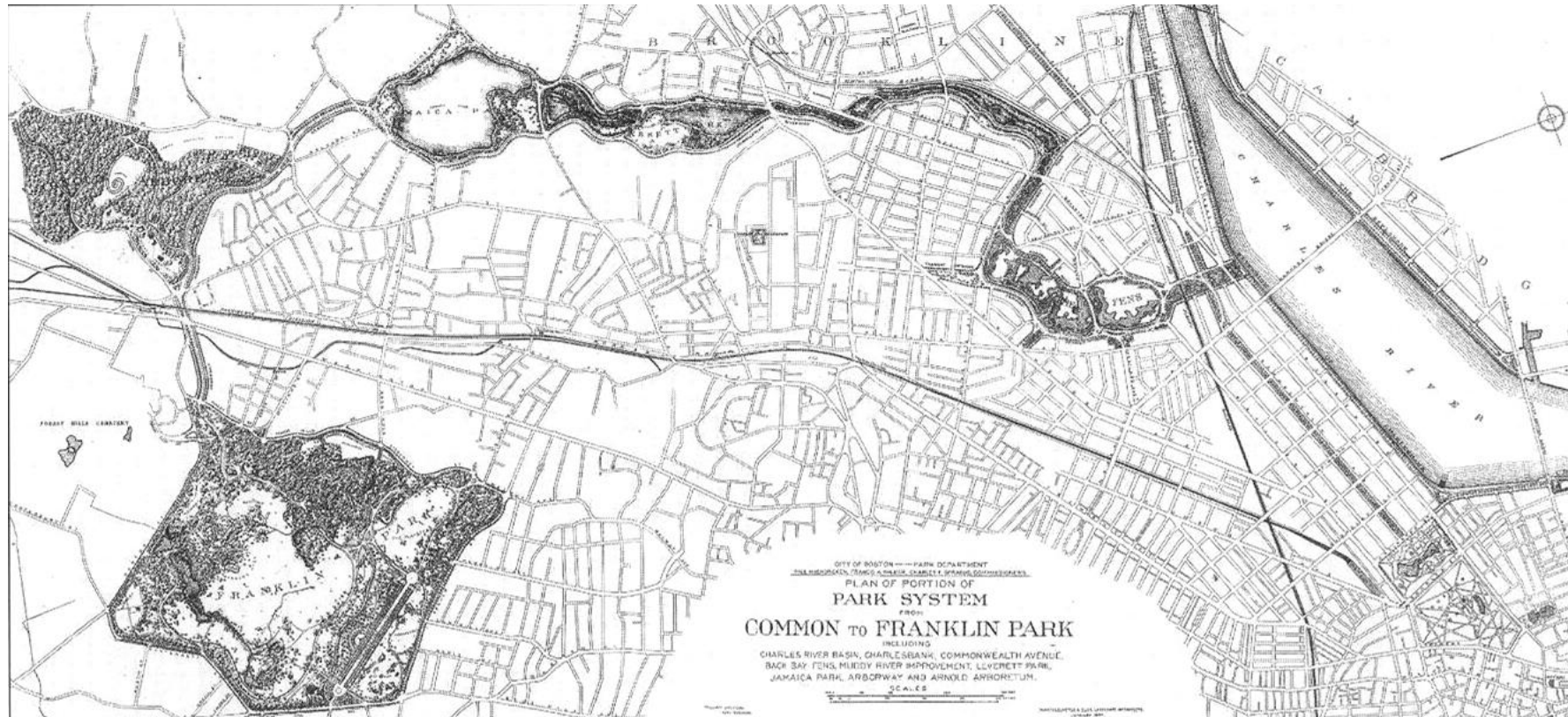
# Introduzione





# Introduzione

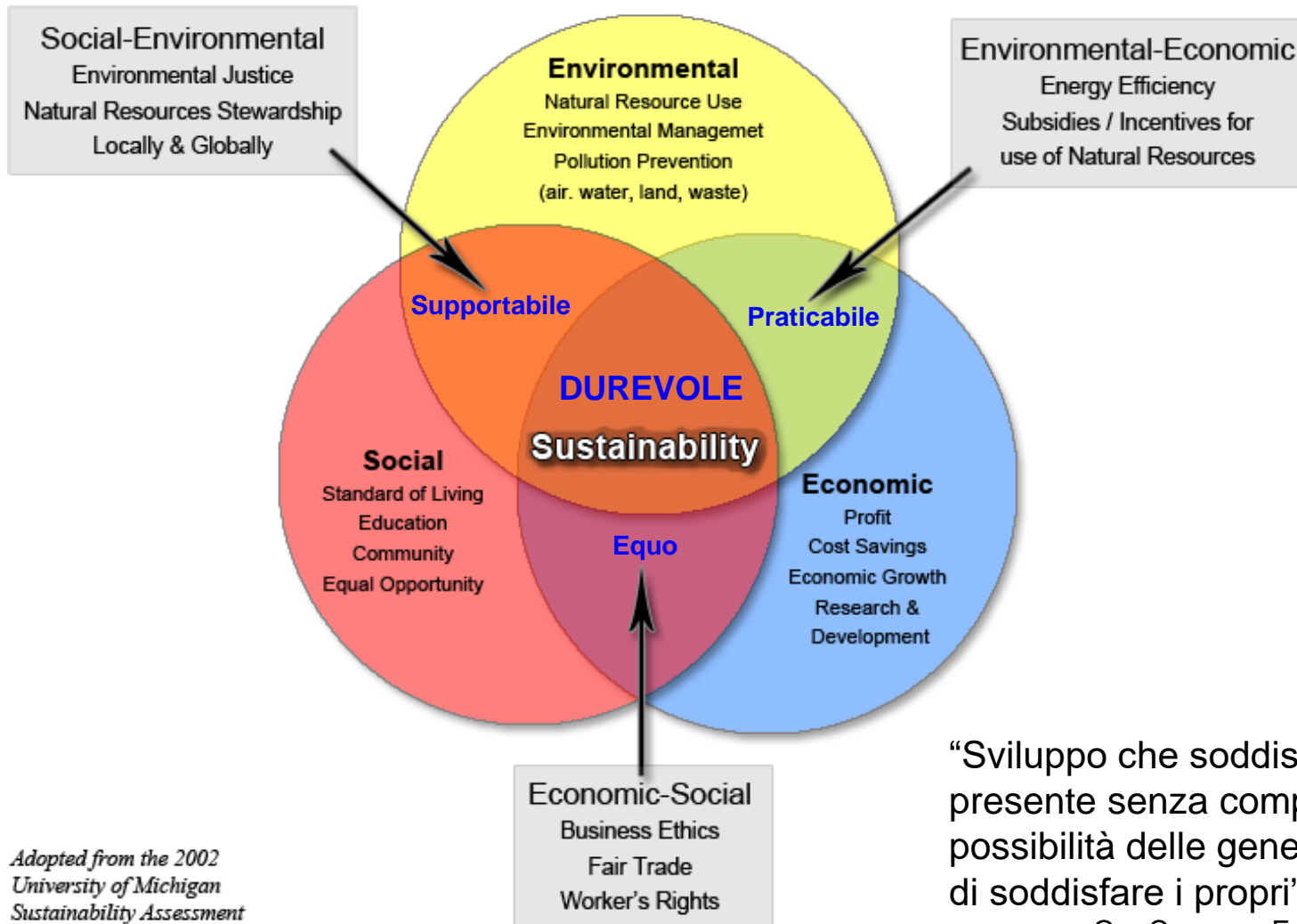
The roots of **landscape architecture** are embedded in both **landscape planning** and **land-use planning**. Frederick Law Olmsted was a landscape planner.





# Introduzione

## *The Three Spheres of Sustainability*



“Sviluppo che soddisfa i bisogni del presente senza compromettere la possibilità delle generazioni future di soddisfare i propri”

Our Common Future (WCED, 1987)

Adopted from the 2002  
University of Michigan  
Sustainability Assessment

# Introduzione. Servizi Ecosistemici

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SEARCH JOURNAL

Go

15 May 1997 Vol 387 No 6630 pp215-315

## The value of the world's ecosystem services and natural capital

**Robert Costanza<sup>\*†</sup>, Ralph d'Arge<sup>‡</sup>, Rudolf de Groot<sup>§</sup>, Stephen Farber<sup>||</sup>, Monica Grasso<sup>†</sup>, Bruce Hannon<sup>¶</sup>, Karin Limburg<sup>#☆</sup>, Shahid Naeem<sup>\*\*</sup>, Robert V. O'Neill<sup>††</sup>, Jose Paruelo<sup>‡‡</sup>, Robert G. Raskin<sup>§§</sup>, Paul Sutton<sup>||||</sup> & Marjan van den Belt<sup>¶¶</sup>**

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<sup>‡</sup> Economics Department (emeritus), University of Wyoming, Laramie, Wyoming 82070, USA

<sup>§</sup> Center for Environment and Climate Studies, Wageningen Agricultural University, PO Box 9101, 6700 HB Wageningen, The Netherlands

<sup>||</sup> Graduate School of Public and International Affairs, University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA

<sup>¶</sup> Geography Department and NCSA, University of Illinois, Urbana, Illinois 61801, USA

<sup>#</sup> Institute of Ecosystem Studies, Millbrook, New York, USA

<sup>\*\*</sup> Department of Ecology, Evolution and Behavior, University of Minnesota, St Paul, Minnesota 55108, USA

<sup>††</sup> Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

<sup>‡‡</sup> Department of Ecology, Faculty of Agronomy, University of Buenos Aires, Av. San Martin 4453, 1417 Buenos Aires, Argentina

<sup>§§</sup> Jet Propulsion Laboratory, Pasadena, California 91109, USA

<sup>||||</sup> National Center for Geographic Information and Analysis, Department of Geography, University of California at Santa Barbara, Santa Barbara, California 93106, USA

<sup>¶¶</sup> Ecological Economics Research and Applications Inc., PO Box 1589, Solomons, Maryland 20688, USA



# Introduzione. Servizi Ecosistemici

“Un ‘ecosistema’ è una combinazione complessa e dinamica di piante, animali, microrganismi e dell'ambiente naturale, che insieme costituiscono un sistema unico di elementi interdipendenti.

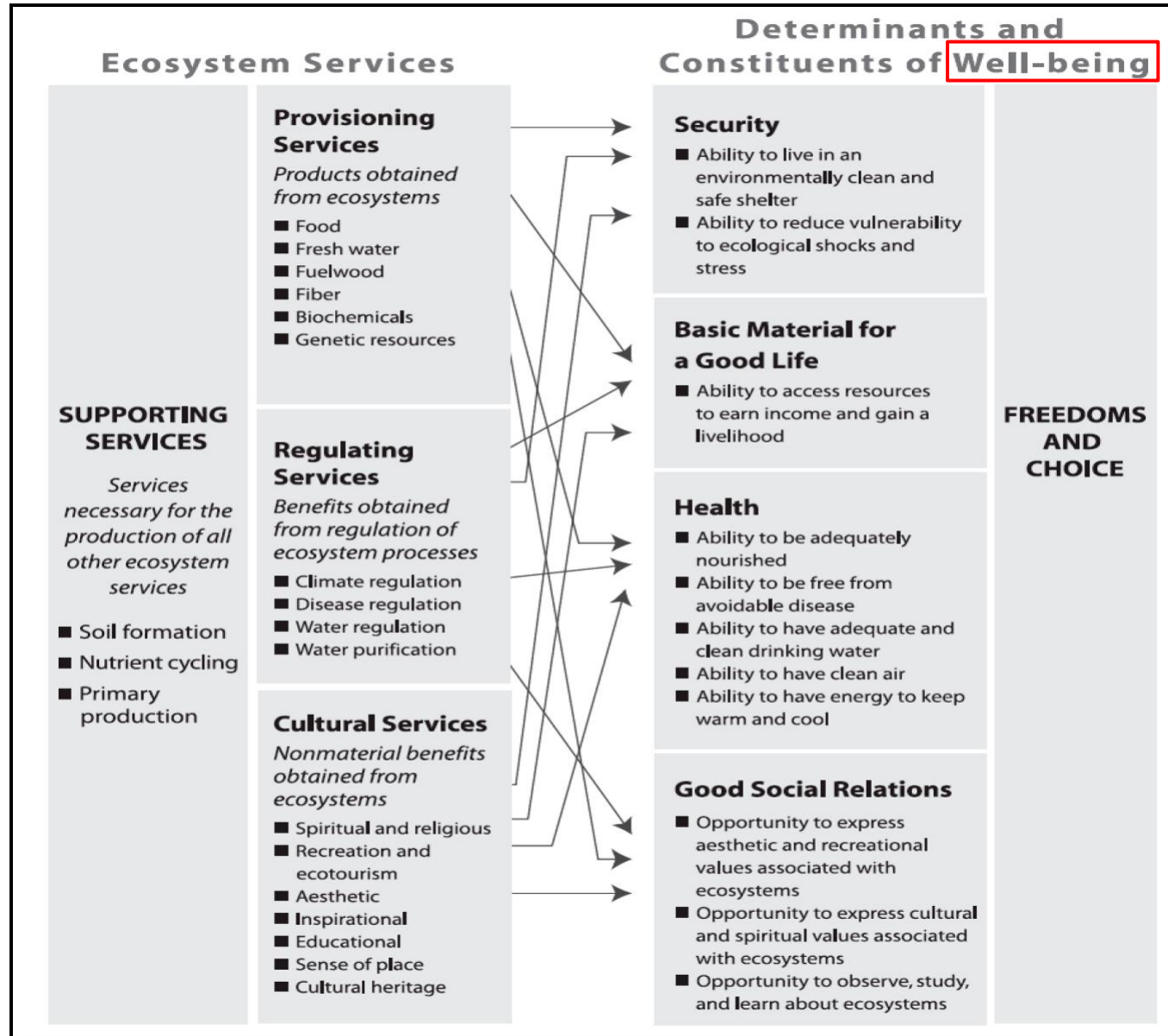
Gli ecosistemi della Terra forniscono all'umanità tutta una serie di vantaggi che vanno sotto il nome di ‘**servizi ecosistemici**’:

- servizi di approvvigionamento;
- servizi di regolazione;
- servizi culturali;
- servizi di supporto”.

*(Unione Europea, 2009)*



# Introduzione. Servizi Ecosistemici





# Introduzione. Il suolo come ecosistema

“Un ‘ecosistema’ è una combinazione complessa e dinamica di piante, animali, microrganismi e dell'ambiente naturale, che insieme costituiscono un sistema unico di elementi interdipendenti.

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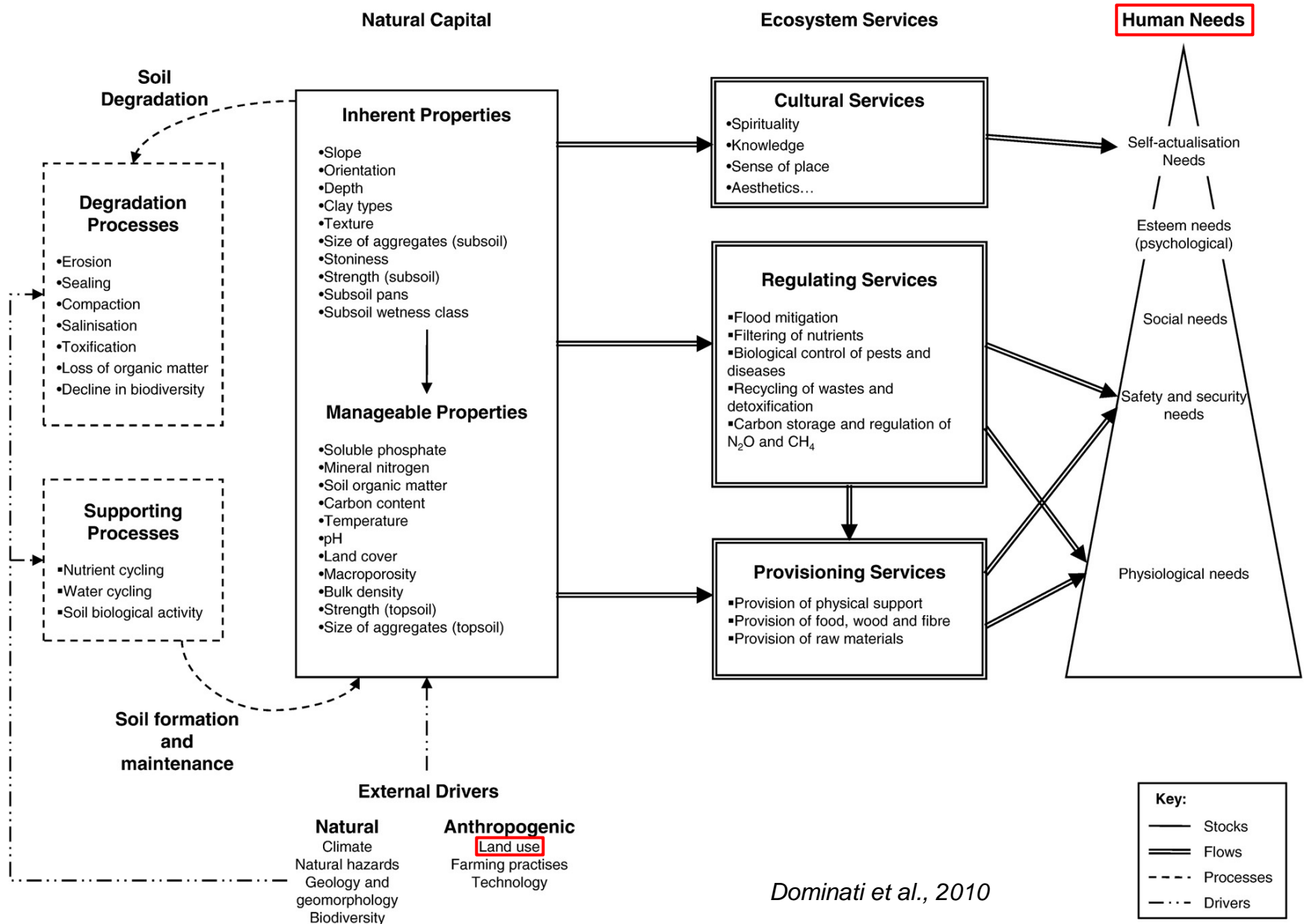
- servizi di approvvigionamento;
- servizi di regolazione;
- servizi culturali;
- servizi di supporto”.

*(Unione Europea, 2009)*

Consumo di suolo  
Land take, Soil sealing



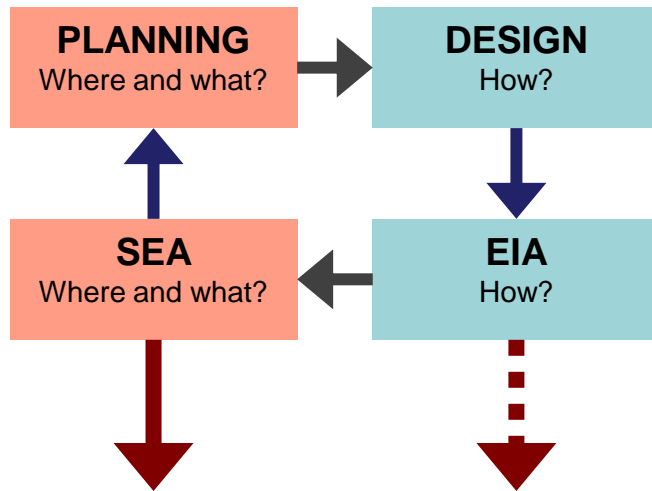
# Introduzione. Il suolo come ecosistema



*Dominati et al., 2010*



# Introduzione. L'impatto delle attività umane



Misure previste per **impedire, ridurre e compensare** nel modo più completo possibile gli eventuali effetti negativi significativi sull'ambiente dell'attuazione del piano/progetto

## Impatto

Possibili effetti significativi sull'ambiente, compresi aspetti quali:

- la biodiversità,
- la popolazione,
- la salute umana,
- la flora e la fauna,
- il suolo,
- **l'acqua**,
- l'aria,
- i fattori climatici,
- i beni materiali,
- il patrimonio culturale, anche architettonico e archeologico,
- il paesaggio,
- e l'interrelazione tra i suddetti fattori.

# Introduzione. Come agire per il futuro

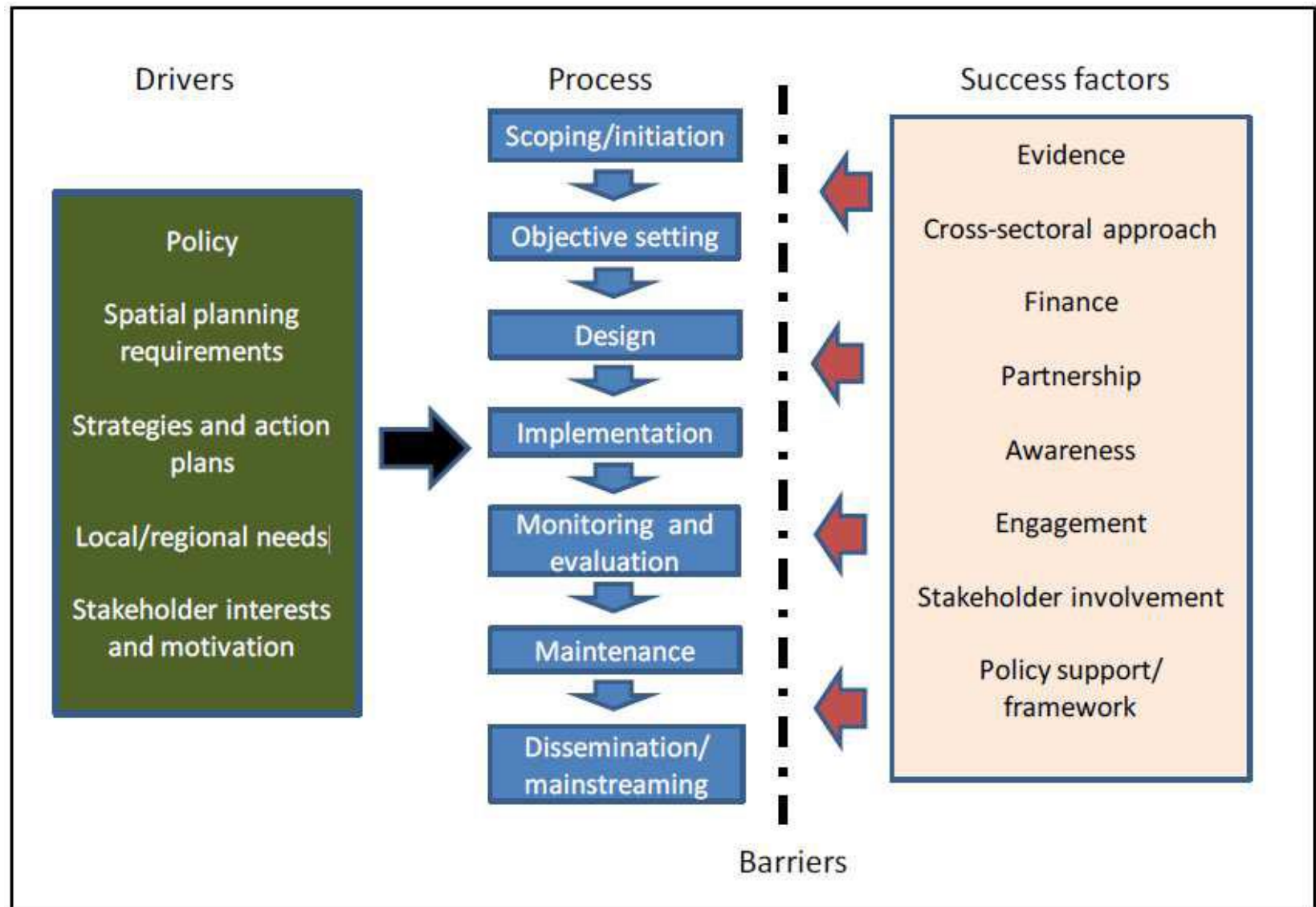


<b>Regolamentazioni</b>	<b>Incentivi e meccanismi di mercato</b>		<b>Informazione e partecipazione</b>
<b>Definizione di vincoli, obblighi e standard e ambientali</b>	<b>Utilizzo di mercati esistenti, attraverso</b>	<b>Creazione di nuovi mercati, attraverso</b>	
Standard e requisiti minimi di legge  Divieti e zone di protezione  Permessi, licenze e quote massime di prelievo  Zonizzazioni  Responsabilità legale	Sussidi, incentivi, contributi  Eco-tasse e/o sgravi fiscali  Tariffe per acquisto di servizi	Attribuzione/ri-attribuzione diritti di proprietà  Compravendita di permessi  Compravendita di quote/diritti sui mercati internazionali  Compravendita diretta di beni e servizi	Informazione e comunicazione  Consultazione degli <i>stakeholder</i>  Certificazioni volontarie, <i>green labelling</i> e <i>green marketing</i>  Partecipazione ai processi decisionali

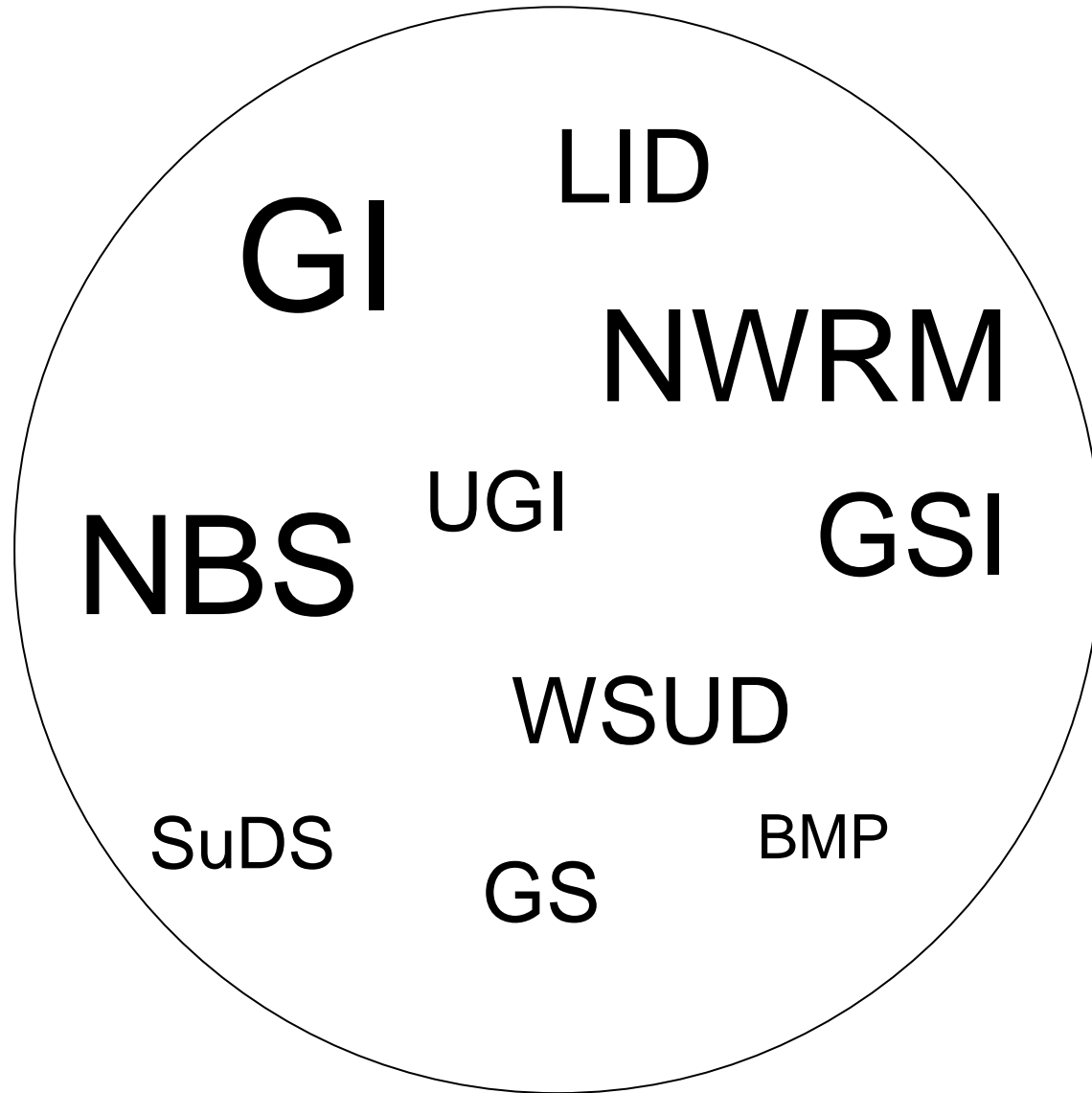
Tab. 2: Una possibile tassonomia degli strumenti per la gestione delle risorse ambientali. ( World Bank, 2003, modificata)



# Introduzione. Come agire per il futuro



# Introduzione





# Introduzione

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Green infrastructure (GI)  
Nature-Based Solutions (NBS)  
Low Impact development (LID)  
Natural Water Retention Measures (NWRM)  
Water-Sensitive Urban Design (WSUD)  
Best management Practices (BMP)  
Sustainable Drainage Systems (SuDS)  
Urban Green Infrastructure (UGI)  
Green Stormwater Infrastructure (GSI)  
Green Street (GS)

.....

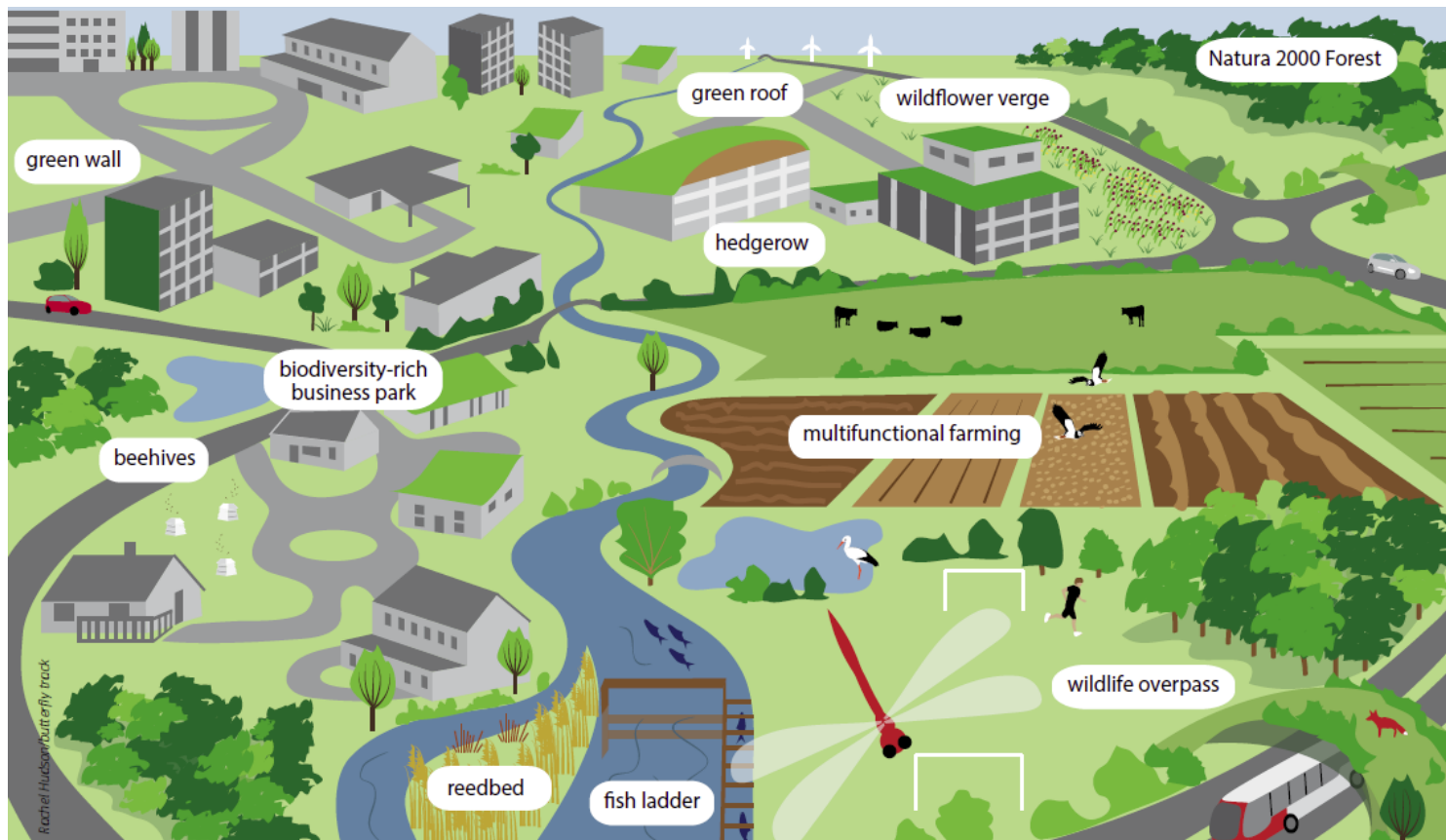


# Green Infrastructure

Una rete di **aree naturali e seminaturali pianificata a livello strategico** con altri elementi ambientali, **progettata e gestita** in maniera da fornire un ampio **spettro di servizi ecosistemici**.

Ne fanno parte gli **spazi verdi** (o blu, nel caso degli ecosistemi acquatici) e altri elementi fisici. Sulla terraferma, le infrastrutture verdi sono presenti in un **contesto rurale e urbano**.

(Commissione Europea, 2013)





# Green Infrastructure

Le infrastrutture verdi sono uno **strumento** di comprovata efficacia per ottenere **benefici ecologici, economici e sociali** ricorrendo a **soluzioni “naturali”**.

Rispetto alle infrastrutture tradizionali (dette anche **infrastrutture grigie**), concepite con un unico scopo, le **infrastrutture verdi presentano molteplici vantaggi**. A volte può rappresentare un'alternativa o una componente complementare rispetto alle tradizionali soluzioni “grigie”.

(Commissione Europea, 2013)

## Potential components of a Green Infrastructure



■ Core areas of high biodiversity value which act as hubs for GI, such as protected areas like Natura 2000 sites



■ Core areas outside protected areas containing large healthy functioning ecosystems



■ Restored habitats that help reconnect or enhance existing natural areas, such as a restored reedbed or wild flower meadow



■ Natural features acting as wildlife corridors or stepping stones, like small watercourses, ponds, hedgerows, woodland strips



■ Artificial features that enhance ecosystem services or assist wildlife movement such as eco-ducts or eco-bridges, fish ladders or green roofs



■ Buffer zones that are managed sustainably and help improve the general ecological quality and permeability of the landscape to biodiversity, e.g. wildlife-friendly farming



■ Multi-functional zones where compatible land uses can join forces to create land management combinations that support multiple land uses in the same spatial area, e.g. food production and recreation



# Green Infrastructure

Table 1: Green Infrastructure Benefits by Type

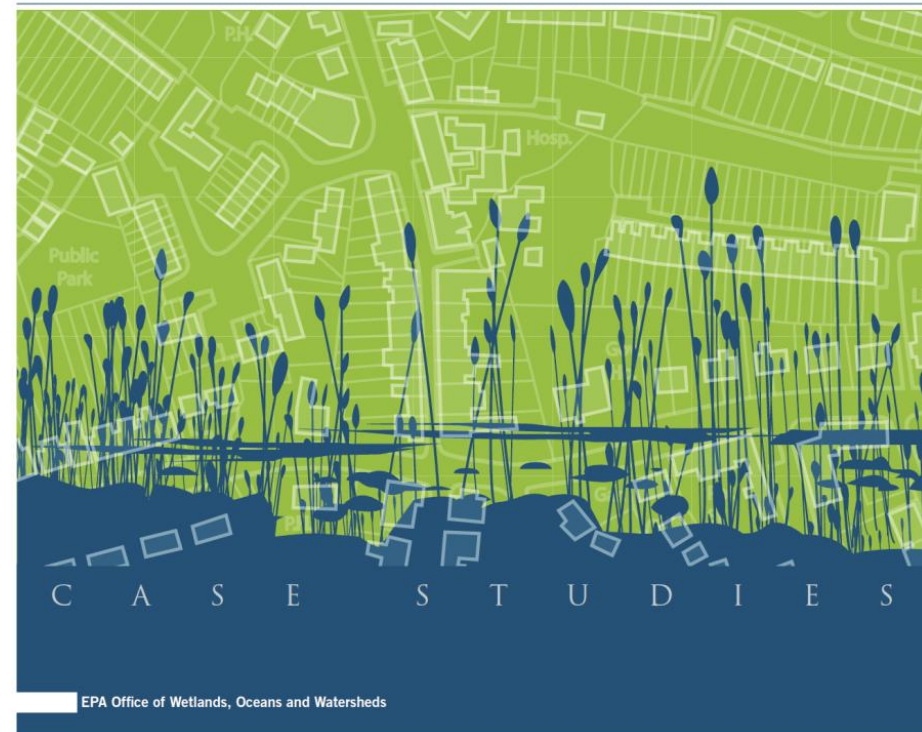
Benefit	Type
Environmental	<ul style="list-style-type: none"> <li>• Increase carbon sequestration</li> <li>• Improve air quality</li> <li>• Additional recreational space</li> <li>• Efficient land use</li> <li>• Improve human health</li> <li>• Flood protection</li> <li>• Drinking water source protection</li> <li>• Replenish groundwater</li> <li>• Improve watershed health</li> <li>• Protect or restore wildlife habitat</li> <li>• Reduce sewer overflow events</li> <li>• Restore impaired waters</li> <li>• Meet regulatory requirements for receiving waters</li> </ul>
Economic	<ul style="list-style-type: none"> <li>• Reduce hard infrastructure construction costs</li> <li>• Maintain aging infrastructure</li> <li>• Increase land values</li> <li>• Encourage economic development</li> <li>• Reduce energy consumption and costs</li> <li>• Increase life cycle cost savings</li> </ul>
Social	<ul style="list-style-type: none"> <li>• Establish urban greenways</li> <li>• Provide pedestrian and bicycle access</li> <li>• Create attractive streetscapes and rooftops that enhance livability and urban green space</li> <li>• Educate the public about their role in stormwater management</li> <li>• Urban heat island mitigation</li> </ul>



EPA-841-F-10-004 | August 2010 | <http://www.epa.gov>

## GREEN INFRASTRUCTURE CASE STUDIES:

*Municipal Policies for Managing Stormwater with Green Infrastructure*



EPA Office of Wetlands, Oceans and Watersheds





# Green Infrastructure



## Benefits provided by Green Infrastructure

### Environmental benefits

- Provision of clean water
- Removal of pollutants from air and water
- Pollination enhancement
- Protection against soil erosion
- Rainwater retention
- Increased pest control
- Improvement of land quality
- Mitigation of land take and soil sealing

### Social benefits

- Better health and human well-being
- Creation of jobs
- Diversification of local economy
- More attractive, greener cities
- Higher property values and local distinctiveness
- More integrated transport and energy solutions
- Enhanced tourism and recreation opportunities

### Climate change adaptation and mitigation benefits

- Flood alleviation
- Strengthening ecosystems resilience
- Carbon storage and sequestration
- Mitigation of urban heat island effects
- Disaster prevention (e.g. storms, forest fires, landslides)

### Biodiversity benefits

- Improved habitats for wildlife
- Ecological corridors
- Landscape permeability

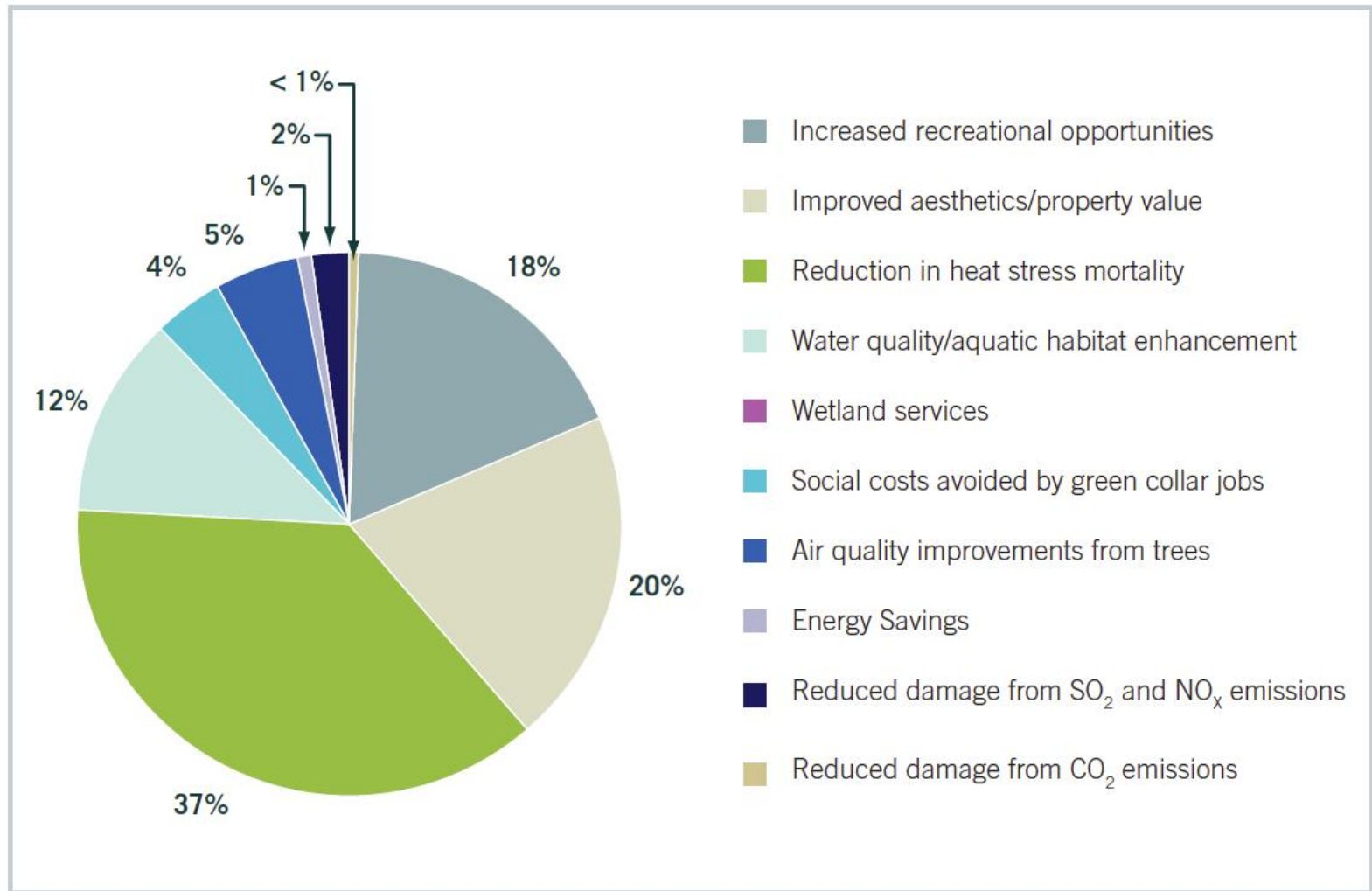


# Green Infrastructure

Multi-scopo  
Multi-funzione  
“Multi-benefici”



# Green Infrastructure

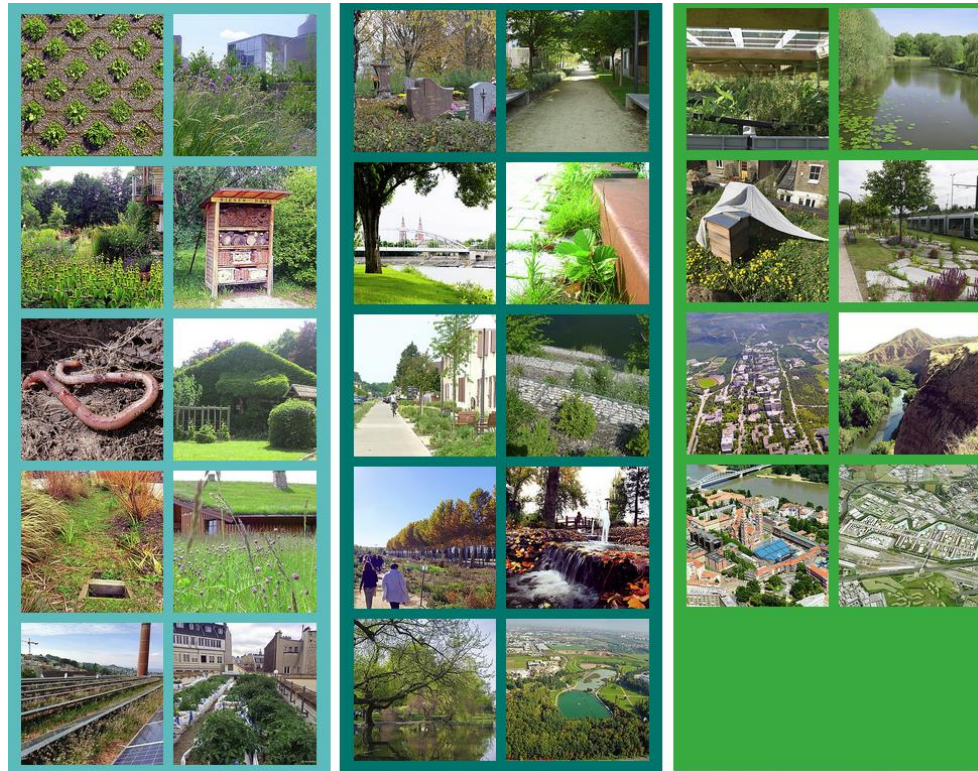
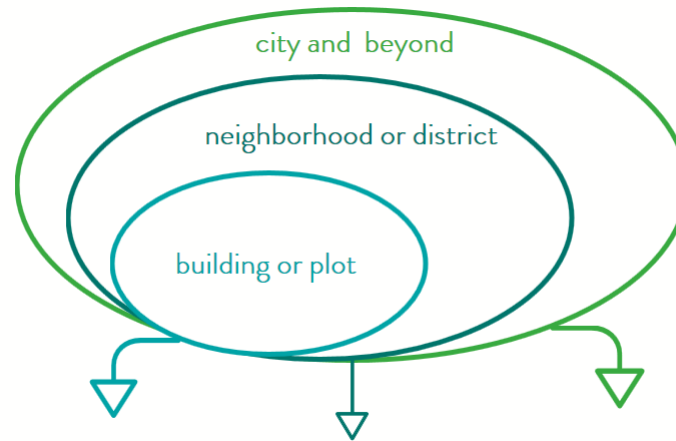


**Figure 15:** Citywide net benefits for green infrastructure options. Courtesy of Philadelphia Water Department.  
[http://www.phillywatersheds.org/lcpcu/Vol02\\_TBL.pdf](http://www.phillywatersheds.org/lcpcu/Vol02_TBL.pdf)



# Green Infrastructure

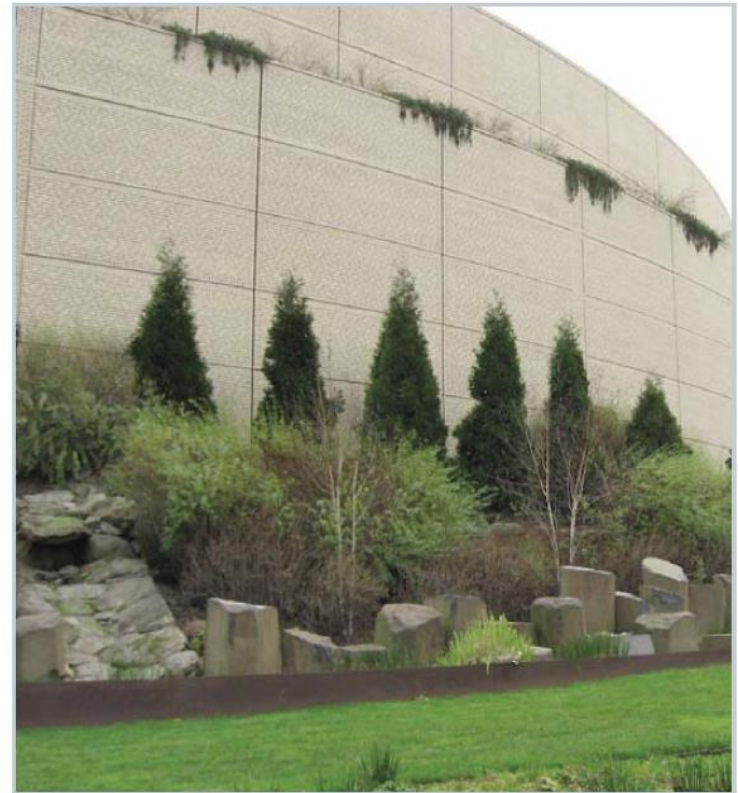
Multi-scopo  
Multi-funzione  
“Multi-benefici”  
Multi-scala



# Green Infrastructure

## TYPES OF LOCAL INCENTIVES FOR GREEN INFRASTRUCTURE

- **Fee Discount:** Requires a stormwater fee that is based on impervious surface area. If property owners can reduce need for service by reducing impervious area, the municipality reduces the fee.
- **Development Incentives:** Offered to developers during the process of applying for development permits. Includes zoning upgrades, expedited permitting, reduced stormwater requirements, etc.
- **Rebates & Installation Financing:** Gives funding, tax credits or reimbursements to property owners who install specific practices. Often focused on practices needed in certain areas or neighborhoods.
- **Awards & Recognition Programs:** Provides marketing opportunities and public outreach for exemplary projects. May include monetary awards.



*Figure 12: Oregon Convention Center saves \$15,600 per year on its stormwater bill by managing roof runoff in these rain gardens.*

# Green Infrastructure



1

## Local authorities

### Turn strategic GI thinking into reality

Ensure that GI is a core requirement in local authority documents, such as Local Plans, Infrastructure Development Plans and development briefs. Proper consideration should also be given to the potential for multifunctional GI to perform some of the roles that 'grey' infrastructure is used for, particularly water management and waste. Why? Not only does GI tend to be cheaper, but it also provides infrastructure that is resilient to an increasingly unpredictable climate.

2

## Local authorities and Business Improvement Districts

### Promote collaboration on GI across boundaries

By its nature, GI often crosses administrative and operational boundaries, so it should be addressed through the Duty to Cooperate between local authorities. It should also be part of the remit of business improvement districts and Local Enterprise Partnerships.

3

## Developers

### New developments should make a contribution to GI

Developers should be aware of an area's strategic GI goals and appreciate their role both in mitigating the environmental impacts of new development and in creating beautiful places. Even small interventions contribute to the overall success of GI, so developers should engage with local communities.

4

## Clients

### Champion GI that is planned, designed and managed effectively

Successful GI is part of a shared vision – one that appreciates landscape character, sense of place and functionality. Make sure that strategies clearly articulate the vision, priorities, responsibilities and actions needed to plan, deliver and manage GI projects, from the start. Public and private sector landowners and managers should be involved in the planning and design of GI, as their buy-in and expertise is vital to its long-term success.

5

## Landowners

### Ensure GI is well-funded for ongoing management and maintenance

Management and maintenance are critical if GI is to continue to deliver long-term benefits. By thinking creatively about how to generate capital and revenue, multifunctional land can be funded from several sources. These could include direct income from renewable energy, food production or events, or indirect savings by reducing flood risk and cutting the cost of cooling in urban areas during hot weather.

6

## Landscape professionals

### Raise awareness of how GI can deliver multiple benefits simultaneously, from boosting the bottom line to mitigating the effects of climate change

Landscape professionals need to appreciate what drives their clients. They advise clients, colleagues and decision-makers about the value of GI, from country parks and community woodlands, to development-specific interventions such as green roofs and sustainable drainage systems. The range of benefits that GI can deliver needs to be communicated to them in a way that resonates with their own objectives.



# Green Infrastructure

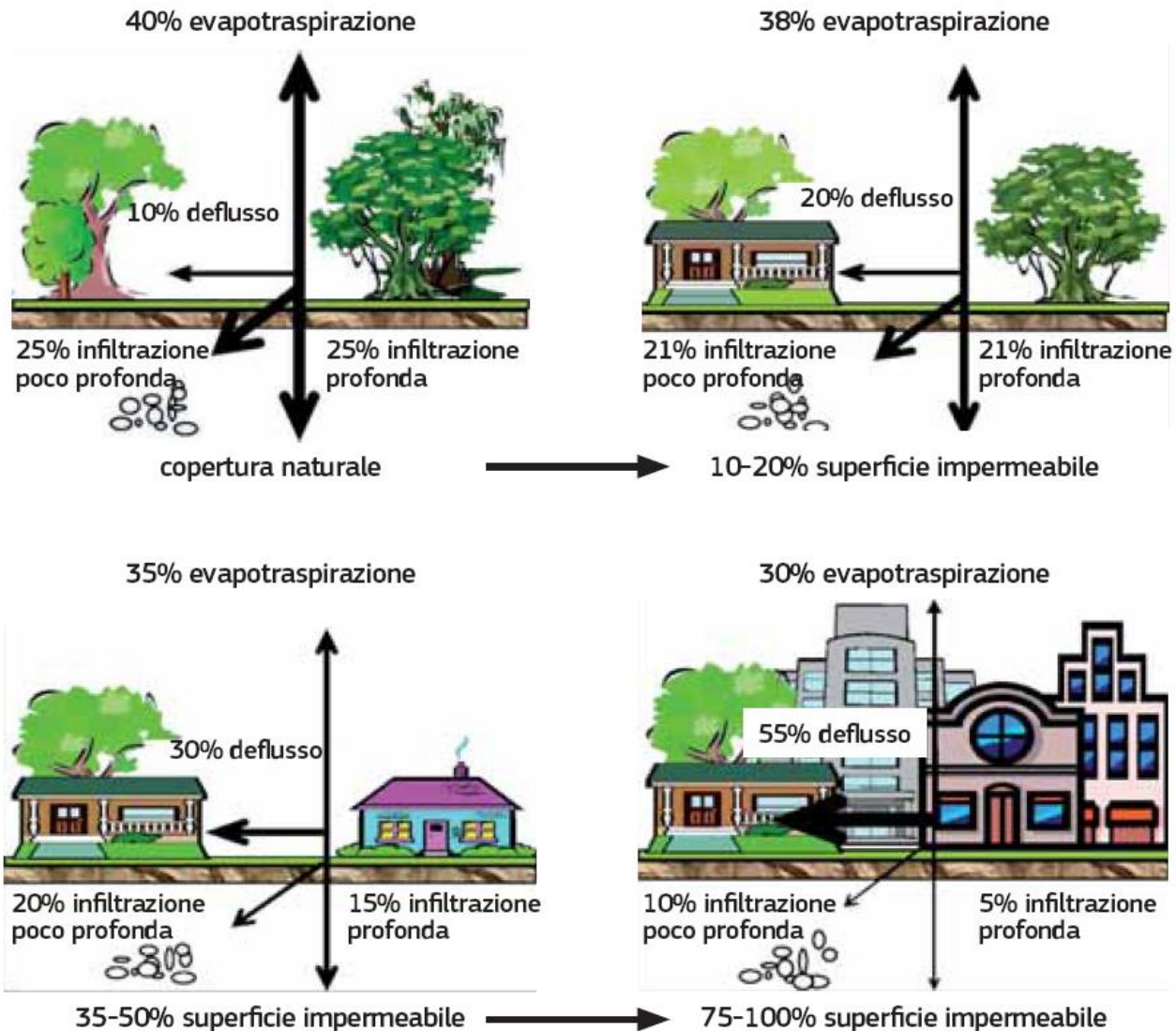
An integrated approach to land use

**Landscape Institute** Position Statement

# Green Infrastructure



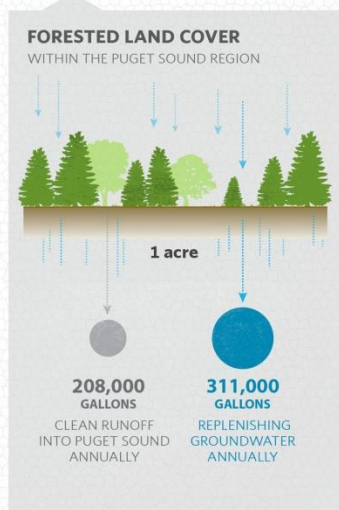
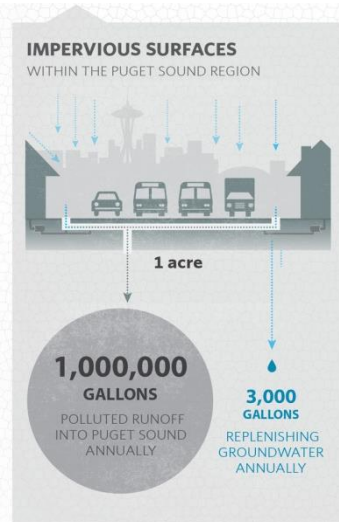
# Green Infrastructure for stormwater managing





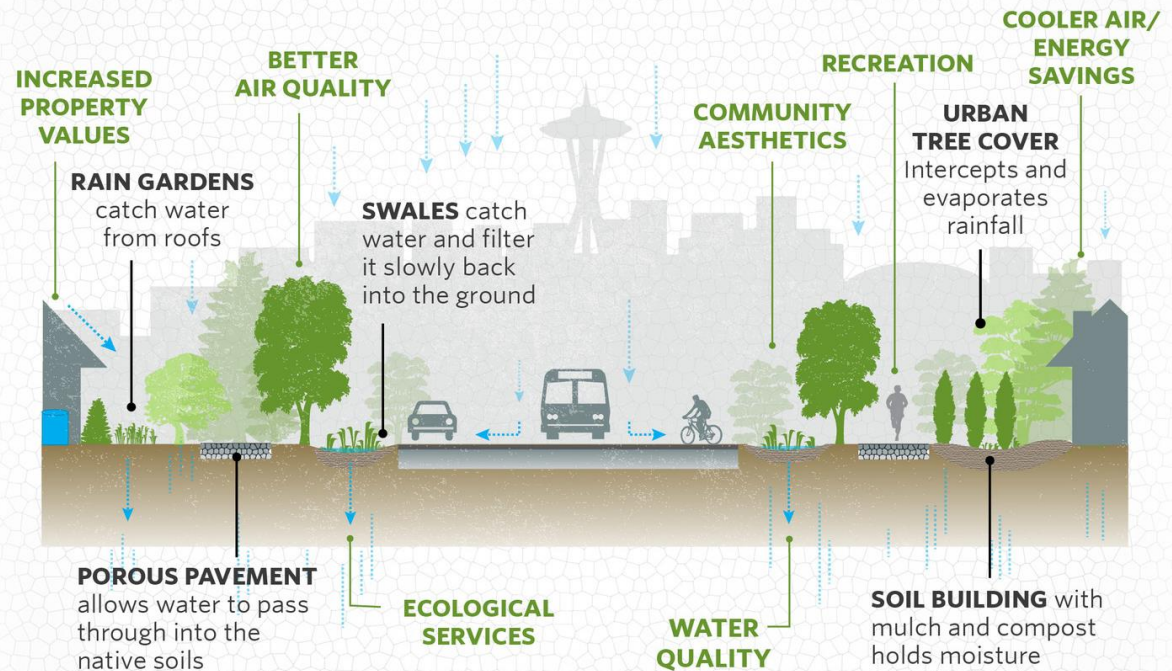
# Green Infrastructure for stormwater managing

## Il problema



## HOW ARE WE RETHINKING THE PROBLEM?

Re-envisioning and re-designing cities to function more like forests so water is absorbed back into the ground, in addition to treating stormwater through traditional means, will solve our region-wide stormwater problem.



### GREEN & GRAY STORMWATER INFRASTRUCTURE

A study by the city of Philadelphia has shown a hybrid approach of green and gray infrastructure can get the same freshwater solutions as gray infrastructure, plus additional benefits to the community.

















# Green Infrastructure for stormwater managing

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					
	Water temperature control	Constructing wetlands					Dams
		Re/afforestation and forest conservation					
		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)					

# Green Infrastructure for stormwater managing

**Table 3 Ecosystem services provided by GI solutions. Blue cells mark services directly related to water management issues while light blue mark co-benefits. Icon design: Jan Sasse for TEEB.**

	Ecosystem services (TEEB classification)																
	Provisional				Regulating							Supporting		Cultural			
	Water supply	Food production	Raw materials	Medicinal resources	Temperature control	Carbon Sequestration + storage	Moderation of extreme events	Water purification	Erosion control (incl. shoreline)	Pollination	Biological control	Habitats for species	Maintenance of genetic diversity	Recreation	Tourism	Aesthetic/cultural value	Spiritual experience
GI solution																	
Re/afforestation and forest conservation																	
Riparian buffers																	
Wetlands restoration/conservation																	
Constructing wetlands																	
Reconnecting rivers to floodplains																	
Establishing flood bypasses																	
Water harvesting																	
Green roofs																	
Green spaces (Bioretention and infiltration)																	
Permeable pavements																	
Protecting/restoring mangroves, marshes and dunes																	
Protecting/restoring reefs (coral/oyster)																	



# Green Infrastructure for stormwater managing

## REGIONAL GREEN INFRASTRUCTURE STRATEGIES

Green infrastructure strategies capture stormwater, provide natural flood management, and bring a multitude of benefits to municipalities and residents. Each strategy shown below has already been implemented throughout the region, and much more is needed to achieve the 2035 Vision goals. The Plan focuses heavily on the strategies that would treat impervious surfaces and turf grass areas to provide economic, social, and environmental benefits to the region.



**GREEN ROOFS**

Business owners and public property owners with large flat roofs were mapped in the Plan and are encouraged to participate in the Regional Green Roof Initiative Program.



**POROUS PAVEMENT**

The Plan recommends use of porous materials for public and private streets and parking lots.



**GREEN ALLEYS, STREETS, AND PARKING LOTS**

The Plan calls for green alleys, streets, and parking lots that include several green infrastructure strategies, offering multiple economic, social, and environmental benefits.



**RAIN GARDENS AND SOIL AMENDMENTS**

The Plan encourages residents to plant rain gardens to prevent stormwater from entering the sewer system too quickly. The Plan includes soil amendments to increase water holding capacity in lawns and improve grass growth when native landscaping is not preferred.



**WETLANDS**

Wetlands (not quantified in this Plan) also known as bogs, marshes, and swamps allow rainwater to pool and slowly infiltrate into the ground.



**RAINWATER CATCHMENT**

The Plan encourages residents and business owners to harvest rainwater. Doing so reduces energy costs and reduces unwanted stormwater from entering the sewer system.



**NATIVE LANDSCAPING**

The Plan encourages the public, business owners, and municipalities to replace turf grass with native landscaping to reduce runoff and save money through reduced landscape maintenance.



**BIORETENTION/BIOSWALES**

Bioretention and bioswales can be used along transportation corridors and parking lots.



**STORMWATER TREES**

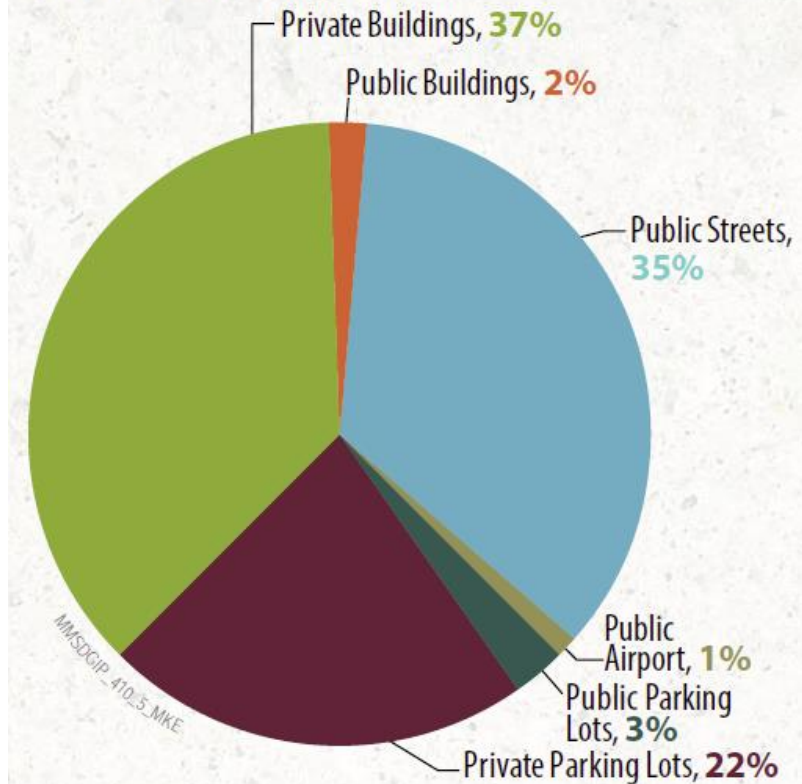
The Plan encourages municipalities to plant trees. They hold rainwater on their leaves and branches, infiltrate it into the ground, absorb it through root systems and evapotranspire it to the atmosphere.



**GREENWAYS**

Greenways (not quantified in this Plan) include riparian and non-riparian buffer zones and strips that store and drain stormwater runoff into the ground naturally.

## Impervious Area by Type and Ownership in the MMSD Planning Area



# Green Stormwater Infrastructure



GSI Tool		How it Works	Benefits	GSI Tool		How it Works	Benefits
Bioretention		 SOAKS IN  SLOWS  CLEANS	<ul style="list-style-type: none"> <li>Can manage large amounts of runoff</li> <li>Can be designed to calm traffic</li> <li>Adds beauty, habitat, and green space</li> <li>Protects against future flooding risks due to climate change</li> <li>Can be used for Green Factor requirements</li> </ul>	Permeable Paving		 SOAKS IN	<ul style="list-style-type: none"> <li>Manages runoff and maintains a durable driving surface for cars and people</li> <li>Can add visual interest/design detail</li> </ul>
Rain Gardens		 SOAKS IN  SLOWS  CLEANS	<ul style="list-style-type: none"> <li>Manages runoff from roofs, paths, driveways</li> <li>Adds beauty and habitat to your property</li> <li>No technical knowledge is required for routine maintenance</li> </ul>	Green Roofs		 SLOWS  EVAPORATES	<ul style="list-style-type: none"> <li>Adds more green space to your property</li> <li>Adds habitat for birds and beneficial insects</li> <li>Improves air quality</li> <li>Has potential for LEED™ credits</li> <li>May be designed for food production</li> </ul>
Stormwater Cisterns		 SLOWS  STORES + REUSES	<ul style="list-style-type: none"> <li>Easy to design, install, and maintain</li> <li>During winter, cistern slowly releases water to yard or side sewer to make room for more</li> <li>During summer, water can be used for irrigation and can reduce overall water use</li> </ul>	Depaving		 SLOWS  SOAKS IN	<ul style="list-style-type: none"> <li>Frees up underutilized paved space for trees, plantings, and other uses, including GSI</li> <li>Allows stormwater to soak into the ground where it falls instead of picking up and carrying pollutants into creeks and waterways</li> <li>Can restore habitats for birds, insects, and other wildlife</li> </ul>
Dispersion		 SLOWS  SOAKS IN	<ul style="list-style-type: none"> <li>Manages runoff from roof, paths and driveways</li> <li>Inexpensive in settings with sufficient space</li> </ul>	Tree Canopy		 SLOWS  EVAPORATES	<ul style="list-style-type: none"> <li>Tree planting and care is easy and fun</li> <li>Mature trees improves air quality</li> <li>Trees offer cool shade in summer and protect against harsh wind in winter</li> <li>Adds beauty and green space to urban areas</li> </ul>
Dry Well/ Infiltration Trench		 SLOWS  SOAKS IN	<ul style="list-style-type: none"> <li>Manages runoff from roof, paths and driveways</li> <li>Inexpensive in settings with sufficient space</li> </ul>	Compost & Mulch		 SLOWS  SOAKS IN	<ul style="list-style-type: none"> <li>Mulching is easy</li> <li>Amending soil with compost helps rain soak in and builds healthier landscapes</li> <li>Saves money by reducing need for irrigation, fertilizers and pesticides</li> </ul>
Biofiltration		 SLOWS  CLEANS	<ul style="list-style-type: none"> <li>Cleans large amounts of runoff</li> <li>Can add beauty and habitat to a range of sites</li> </ul>				

Seattle  
Public  
Utilities



Department of  
Natural Resources and Parks  
Wastewater Treatment  
Division

## Green Stormwater Infrastructure in Seattle

[www.700MillionGallons.org](http://www.700MillionGallons.org)

Working Together to Protect our Waterways

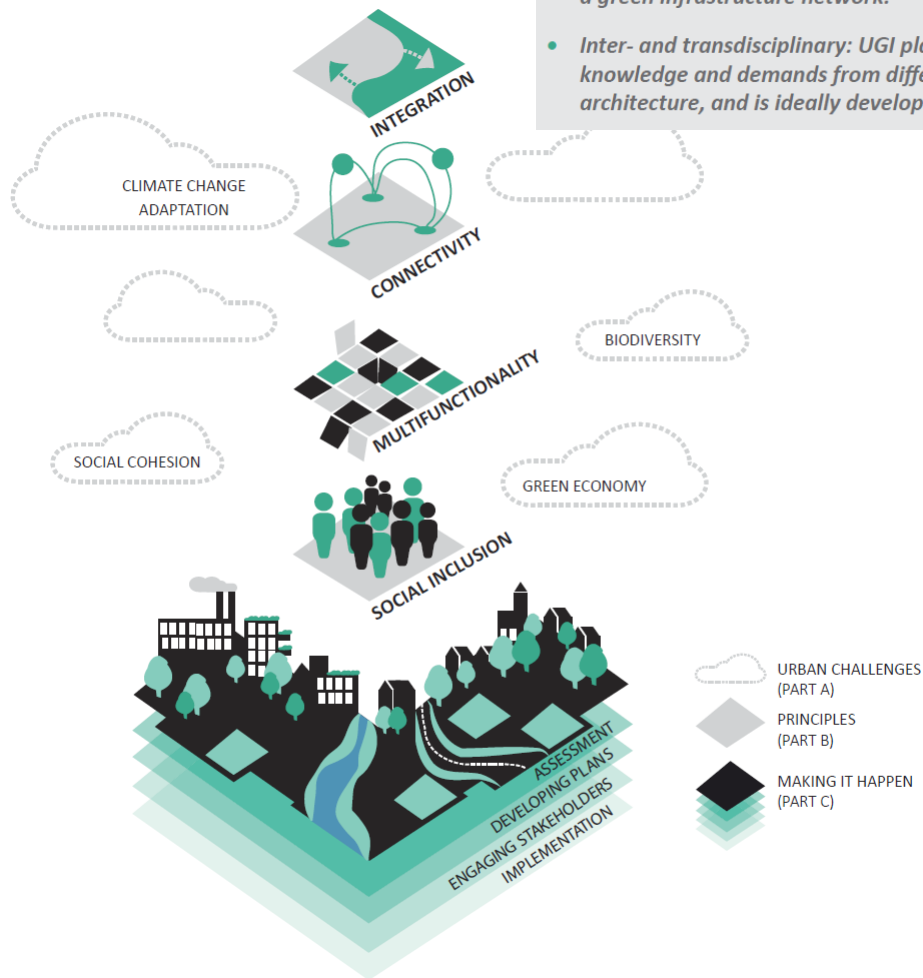


# Urban Green Infrastructure

## SUPPORTING PRINCIPLES

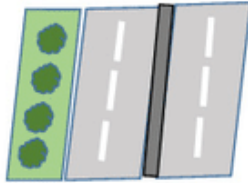
While the four core principles provide a fundamental basis for UGI planning, certain supporting principles should be also taken into account:

- *Multi-scale: UGI planning aims to link different spatial levels, ranging from metropolitan regions to individual sites.*
- *Multi-object: All types of urban green and blue spaces, regardless of ownership and origin, can be considered as part of a green infrastructure network.*
- *Inter- and transdisciplinary: UGI planning aims at linking disciplines, as well as science, policy and practice. It integrates knowledge and demands from different fields, such as landscape ecology, urban and regional planning, and landscape architecture, and is ideally developed in partnership between local authorities and other stakeholders.*

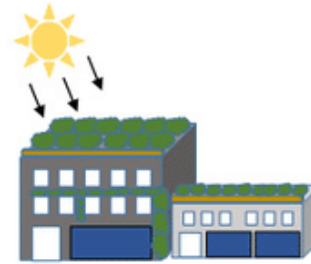




# Urban Green Infrastructure



Roadside vegetation in the form of bioswales can reduce runoff from impervious surfaces. The key factor is degree of permeability of the soil which can be enhanced through the selection of different vegetation.



Direct application of plants to the building envelope. Green walls (vine coverage or specially designed modules), and green roofs can contribute to building thermoregulation.



Street vegetation can help to provide shade, as well as a greater sense of wellbeing for residents in urban areas. It can also be used to create green corridors to improve biodiversity.

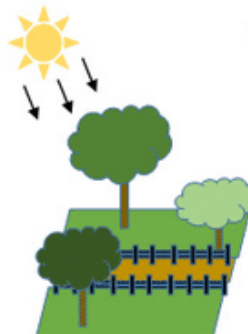


**Green Infrastructure.**

**The integration of plants  
in the urban environment**



Courtyards have been part of vernacular architecture in tropical climates for centuries. When combined with passive ventilation systems they provide cooler air at ground level.

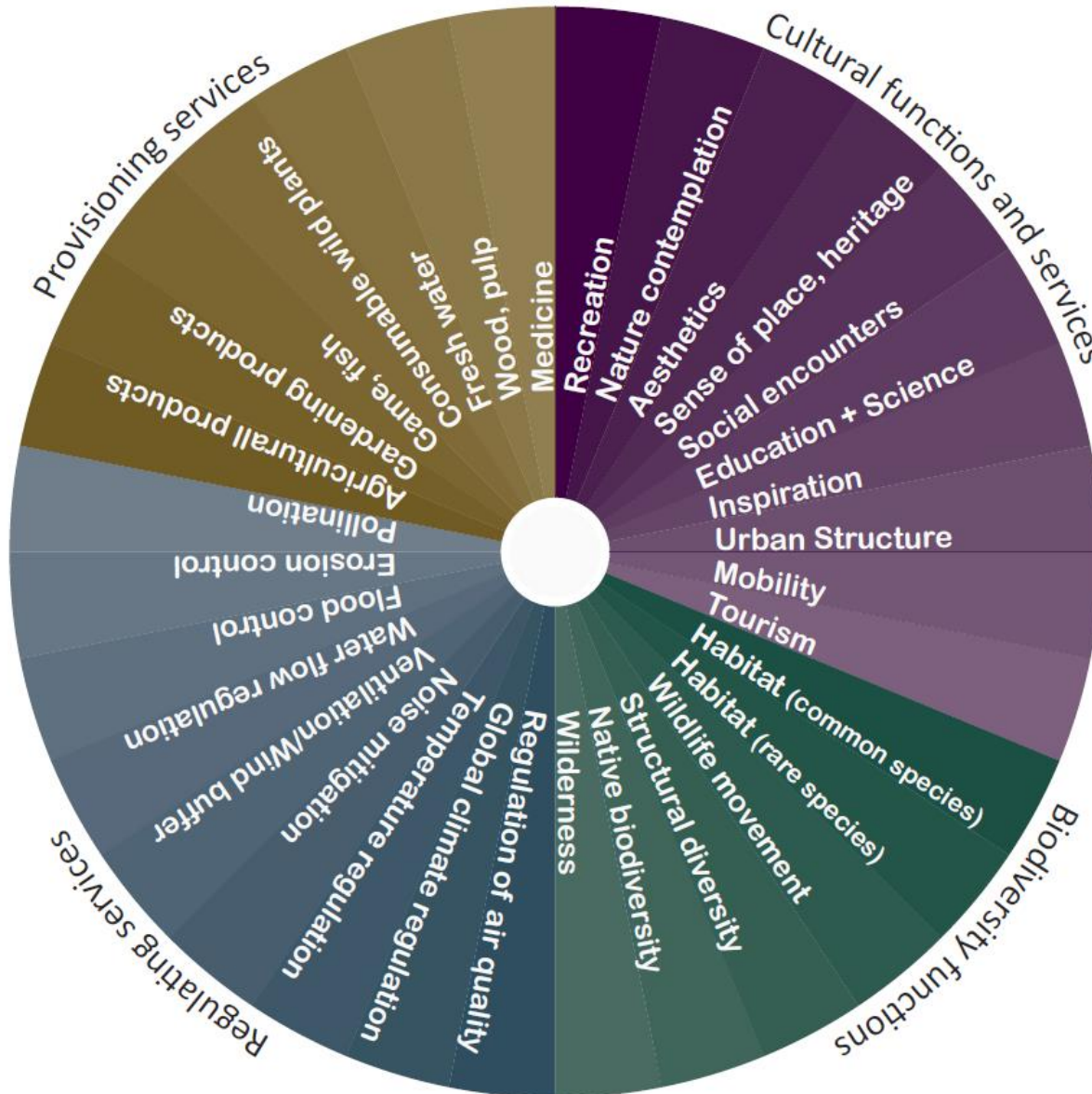


Urban parks can be vital to biodiversity in the urban ecosystem as well as providing space for recreation. Green spaces like parks can sequester more CO<sub>2</sub> than previously assumed and also contribute heavily to absorbing storm water.



Street trees contribute to the fixation of CO<sub>2</sub> and remediation of air pollution. When designed correctly they also provide shading and run-off reduction benefits. Different species are more suited to these application than others

# Urban Green Infrastructure



## Assessment of selected services



### Cultural

- Recreation (active)
- Nature contemplation (passive)
- Aesthetics
- Social encounters
- Mobility



### Biodiversity

- Habitat for rare species
- Structural diversity
- Native biodiversity



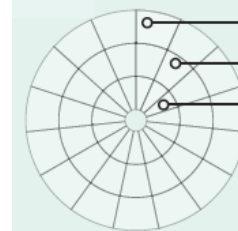
### Regulating

- Urban temperature regulation
- Noise mitigation
- Run-off mitigation
- Flood control (water retention)
- Pollination



### Provisioning

- Farming/Gardening products
- Consumable wild plants



High provision

Medium provision

Low provision

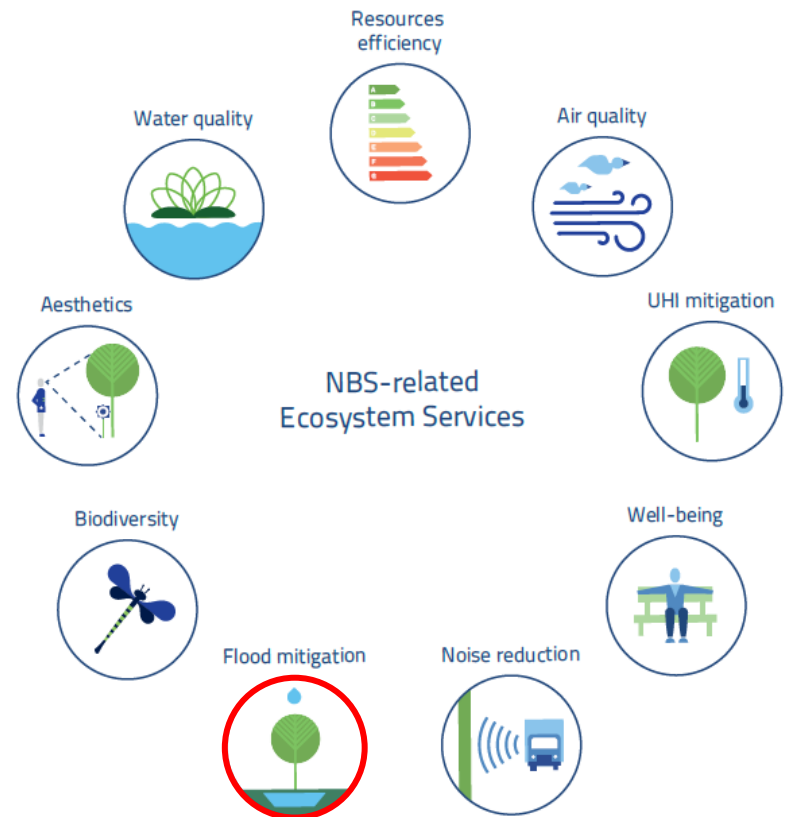
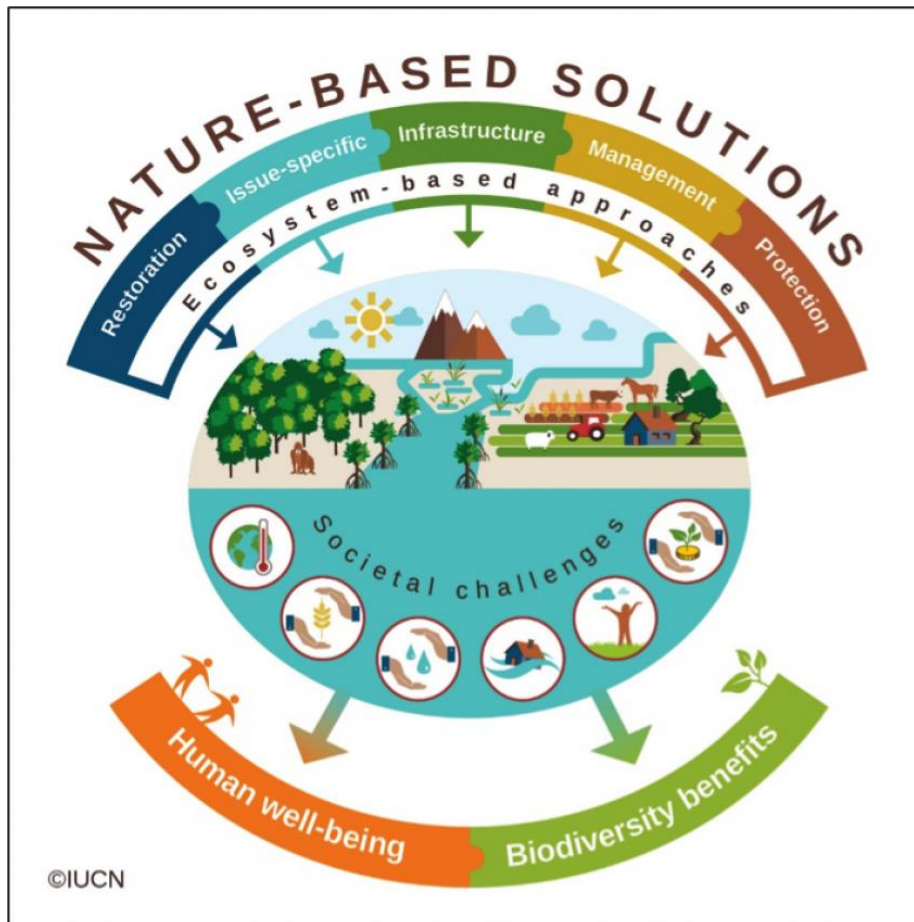
*Urban green spaces provide a range of functions and services which can be grouped into four broad types.*

*Credit: Rieke Hansen*

# NatureBased Solutions

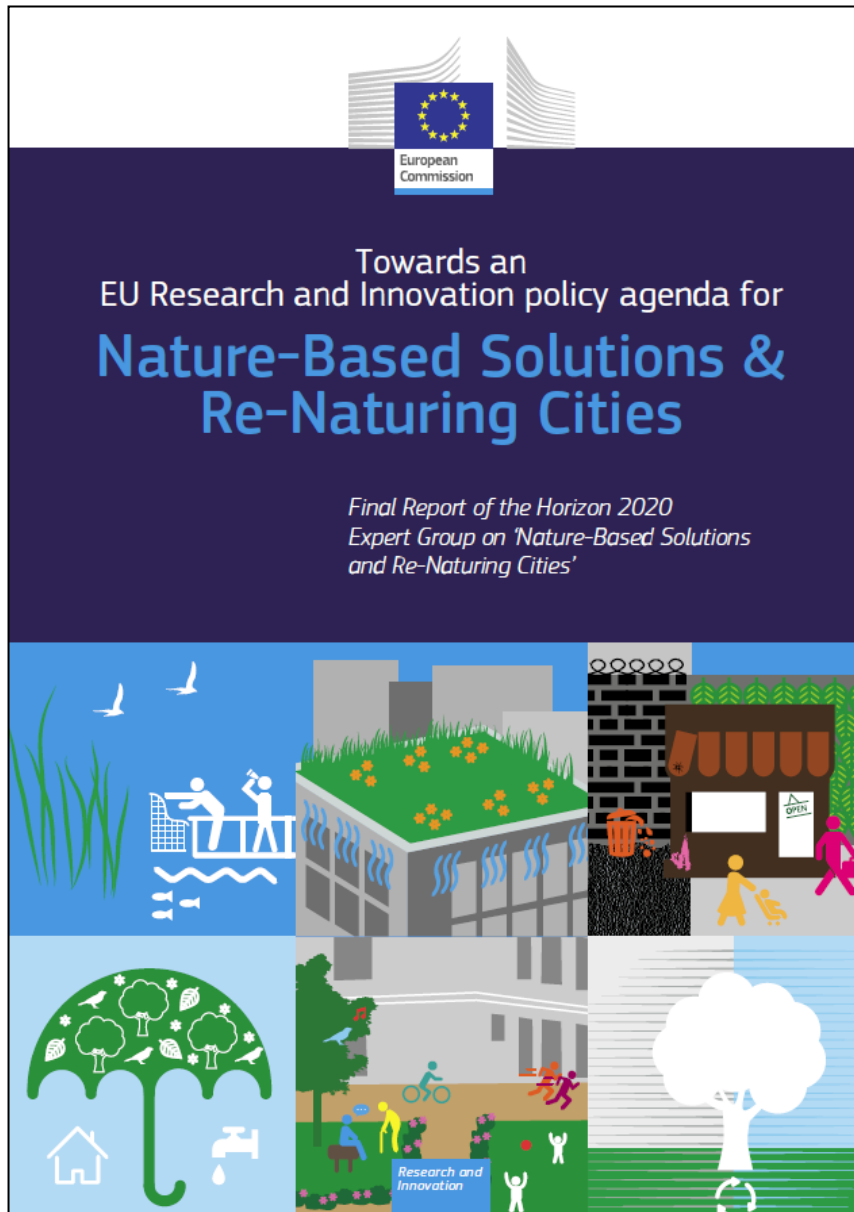
**NatureBased Solutions** (NBSs) are **actions** to **protect**, sustainably **manage**, and **restore** natural or modified **ecosystems**, that address societal challenges effectively and adaptively, **simultaneously providing human well-being and biodiversity benefits** (IUNC, 2016).








NBSs **range in scale**, from individual street **trees**, **green roofs** and **private gardens** through to **parks**, **rivers** and **woodlands**, **transport corridors**, and, at the larger scale, **wetlands**, **forests** and **agricultural land**.



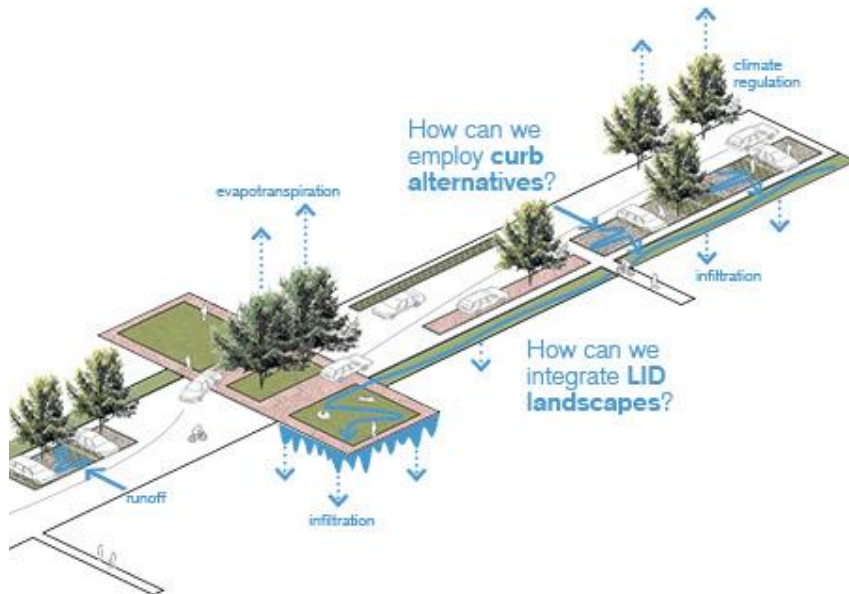
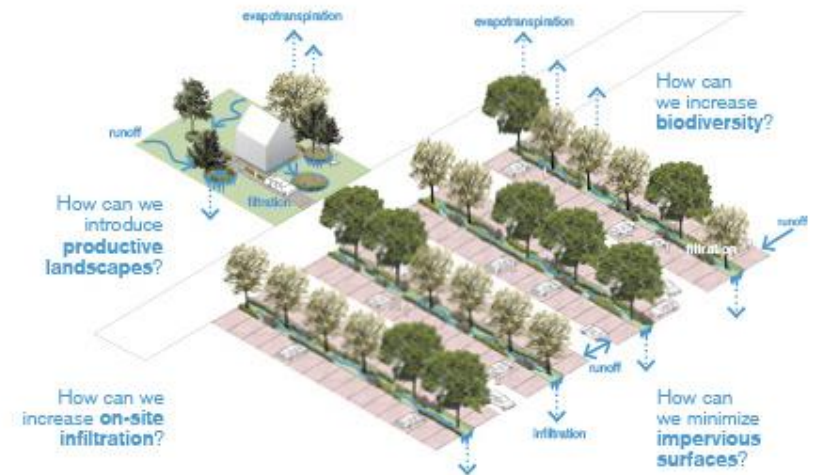
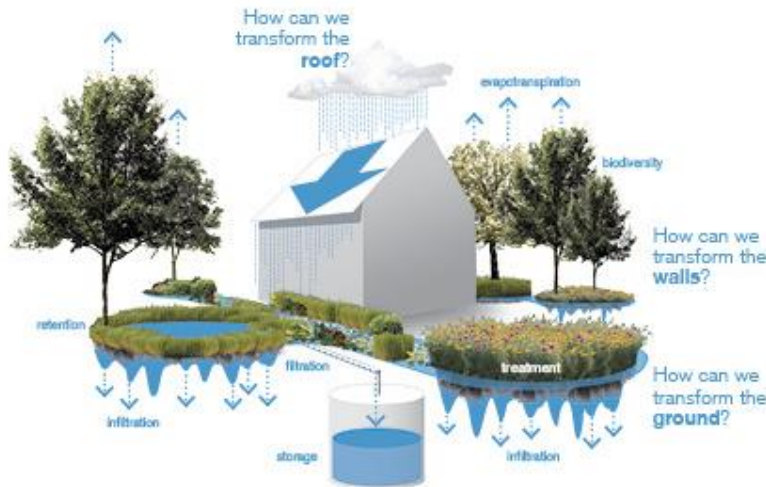


# NatureBased Solutions

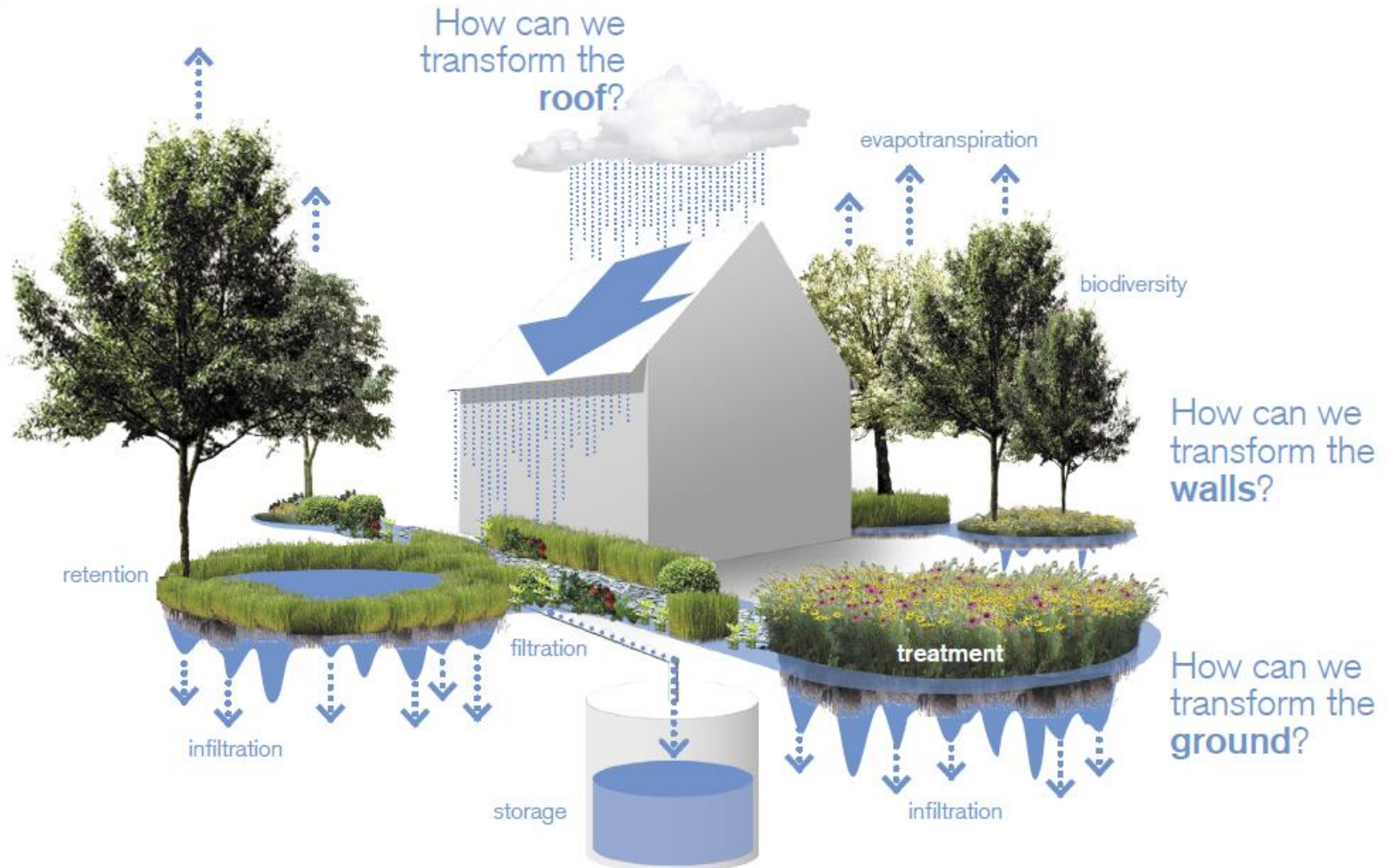


Research & Innovation Agenda on Nature-Based Solutions and Re-Naturing Cities	
Goals	Research & Innovation Actions
Enhancing sustainable urbanisation	 Urban regeneration through nature-based solutions  Nature-based solutions for improving well-being in urban areas
Restoring degraded ecosystems	 Establishing nature-based solutions for coastal resilience  Multi-functional nature-based watershed management and ecosystem restoration
Developing climate change adaptation and mitigation	 Nature-based solutions for increasing the sustainable use of matter and energy  Nature-based solutions for enhancing the insurance value of ecosystems
Improving risk management and resilience	 Increasing carbon sequestration through nature-based solutions

# NatureBased Solutions at different scales

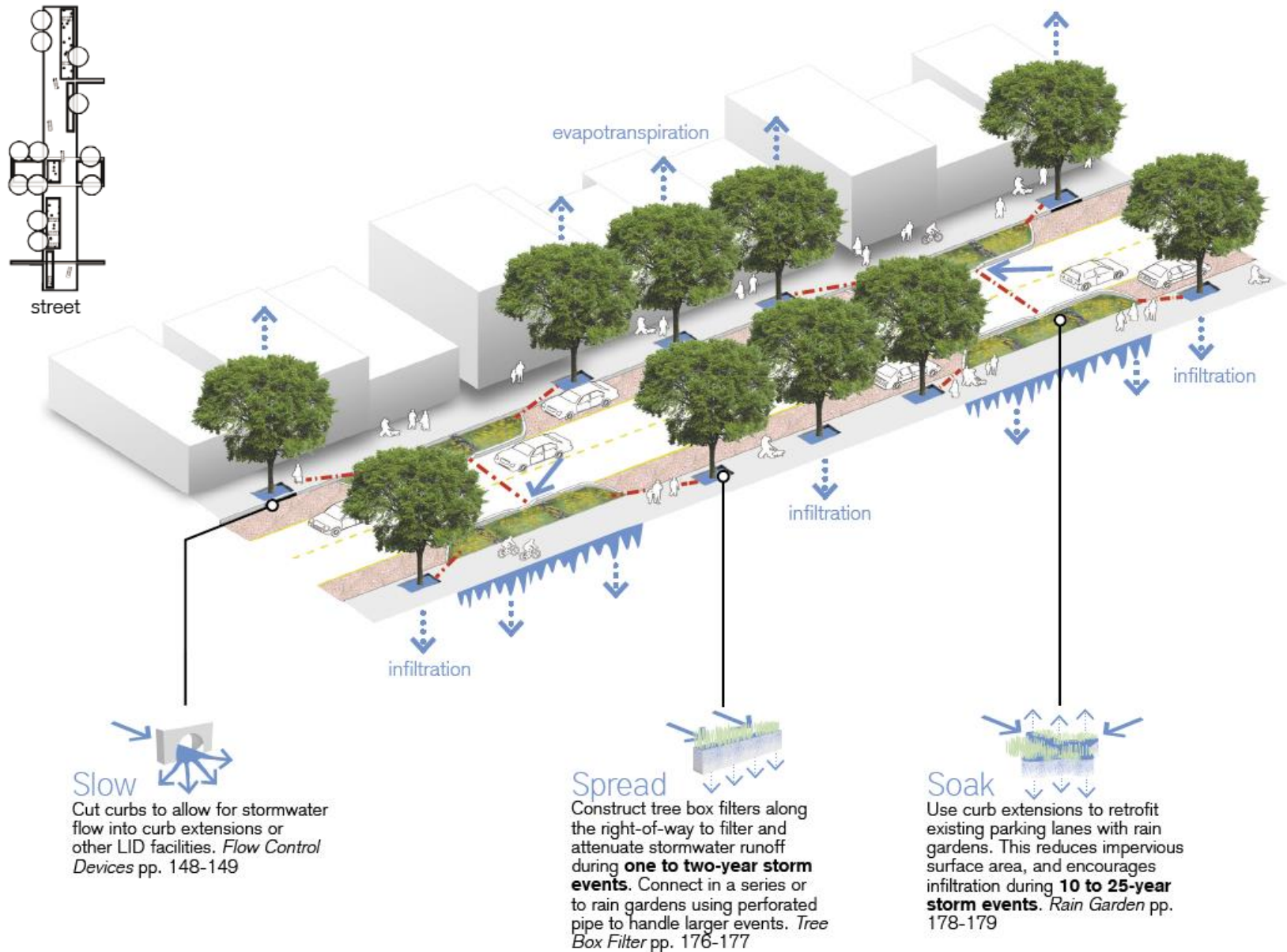


# NatureBased Solutions at different scales

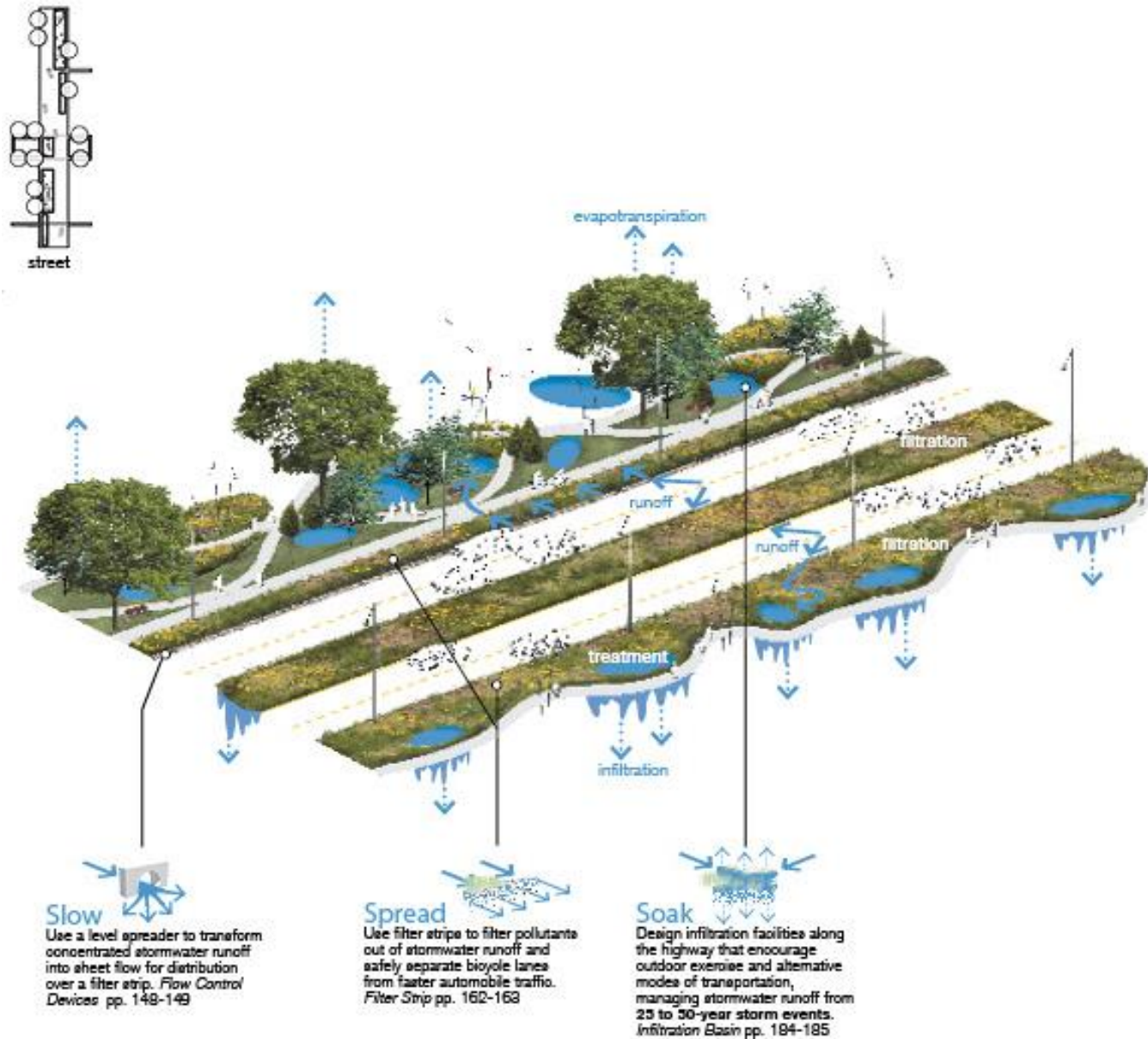




# NatureBased Solutions at different scales



# NatureBased Solutions at different scales



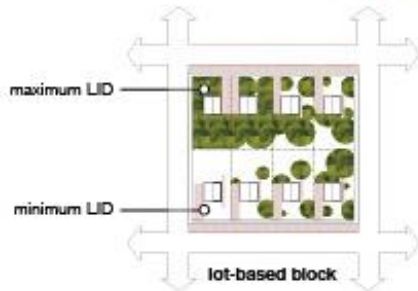
# NatureBased Solutions at different scales

## Lot Design



One-third of all residential water use in the US is currently used for landscaping.

Property owners can implement varying degrees of LID on their lots.



filtration



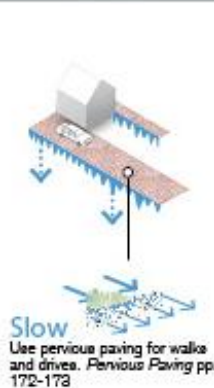
infiltration



treatment

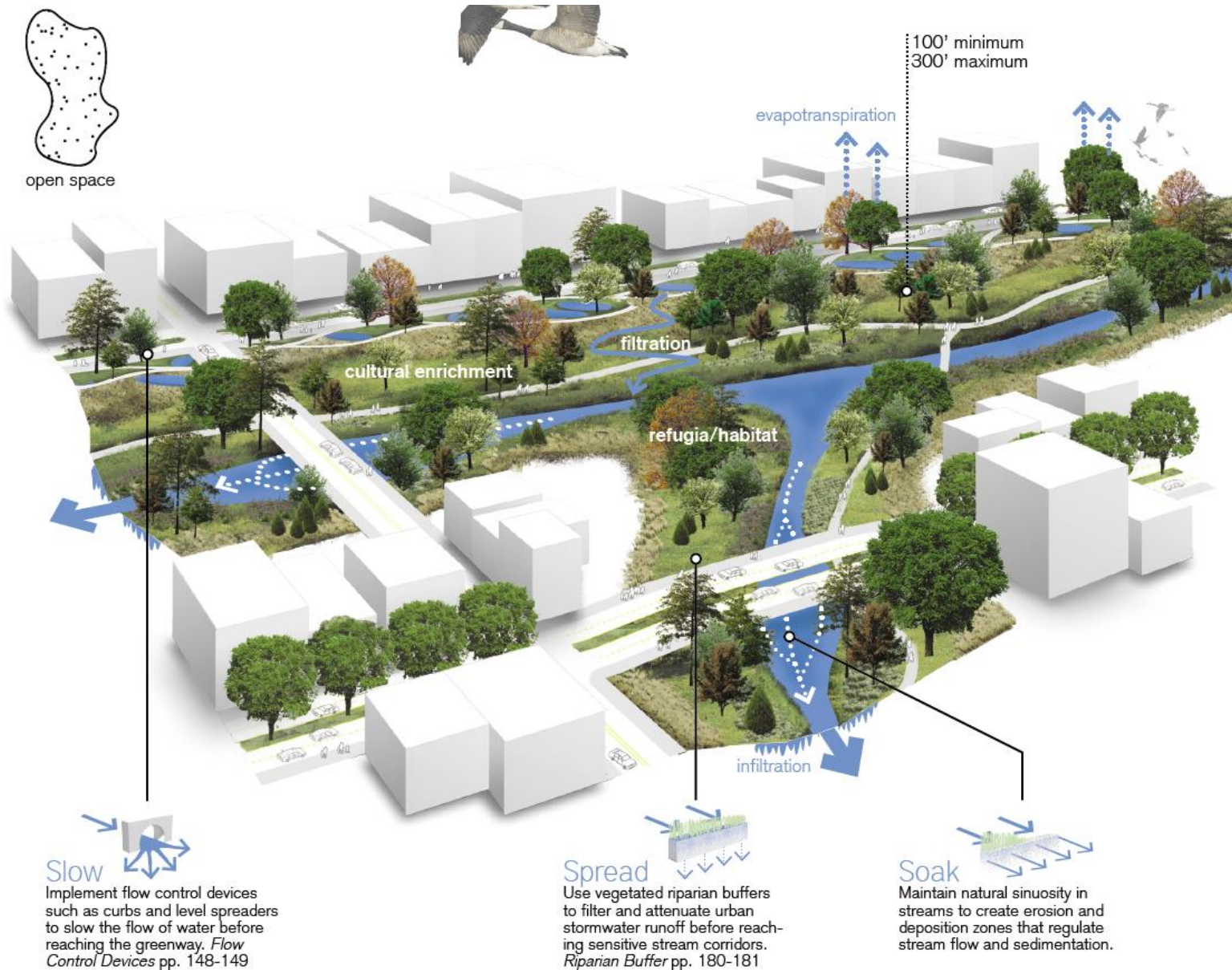
For property owners, one of the easiest ways to adapt LID to existing sites is by installing rain gardens in low lying areas. More holistic measures involve replacing existing lawns with native or local vegetation as well as replacing drives and walks with pervious paving. Before digging, however, make sure to contact a central agency or your local utility companies to locate all existing underground utilities.

For new construction, site planning should include measures that minimize impervious surfaces, protect ecologically sensitive areas of the site, and increase infiltration through the use of vegetation. Consider measures like reducing the length of driveways, limiting regrading of existing topography, minimizing building footprints, and protecting existing vegetation.





# NatureBased Solutions at different scales



# NatureBased Solutions at different scales

The building



Street level



Neighbourhood level



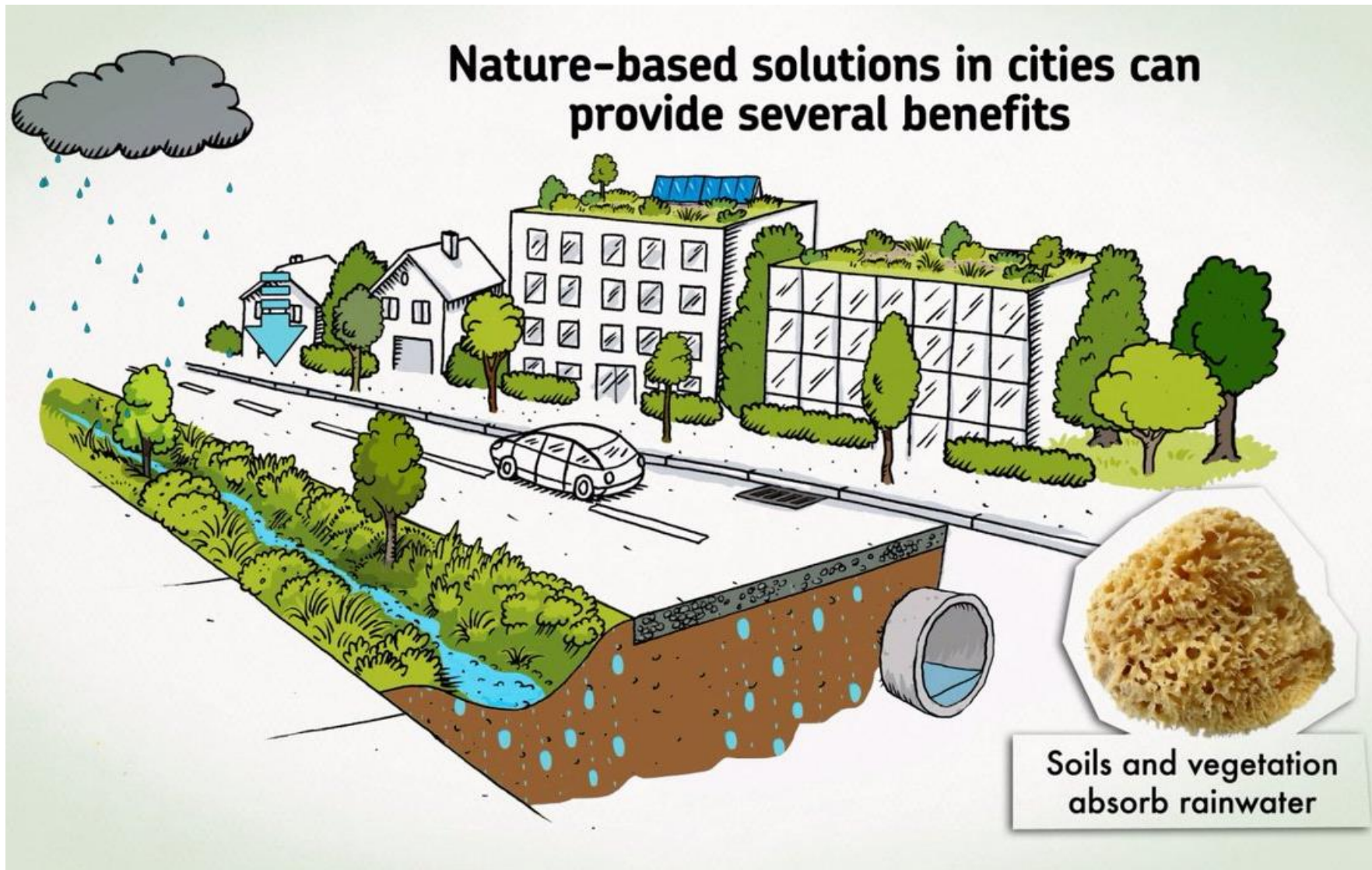
Strategic level



The building – home, garden or workspace	Connections	The street	Connections	Neighbourhood	Connections	Strategic places
 <ul style="list-style-type: none"> <li>• Green roofs</li> <li>• Living walls</li> <li>• Gardens or grounds</li> <li>• Rainwater harvesting systems</li> <li>• Driveways (permeable)</li> </ul>	 <ul style="list-style-type: none"> <li>• Pedestrian paths and rights of way</li> <li>• Cycling routes</li> <li>• Green Links and corridors</li> </ul>	 <ul style="list-style-type: none"> <li>• Boundary features eg hedges</li> <li>• Street trees</li> <li>• Verges</li> <li>• Swales</li> <li>• Porous paving</li> <li>• Sustainable Urban Drainage Systems (SUDS)</li> </ul>	 <ul style="list-style-type: none"> <li>• Pedestrian paths and rights of way</li> <li>• Cycling routes</li> <li>• Green Links and corridors</li> </ul>	 <ul style="list-style-type: none"> <li>• Amenity greenspace</li> <li>• Informal recreation spaces</li> <li>• Playspaces</li> <li>• Allotments, community growing spaces</li> <li>• Playing fields</li> <li>• Sports areas</li> <li>• Urban parks</li> <li>• Burial grounds, cemeteries</li> <li>• Swales</li> <li>• Urban woodlands</li> <li>• Ponds</li> <li>• Water courses</li> </ul>	 <ul style="list-style-type: none"> <li>• Pedestrian paths and rights of way</li> <li>• Cycling routes</li> <li>• Green Links and corridors</li> <li>• River and canal corridors including their banks</li> </ul>	 <ul style="list-style-type: none"> <li>• Civic scale spaces</li> <li>• Public parks and gardens</li> <li>• Green Networks</li> <li>• Country &amp; Regional Parks</li> <li>• Natural/semi-natural greenspaces</li> <li>• Forests and Woodlands</li> <li>• Grasslands</li> <li>• Designed landscapes</li> <li>• Formal gardens</li> <li>• City farms</li> <li>• Blue Networks</li> <li>• Rivers, lochs and Wetlands</li> </ul>



# NatureBased Solutions





# NatureBased Solutions - Sponge City



A "Sponge city" refers to a city where its urban underground water system operates like a sponge to absorb, store, leak and purify rainwater, and release it for reuse when necessary.



# Low Impact Development



## Low Impact Development Best Management Practices Design Guide Edition 1.1

December 2014

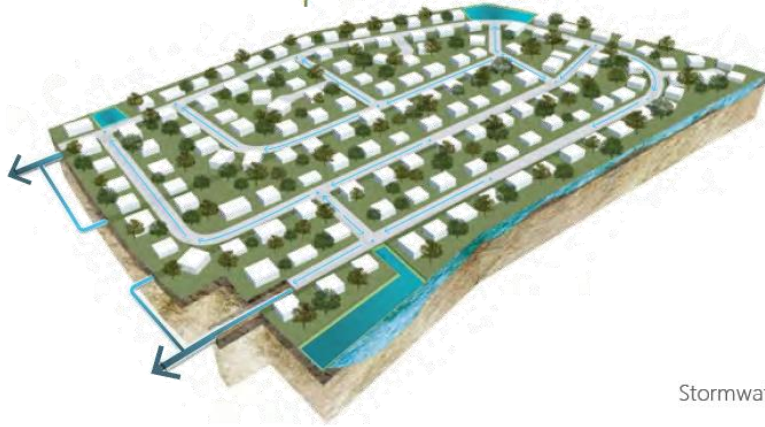


The U.S. Environmental Protection Agency defines **Low Impact Development (LID)** as “*an approach to land development (or re-development) that **works with nature** to manage stormwater as close to its source as possible*” (US EPA, 2010).



# Low Impact Development

conventional development



LID

Comparative Site Data

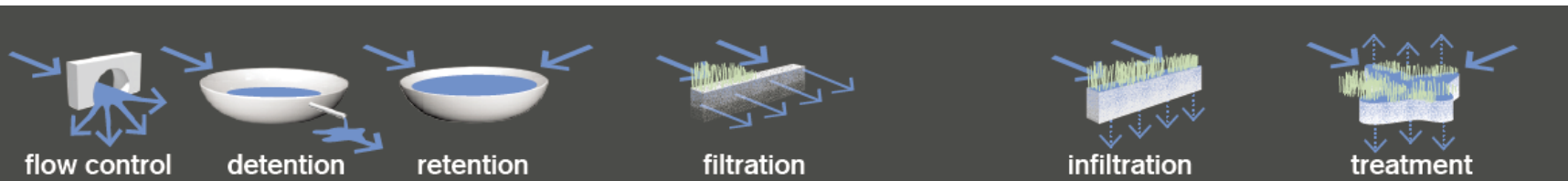
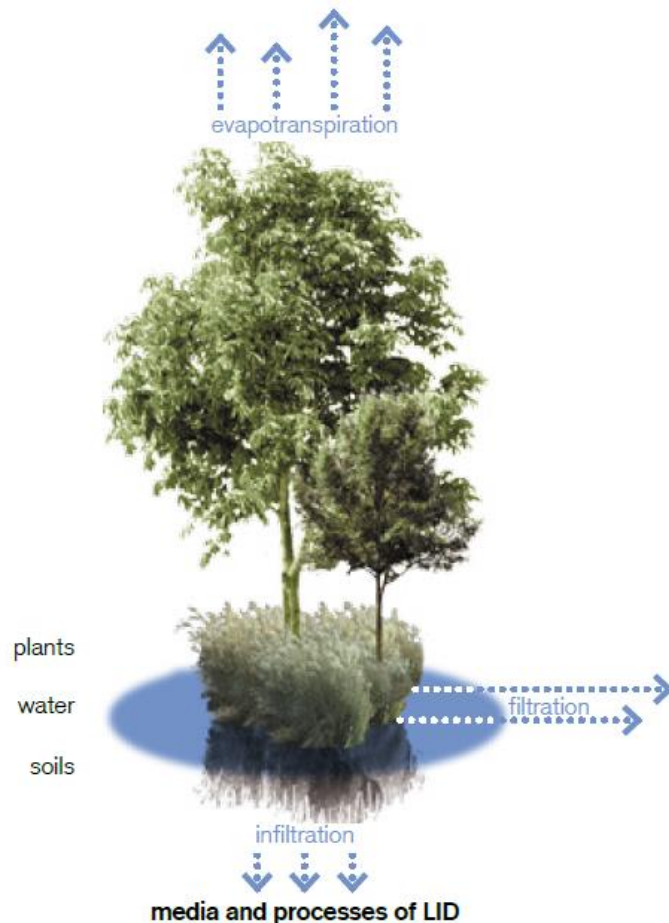
Conventional Development	LID Development
142 Lots	142 Lots
0% Shared Open Space	50% Shared Open Space
29% Impervious	15% Impervious
\$400K Stormwater Infrastructure	\$164K Stormwater Infrastructure
\$2M Pavement Construction	\$663K Pavement Construction



# Low Impact Development - BMPs

The U.S. Environmental Protection Agency defines **Low Impact Development (LID)** as “an *approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible*” (US EPA, 2010).

**LID** best management practices (**BMPs**) are **techniques** that rely on **natural processes to manage water quantity and quality** (absorption, infiltration, evaporation, evapotranspiration, filtration).



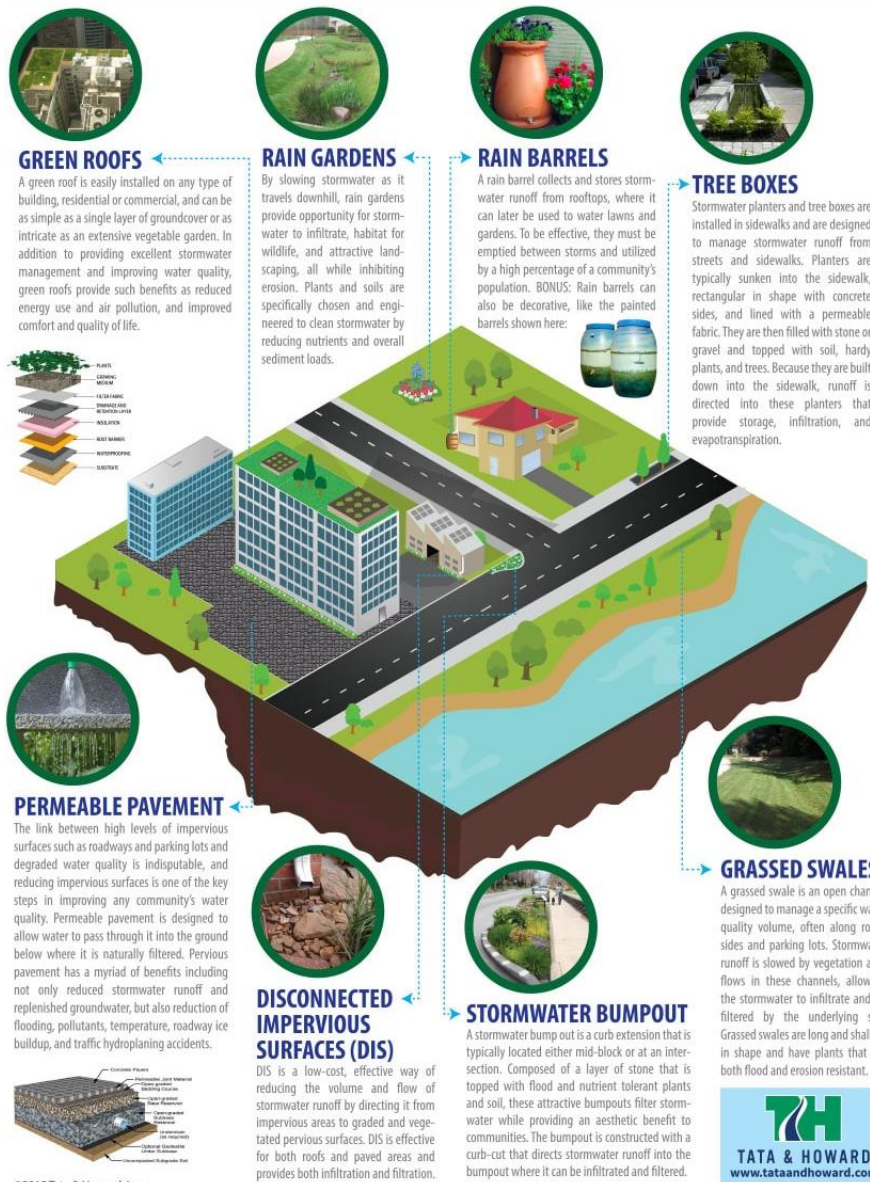
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## LID-BMPs

- (1) bioretention/ rain gardens;
- (2) bioswales;
- (3) green roofs;
- (4) permeable pavements;
- (5) box planters;
- (6) naturalized drainage ways;
- (7) rainwater harvesting for re-use.

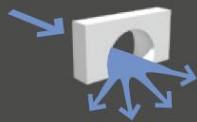


# Low Impact Development - BMPs

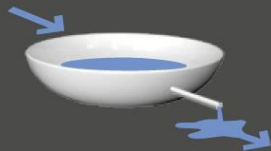


mechanical

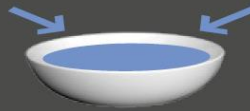
biological



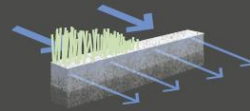
flow control



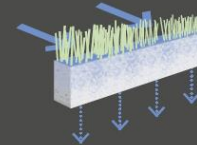
detention



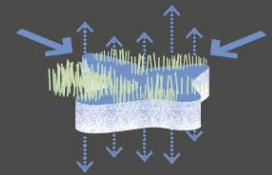
retention



filtration



infiltration



treatment

slow

→ spread

→ soak

**flow control:** The regulation of stormwater runoff flow rates.

**detention:** The temporary storage of stormwater runoff in underground vaults, ponds, or depressed areas to allow for metered discharge that reduce peak flow rates.

**retention:** The storage of stormwater runoff on site to allow for sedimentation of suspended solids.

**filtration:** The sequestration of sediment from stormwater runoff through a porous media such as sand, a fibrous root system, or a man-made filter.

**infiltration:** The vertical movement of stormwater runoff through soil, recharging groundwater.

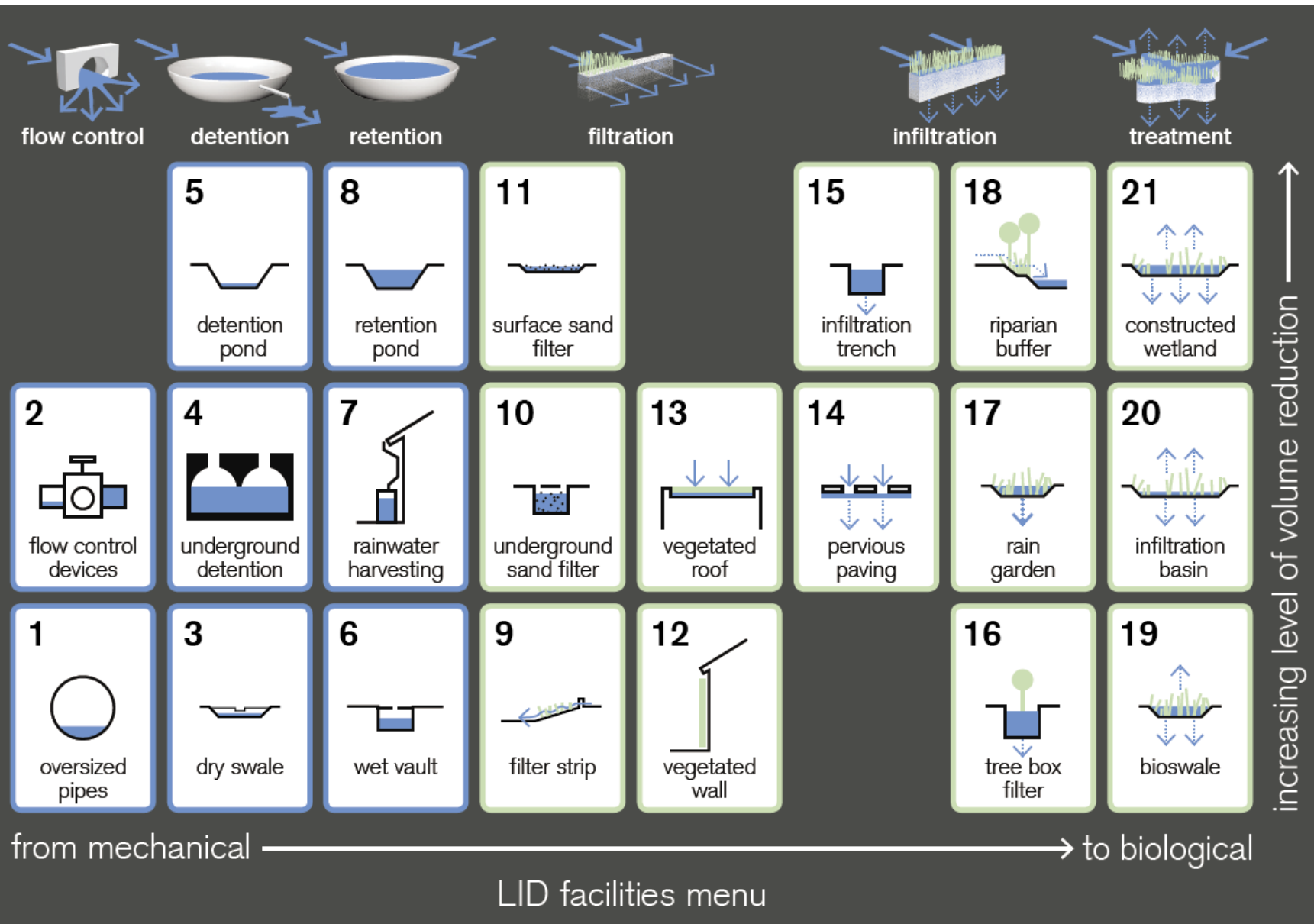
**treatment:** Processes that utilize phytoremediation or bacterial colonies to metabolize contaminants in stormwater runoff.



**GREY TO GREEN**



# Low Impact Development - BMPs

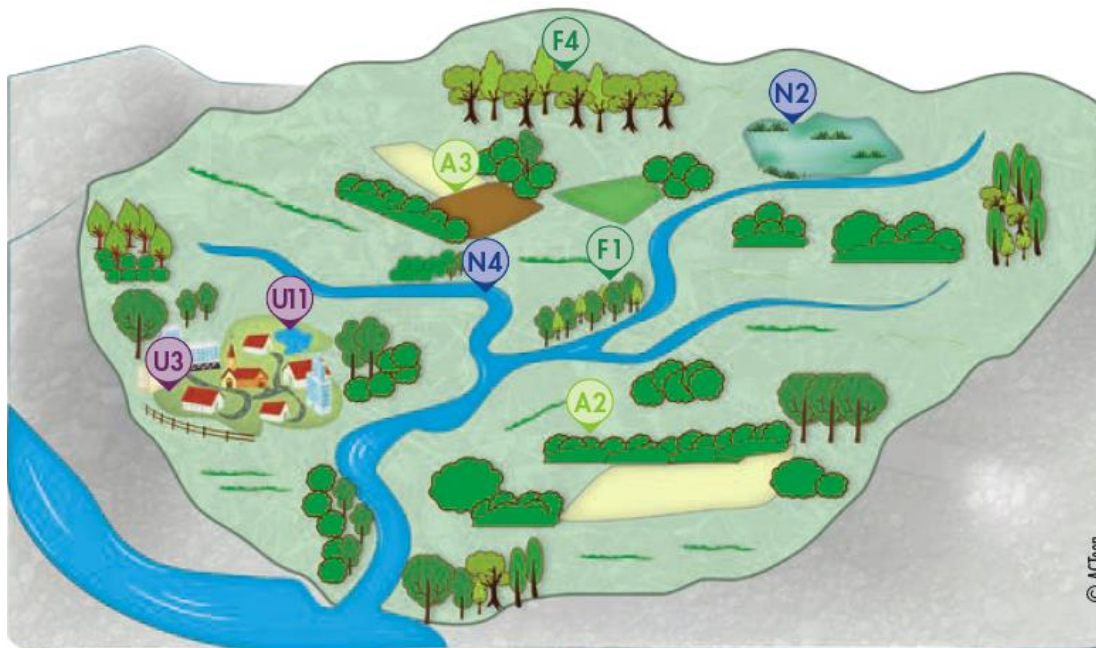


# Natural Water Retention Measures

**Natural Water Retention Measures** or NWRM are measures with the primary function of **enhancing and/or restoring the retention capacity of natural and man-made soil and aquatic ecosystems**. As a result, they deliver a range of services and multiple benefits to people while contributing to the achievement of the objectives of different environmental strategies and policies.

The application of NWRM **supports green infrastructure**, improves the quantitative status of water bodies as such, and reduces the vulnerability to floods and droughts.

(European Commission, 2014)



<b>A2</b>	Buffer strips and hedges
<b>A3</b>	Crop rotation
<b>U3</b>	Permeable surfaces
<b>U11</b>	Retention ponds

<b>F1</b>	Forest riparian buffers
<b>F4</b>	Targeted planting for catching precipitation
<b>N2</b>	Wetland restoration and management
<b>N4</b>	Re-meandering

© ACleon

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(European Commission, 2014)

Legend: Qualitative Scale		Mechanisms of Water Retention							Biophysical Impacts Resulting from Water Retention									
		Slowing and Storing Runoff				Reducing Runoff			Reducing Pollution		Soil Conservation		Creating Habitat			Climate Alteration		
		BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	BP17
		Store runoff	Slow runoff	Store live water	Slow river water	Increase evapotranspiration	Increase infiltration and/or groundwater recharge	Increase soil water retention	Reduce Pollutant Sources	Intercept Pollution Pathways	Reduce Erosion and/or Sediment Delivery	Improve Soils	Create Aquatic Habitat	Create Riparian Habitat	Create Terrestrial Habitat	Enhance Precipitation	Reduce Peak Temperature	Absorb and/or Retain CO <sub>2</sub>
U1	Green roofs																	
U2	Rainwater harvesting																	
U3	Permeable paving																	
U4	Swales																	
U5	Channels and rills																	
U6	Filter strips																	
U7	Soakaways																	
U8	Infiltration trenches																	
U9	Rain gardens																	
U10	Detention basins																	
U11	Retention ponds																	
U12	Infiltration basins																	



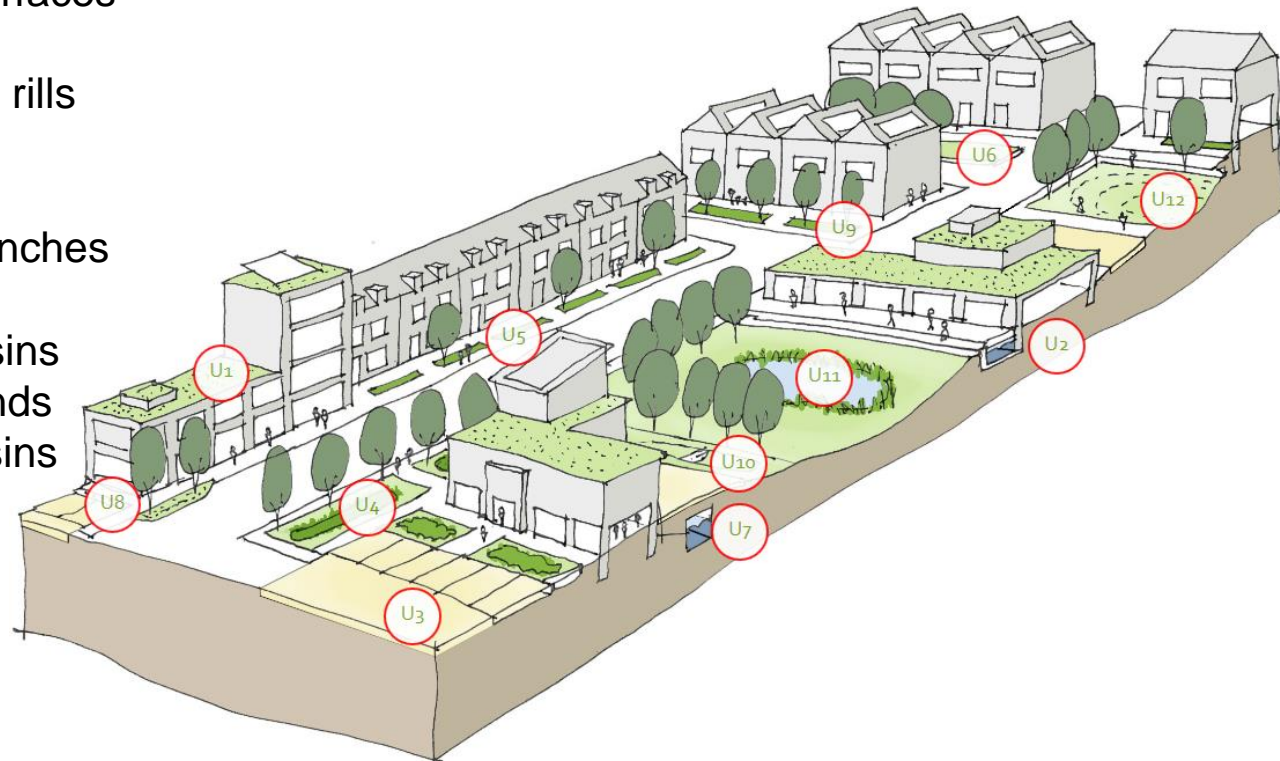
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(European Commission, 2014)

- U01 Green Roofs
- U02 Rainwater Harvesting
- U03 Permeable surfaces
- U04 Swales
- U05 Channels and rills
- U06 Filter Strips
- U07 Soakaways
- U08 Infiltration Trenches
- U09 Rain Gardens
- U10 Detention Basins
- U11 Retention Ponds
- U12 Infiltration basins



# Rain gardens



Rain Garden with Typical Features



# Rain gardens



A rain garden may look similar to a street tree pit or a small garden, but there are some key differences. Here's how you can tell the difference:

- 1. Curb inlet** - The inlet allows water to flow into the rain garden as it flows down the curb toward the catch basin.
- 2. Outlet** - Larger rain gardens also have an outlet. If the rain garden fills to capacity, water can exit through the outlet and continue into the catch basin on the street corner.
- 3. Stone Strip** - The stone strip allows people to step out of their cars without damaging the plants

- 4. Plants** - All rain gardens have plants and grasses which have been carefully selected to ensure they can survive on busy New York City streets.
- 5. Soil** - The soil is graded so that water ponds in the center of the rain garden.
- 6. Tree Guard** - All rain gardens have tree guards around them that protect the plants and keep people and dogs from walking inside of it.
- 7. Tree** - DEP plants trees in rain gardens as often as possible. Trees benefit neighborhoods by lowering temperatures in hot summer months, improving air quality, and providing habitat for birds and butterflies.



# Rain gardens



**Rain gardens** are planted areas designed to collect and manage stormwater that runs off the streets and sidewalks when it rains.



# Rain gardens



## RAIN GARDEN



### Benefits

#### STORMWATER MANAGEMENT

- Runoff reduction
- Retention
- Infiltration
- Sedimentation
- Filtration
- Extended biological treatment

#### ADDITIONAL

- Wildlife habitat
- Aesthetic quality
- Improves air quality
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: Low to Medium
- Maintenance: Low once vegetation is established
- Check for maintenance following intense storm events and amend any erosion of berm
- Apply/amend mulch layer annually
- Maintain permeability of soil to prevent ponding
- Retained water should infiltrate after 24 hours
- Avoid use of fertilizers



### Construction & Site Considerations

- Avoid heavy equipment on and around Rain Garden
- Locate at least 10' from building foundations
- Locate in full sun
- May amend soil for adequate permeability



### Contaminant Removal

- Suspended Solids
- Nutrients
- Heavy Metals



# Residential rainwater harvesting



## RESIDENTIAL RAINWATER HARVESTING



### Benefits

#### STORMWATER MANAGEMENT

- Runoff reduction
- Retention

#### ADDITIONAL

- Aesthetic quality
- Stores stormwater for alternative use



### Cost & Maintenance Considerations

- Cost: Low
- Stormwater as irrigation supply offsets utility costs
- Maintenance: Low
- Inspect after storm events for debris and proper inflow/outflow
- Install gutter screens to minimize debris
- Install a first flush diverter to minimize debris and potential contaminants
- Periodically drain unused water to prevent insect breeding
- Disconnect inlet and drain in freezing temperatures



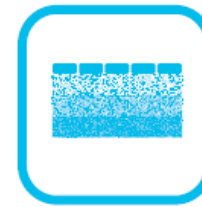
### Construction & Site Considerations

- Use a dark colored, opaque storage device and locate in shade to decrease algae growth
- Locate near landscape areas requiring frequent irrigation
- Petroleum-based and treated wood products are known to leach toxins into rainwater that pose health risks if consumed. Rainwater collected from these surfaces is only suitable for irrigating ornamental landscapes. Metal roofs (except copper and those with lead components) are generally regarded as ideal for rainwater harvesting. Consult with a professional regarding allowable uses and potential treatment requirements for harvested rainwater





# Permeable paving



## PERMEABLE PAVING



### Benefits

#### STORMWATER MANAGEMENT

- Runoff reduction
- Retention
- Infiltration
- Filtration

#### ADDITIONAL

- Aesthetic quality
- Provides additional pervious surfaces
- Improves air quality
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: Medium to High
- Maintenance: High
- Vacuum twice annually to maintain permeability
- Pre-treat water flowing onto permeable paving with a filtration BMP



### Construction & Site Considerations

- Not suitable for sites with hazardous materials or high sediment runoff
- Variations on construction details are available for sites with soils with low infiltration rates
- Adaptable to a wide variety of site designs
- Research load-bearing capacity of pervious materials against anticipated vehicle types and traffic pattern
- Parking lots sloped greater than 5% require special consideration for subsurface grading and drainage

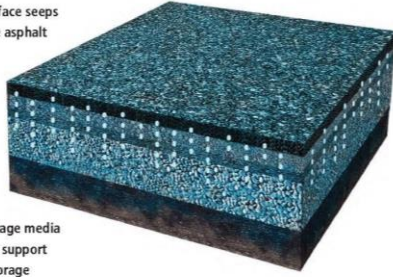


# Permeable paving

## Permeable Pavement

Permeable Asphalt

Stormwater on surface seeps through permeable asphalt



Stone or other storage media provides structural support and stormwater storage

Permeable Concrete

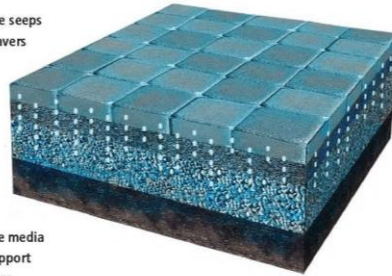
Stormwater on surface seeps through permeable concrete



Stone or other storage media provides structural support and stormwater storage

Permeable Paver

Stormwater on surface seeps through permeable pavers



Stone or other storage media provides structural support and stormwater storage



*Waterview Recreation Center*



# Green roofs



## VEGETATED ROOF



### Benefits

#### STORMWATER MANAGEMENT

- Runoff reduction
- Retention
- Evapotranspiration
- Filtration
- Extended biological treatment

#### ADDITIONAL

- Aesthetic quality
- Provides additional pervious surfaces
- Improves air quality
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: Medium to High (extensive), High (intensive)
- Added insulation and evaporative cooling may reduce utility costs
- Maintenance: Low to Medium (extensive), High (intensive)

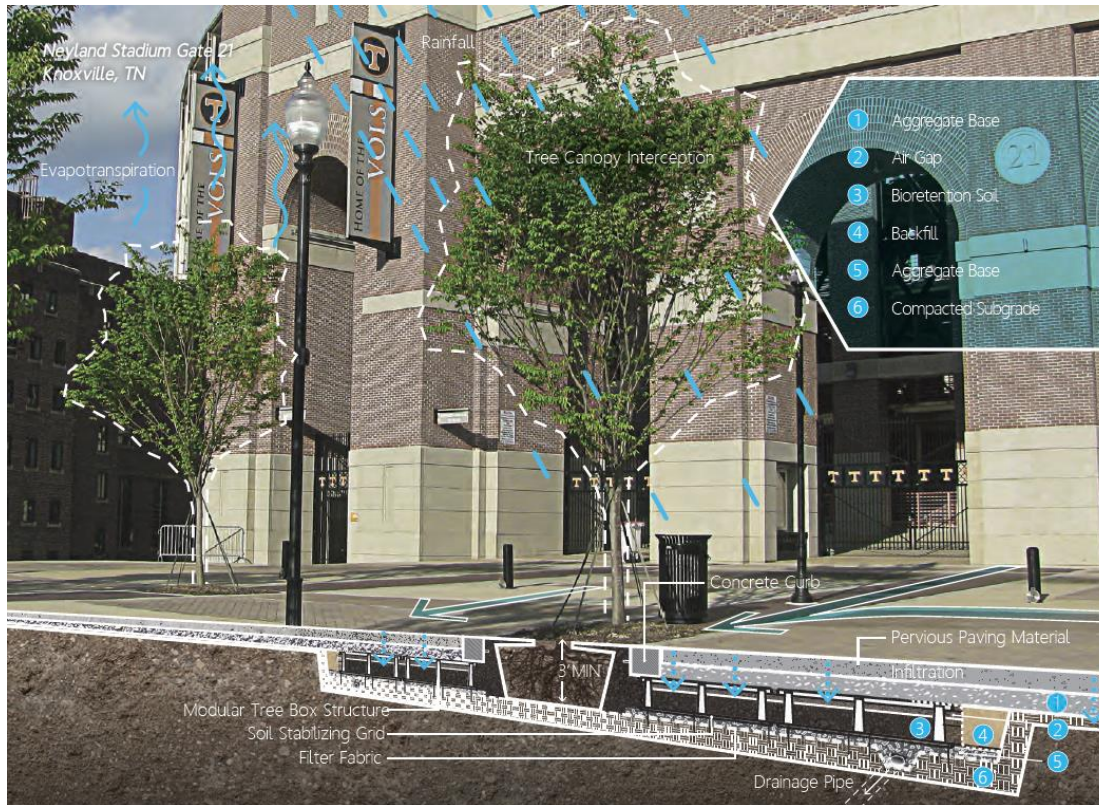


### Construction & Site Considerations

- Requires adequate roof structure; consult with a structural engineer for both new construction and potential retrofit applications
- Intensive green roofs can provide additional habitable amenity space



# Tree box



## TREE BOX



### Benefits

#### STORMWATER MANAGEMENT

- Runoff reduction
- Retention
- Evapotranspiration
- Extended biological treatment

#### ADDITIONAL

- Aesthetic quality
- Provides additional pervious surfaces
- Improves air quality



### Cost & Maintenance Considerations

- Cost: Medium
- Maintenance: Medium
- Periodically test soil for high contamination levels and replace if necessary
- Periodically aerate soil
- Remove litter and debris after storm events



### Construction & Site Considerations

- Tree boxes can be implemented in dense urban areas
- Research and choose trees appropriate to site cultural conditions
- Provide grate over root zone if implemented in high foot traffic areas
- Avoid low spots



### Contaminant Removal

- Suspended Solids
- Nutrients
- Heavy Metals



# Tree box

## Stormwater Tree

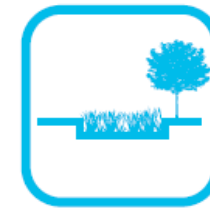
TREE FILTERS AND TRANSPIRES  
WATER WHILE PROVIDING  
SHADE AND ENHANCING THE  
STREETSCAPE



Stormwater Tree Precedent



# Bioretention cell



## BIORETENTION CELL



### Benefits

#### STORMWATER MANAGEMENT

- Runoff Reduction
- Retention
- Infiltration
- Evapotranspiration
- Extended biological treatment

#### ADDITIONAL

- Wildlife habitat
- Aesthetic quality
- Provides additional pervious surfaces
- Improves air quality
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: Medium to High
- Maintenance: Medium to High
- Inspect monthly and after large storm events
- Inspect inlet/outlet for blockages such as plant debris/litter



### Construction & Site Considerations

- Locate at least 2 feet above groundwater table
- Site slope should be less than 20%



### Contaminant Removal

- Suspended Solids
- Nutrients
- Heavy Metals





# Bioretention cell

## Stormwater Planter



*Columbus Square*

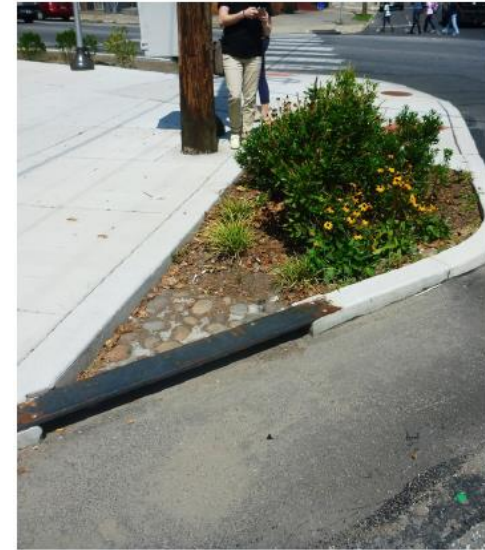


*The Philadelphia Navy Yard*



# Bioretention cell

## Stormwater Bump-out



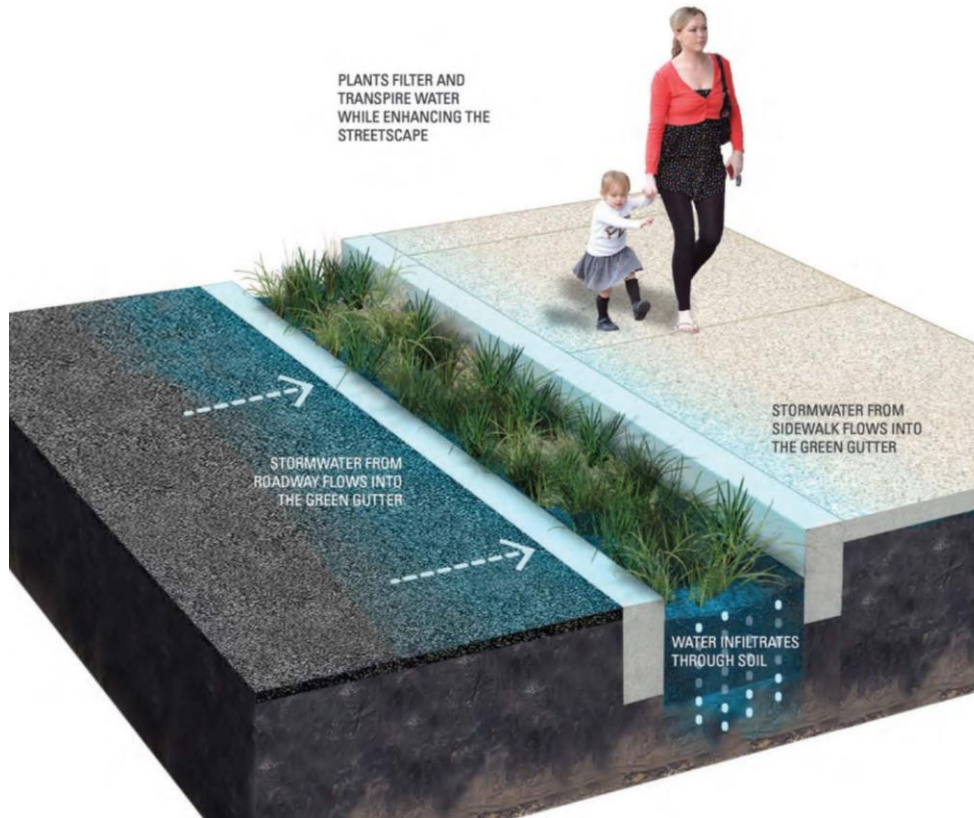
Shepard Recreation Center Corner Bump-out



Queen Lane Mid-Block Bump-out

# Bioretention cell

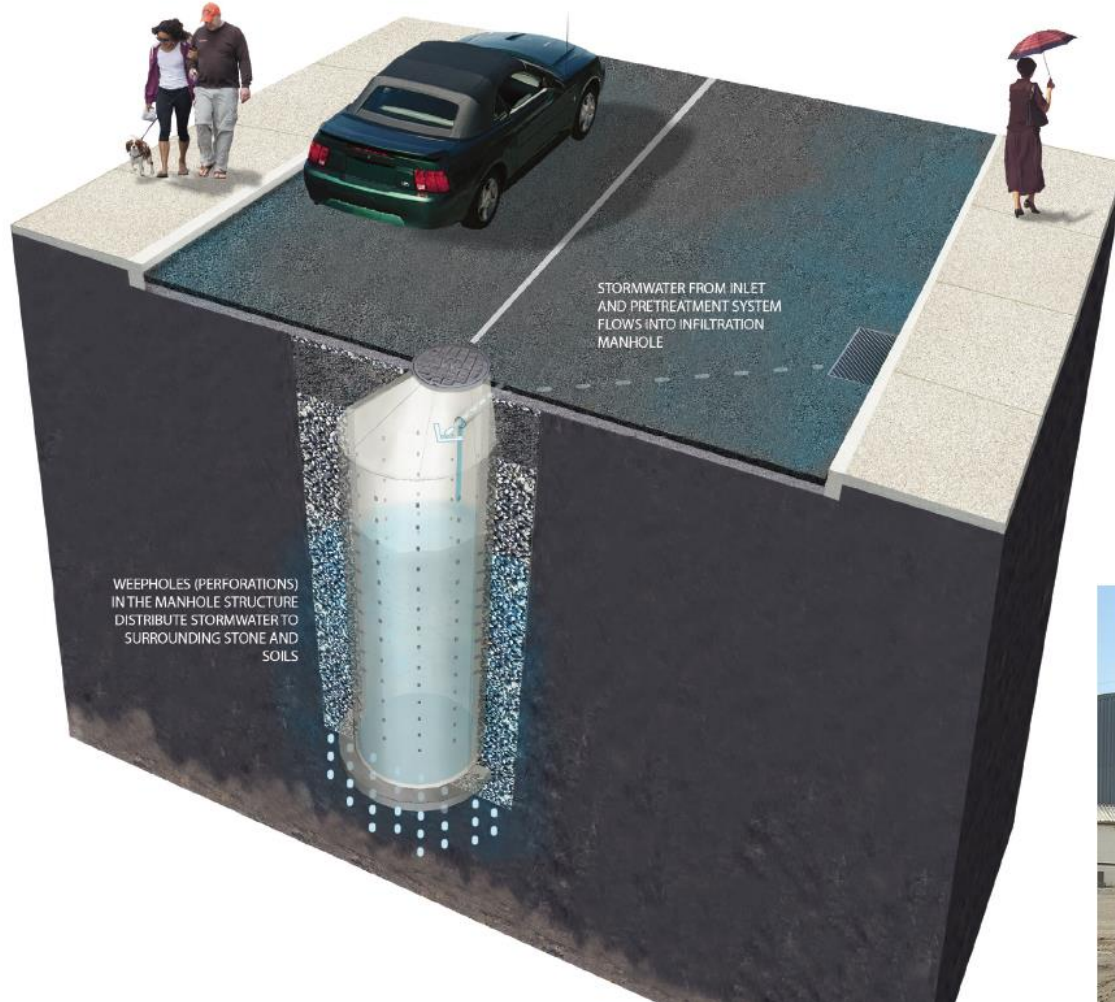
## Green Gutter





# Bioretention cell

## Stormwater Drainage Well



# Vegetated swale



## VEGETATED SWALE



### Benefits

#### STORMWATER MANAGEMENT

- Extended biological treatment
- Sedimentation
- Evapotranspiration
- Straining

#### ADDITIONAL

- Wildlife habitat
- Improves air quality
- Aesthetic quality



### Cost & Maintenance Considerations

- Cost: Low to Medium
- Maintenance: Medium
- Reduces need for conventional stormwater infrastructure
- Maintain vegetation and soil stability
- Inspect inlet/outlet for blockages such as plant debris/litter after storm events



### Construction & Site Considerations

- Locate at least 2 feet above groundwater table
- Ideal for sites with less than a 1-2% slope



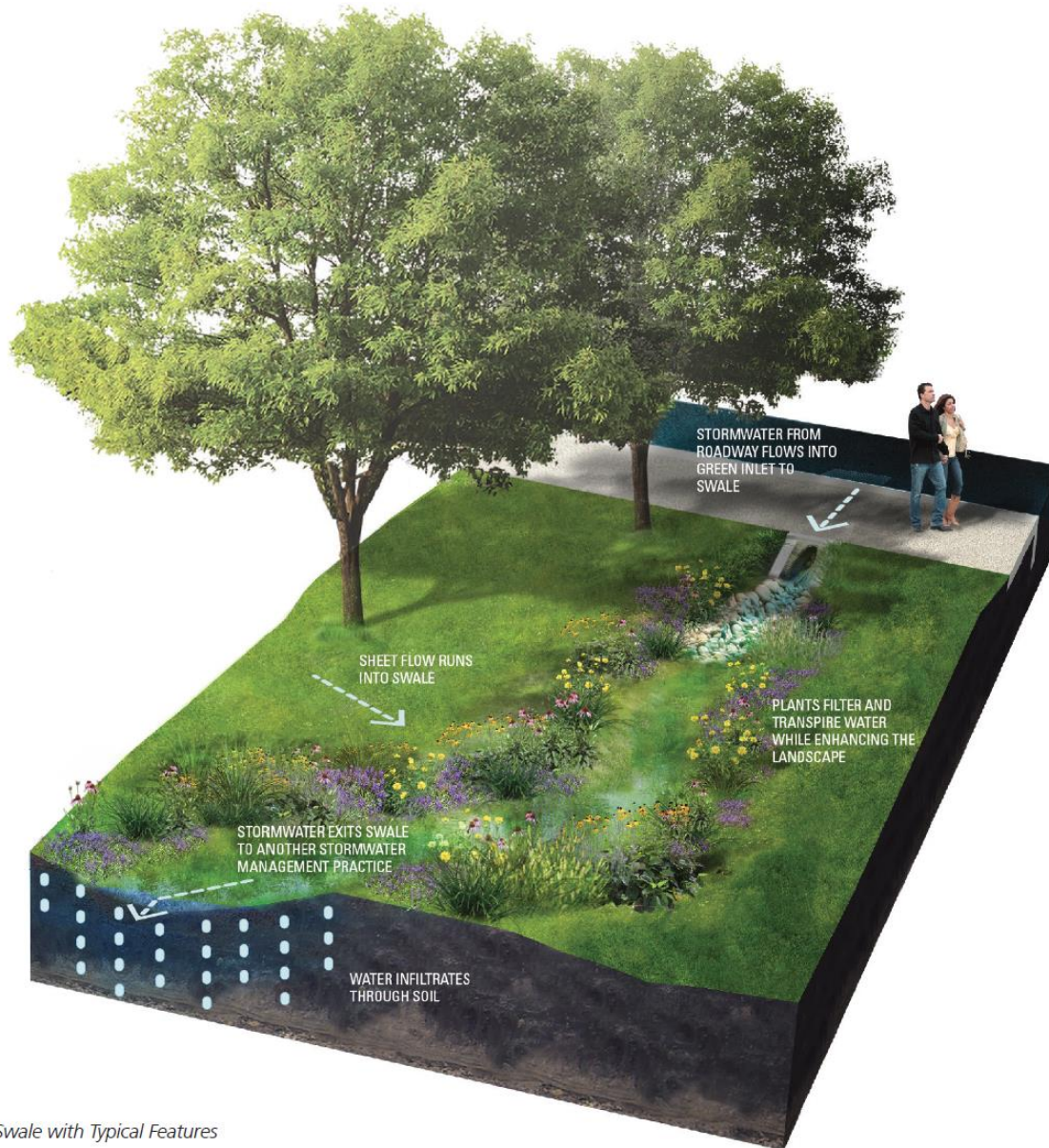
### Contaminant Removal

- Suspended Solids
- Heavy Metals





# Vegetated swale



Stormwater Swale with Typical Features





# Stormwater trench

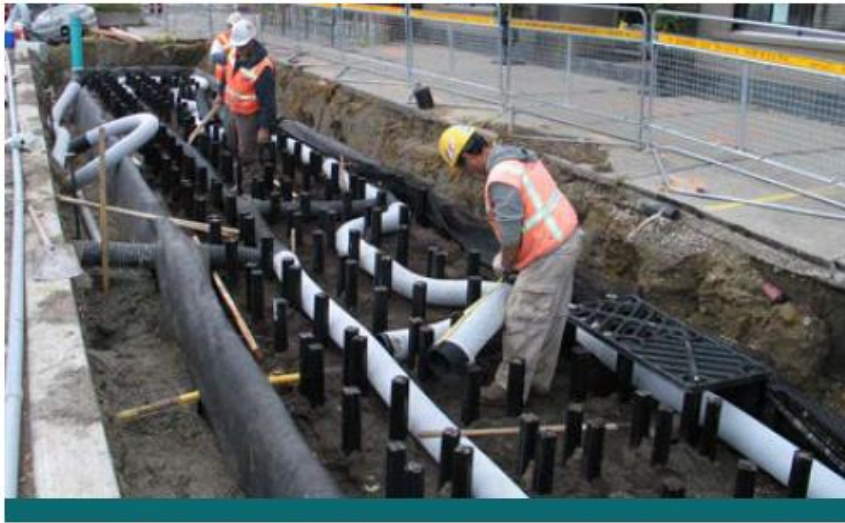
## Stormwater Tree Trench



*Shissler Recreation Center*



# Stormwater swale



**Figure 2.4.3:** Installing the soil support system under the sidewalk on part of the Queensway in Toronto. (Source: Deep Root Inc.)



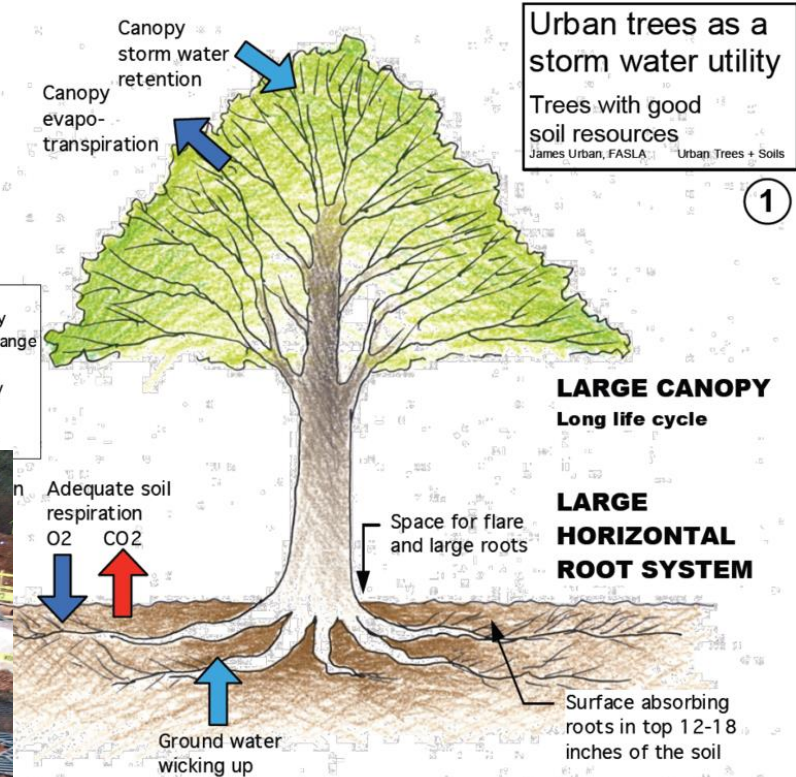
**Figure 2.4.4:** Sidewalk following construction, showing healthy trees. (Source: Deep Root Inc.)



# Stormwater swale



**SOIL CONDITIONS**  
Diverse, healthy soil biology  
High cation (nutrient) exchange capacity  
High water holding capacity  
Organic replacement  
Low Compaction



“Isola vegetativa”



# Commercial rainwater harvesting



## COMMERCIAL RAINWATER HARVESTING



### Benefits

#### STORMWATER MANAGEMENT

- Runoff Reduction
- Retention

#### ADDITIONAL

- Stores stormwater for alternative reuse
- Educational opportunity
- Aesthetic Quality



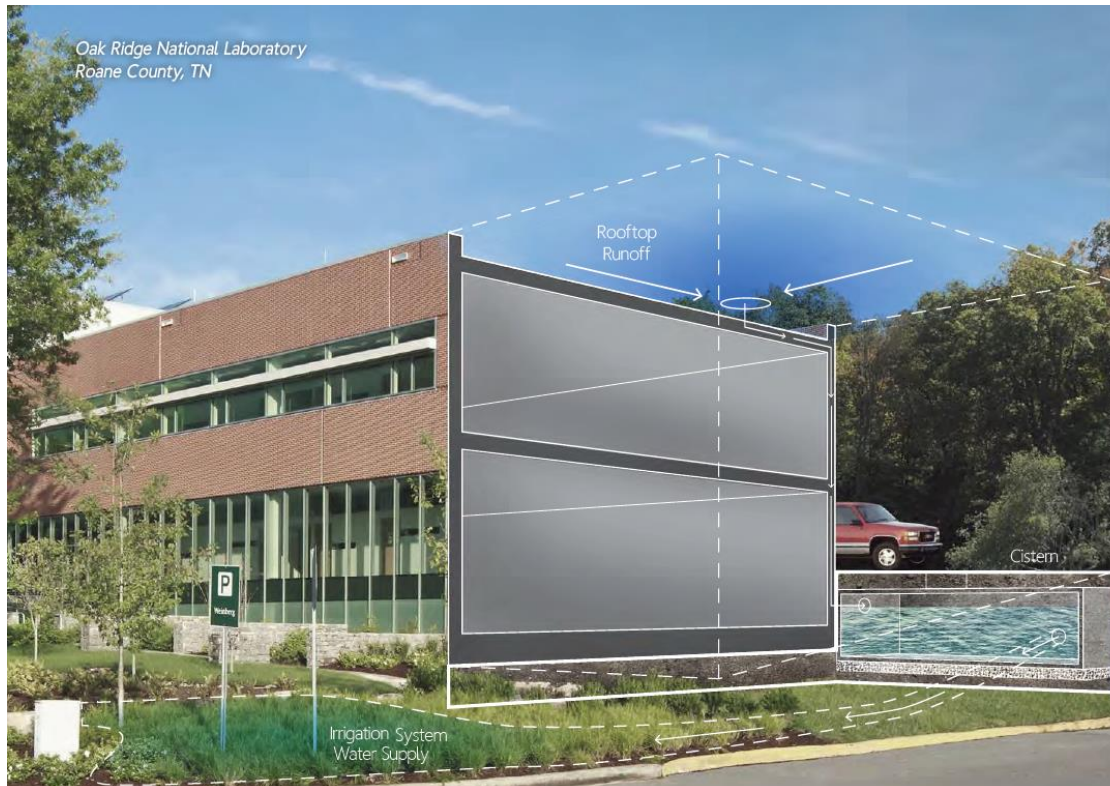
### Cost & Maintenance Considerations

- Cost: Medium to High
- Irrigation with harvested rainwater can offset utility costs
- Maintenance: Medium
- Inspect after storm events for debris and proper inflow/outflow
- Install gutter screens to minimize debris
- Install a first flush diverter to minimize debris and potential contaminants
- Periodically drain/treat unused water to prevent insect breeding
- If located above freeze/thaw line, disconnect inlet and drain in freezing temperatures

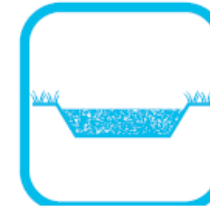


### Construction & Site Considerations

- Size of storage facility based on rainfall patterns, rainfall intensity, roof size, and anticipated usage
- Possible odor if left stagnant and unused
- Storage vaults can be located above or below ground
- If above ground, use a dark colored, opaque storage device and locate in shade to decrease algae growth
- May be connected to an irrigation system
- Consult with a professional regarding allowable uses and potential treatment requirements for harvested rainwater



# Sand filter



## SAND FILTER



### Benefits

#### STORMWATER MANAGEMENT

- Extended biological treatment
- Sedimentation
- Filtration



### Cost & Maintenance Considerations

- Cost: Medium (Surface) to High (Underground)
- Maintenance: Medium to High
- Inspect at least once a month, or after large storm events
- Special disposal method may be required in cases of severe contamination



### Construction & Site Considerations

- Size: Approximately 2-3% of drainage area
- May require forebay in areas of high sediment runoff
- Vehicles should not drive on top of underground facilities
- Provide access to the devices for inspection/maintenance



### Stormwater Management Characteristics

- Suspended Solids
- Nutrients
- Heavy Metals
- Hydrocarbons



# Infiltration structure



## INFILTRATION STRUCTURE



### Benefits

#### STORMWATER MANAGEMENT

- Runoff Reduction
- Retention
- Infiltration

#### ADDITIONAL

- Provides additional pervious surfaces
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: Low to High
- Maintenance: Medium to High
- Can be difficult to access and perform maintenance
- Sub-surface storage decreases land area needed for stormwater management; opportunity to add value to property by preserving buildable space
- Maximum drainage area is approximately 2 acres
- Pre-treat contaminated runoff flowing onto infiltration structure with a filtration BMP



### Construction & Site Considerations

- Inspect for underlying karst topography
- Ideal for urban settings with limited space



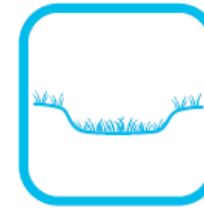
### Contaminant Removal

- Hydrocarbons
- Heavy Metals





# Dry pond



## VEGETATED DETENTION BASIN (Dry pond)



### Benefits

#### STORMWATER MANAGEMENT

- Peak flow reduction
- Detention
- Sedimentation

#### ADDITIONAL

- Wildlife habitat
- Aesthetic quality
- Provides additional pervious surfaces
- Improves air quality



### Cost & Maintenance Considerations

- Cost: Low to Medium
- Maintenance: Medium to High
- Long lasting and durable
- Annual sediment removal
- Inspect inlet/outlet for blockages such as plant debris/litter after storm events



### Construction & Site Considerations

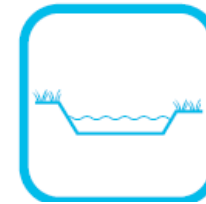
- Size: Approximately 1-3% of drainage area
- Inspect for underlying karst geology
- Locate at least 2 feet above groundwater table
- Needs differential inlet and outlet elevation
- Locate in full sun



### Contaminant Removal

- Suspended Solids

# Wet pond



## WET POND



### Benefits

#### STORMWATER MANAGEMENT

- Peak flow reduction
- Retention
- Sedimentation

#### ADDITIONAL

- Wildlife habitat
- Aesthetic quality



### Cost & Maintenance Considerations

- Cost: Medium
- Maintenance: Medium to high
- Vegetation upkeep
- Pond aeration often required
- Inspect inlet/outlet for blockages such as plant debris/litter after storm events
- Requires base flow to prevent stagnation
- Avoid fertilizer use around wet pond
- Dredging necessary once a percentage of pool is replaced with accumulated sediment



### Construction & Site Considerations

- Requires an impermeable liner/membrane or soil layer
- Inspect for underlying karst geology
- Permanent standing water may pose safety liability



### Contaminant Removal

- Suspended Solids







## CONSTRUCTED WETLAND



### Benefits

#### STORMWATER MANAGEMENT

- Extended biological and chemical treatment
- Evapotranspiration
- Sedimentation
- Straining
- Filtration
- Peak flow reduction

#### ADDITIONAL

- Wildlife habitat
- Aesthetic quality
- Improves air quality
- Educational opportunity



### Cost & Maintenance Considerations

- Cost: High
- Maintenance: Medium
- Soil may need to be replaced every 5-10 years due to buildup of contaminants
- Periodic removal of debris and trash
- Maintenance of vegetation to prevent undesirable species



### Construction & Site Considerations

- Applicable to large drainage areas
- High educational opportunity; good for school yards
- Safety challenges posed by standing water need to be considered and addressed
- Locate in full sun



### Contaminant Removal

- Suspended Solids
- Nutrients
- Heavy Metals





# Filter strip



## FILTER STRIP



### Benefits

#### STORMWATER MANAGEMENT

- Sedimentation
- Filtration
- Straining

#### ADDITIONAL

- Wildlife habitat
- Provides additional pervious surfaces



### Cost & Maintenance Considerations

- Cost: Low
- Maintenance: Low
- Mow only in late winter, frequent mowing reduces effectiveness
- Stable groundcover must be maintained to ensure proper functioning of filter strip
- Occasional soil aeration may be required



### Construction & Site Considerations

- Size: 50-100% of drainage area
- Drainage area not to exceed 150 linear feet
- 50% maximum slope
- Not applicable to high-density sites due to high square-footage required



### Contaminant Removal

- Suspended Solids
- Nutrients (Incidental)
- Heavy Metals (Incidental)
- Litter





# Synthesis

- Primary Function
- Secondary Function
- Incidental
- Additional Benefit

		Runoff Reduction								Peak Flow Reduction		Improved Water Quality			
Hydrologic Functions	Stormwater Quantity Functions	Retention	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Incidental	Secondary	Incidental	Incidental	Secondary	Secondary
	Stormwater Quality Functions	Infiltration	Primary	Incidental	Primary	Secondary	Primary	Incidental	Primary	Incidental	Incidental	Incidental	Incidental	Secondary	Secondary
		Detention	Secondary		Secondary	Secondary	Secondary		Incidental	Primary	Secondary	Incidental	Secondary		Secondary
		Evapotranspiration	Secondary	Incidental	Primary	Primary	Primary	Incidental		Secondary	Incidental	Primary	Primary	Incidental	Secondary
		Sedimentation	Primary	Incidental	Secondary		Secondary	Incidental		Primary	Primary	Primary	Primary	Primary	Primary
		Filtration	Primary	Incidental	Primary	Primary	Secondary	Incidental		Incidental		Primary	Secondary	Primary	Primary
		Straining	Secondary	Incidental			Secondary	Incidental		Incidental		Primary	Primary		Primary
		Extended Treatment (Chemical)	Secondary		Incidental					Incidental	Incidental	Primary	Secondary	Secondary	
		Extended Treatment (Biological)	Primary		Primary	Primary	Secondary			Incidental	Incidental	Primary	Primary	Primary	Incidental
	Additional Benefits	Provides Wildlife Habitat	Additional			Additional	Additional			Additional	Additional	Additional	Additional		Additional
		Aesthetic Quality	Additional	Additional	Additional	Additional	Additional	Additional		Additional	Additional	Additional	Additional		Additional
		Stores Runoff for Alternative Use		Additional				Additional			Additional				
		Provides Additional Pervious Surfaces			Additional	Additional	Additional		Additional	Additional					Additional
		Improves Air Quality	Additional		Additional	Additional	Additional			Additional		Additional	Additional		Additional
		Provides Educational Opportunities	Additional		Additional	Additional	Additional	Additional	Additional			Additional			Additional

# Synthesis

## Cost Benefit Comparison

Direct Benefit Rating: ● High ● Moderate ○ Low ○ None



### Boulevard bioretention units and permeable paver driveway:

#### Direct benefits:

- Volume reduction
- Erosion control
- Water quality
- Flood control

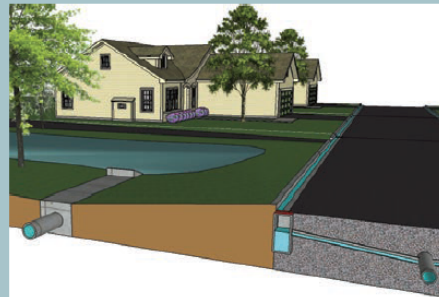
#### Indirect benefits:

- ✓ Climate change mitigation & adaptation
- ✓ Protect Great Lakes
- ✓ Increase amenity value
- ✓ Street greening
- ✓ Groundwater recharge
- ✓ Improve baseflow
- ✓ Helps to meet or exceed environmental strategic plan objectives

#### Municipal Considerations:

- ✗ Impaired function from owner encroachment or lack of maintenance
- ✗ Long-term soil replacement

**Best value \$895,000**



### Curb-and-gutter with stormwater management pond:

#### Direct benefits:

- Volume reduction
- Erosion control
- Water quality
- Flood control

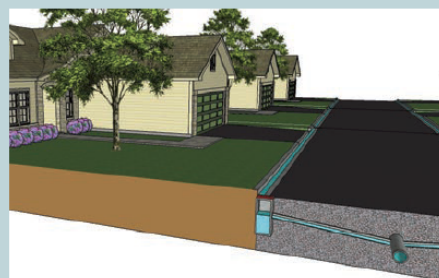
#### Indirect benefits:

- ✓ Maintains traditional road aesthetic
- ✓ Protect Great Lakes
- ✓ Help meet environmental strategic plan objectives
- ✓ Open space amenity

#### Municipal Considerations:

- ✗ Higher maintenance costs
- ✗ Increased erosion control costs
- ✗ No groundwater recharge
- ✗ Pond sediment clean out

**High cost, moderate benefits \$1,090,000**



### Conventional road reconstruction (curb-and-gutter):

#### Direct benefits:

- Volume reduction
- Erosion control
- Water quality
- Flood control

#### Indirect benefits:

- ✓ Maintains traditional road aesthetic

#### Municipal Considerations:

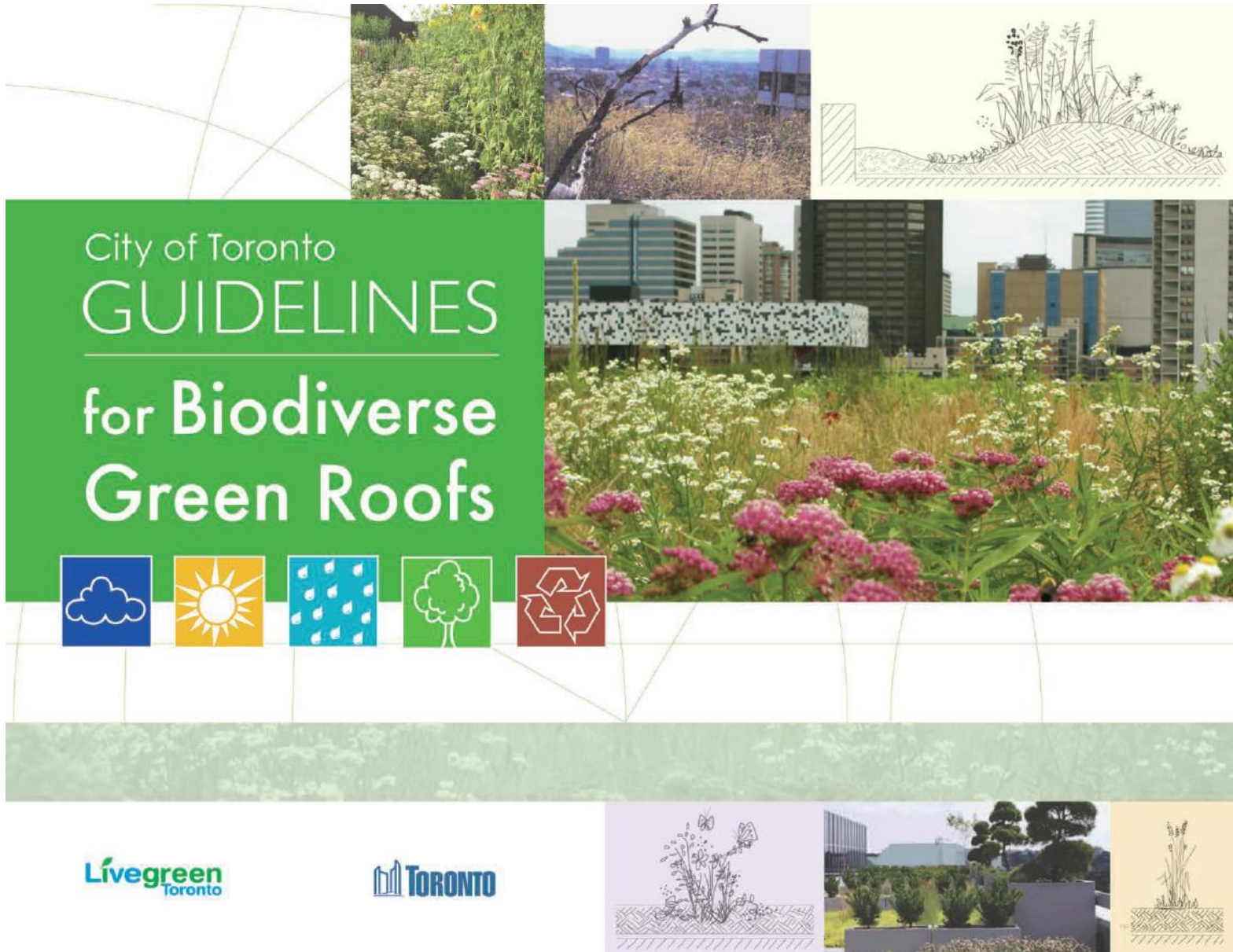
- ✗ Downstream flood risk
- ✗ Increased erosion control costs
- ✗ Impaired water quality
- ✗ Beach closures
- ✗ Harm to fisheries
- ✗ No groundwater recharge

**Lowest cost, few benefits \$635,000**

Figure 1.2.1: Comparison of road retrofit alternatives for a local residential road converting from a rural cross section to an urban cross section



# Biodiverse green roofs



Livegreen  
Toronto

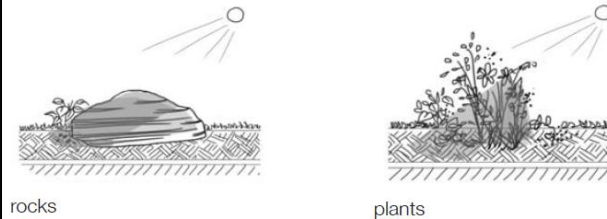
TORONTO

# Biodiverse green roofs

Increase Depth of  
Growing Media

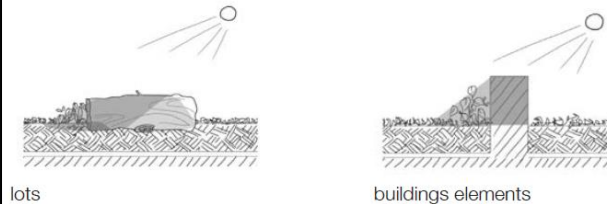


Provide Microclimates



rocks

plants



lots

buildings elements

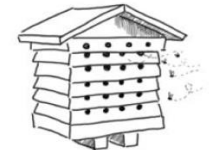
Provide Nesting  
Opportunities



Tall grasses and shrubs



Logs and branches



Bee nest boxes



Birdhouses



Open soil areas

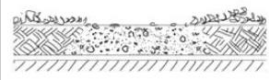
Vary Composition  
(Structure) of  
Growing Media



vary granule size



vary mixtures



incorporate bare areas of gravel

Provide Topographic Variety



Diversify  
Plant Species



Provide Perching Habitat



rocks



forbs, grasses and shrubs

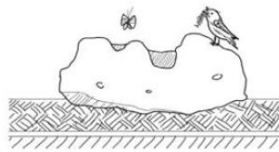


branches and platforms



logs

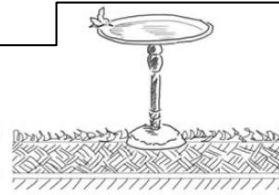
Provide  
Water  
Source(s)



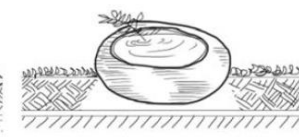
naturally pitted cap rock



water features



bird baths



basins



# Biodiverse green roofs

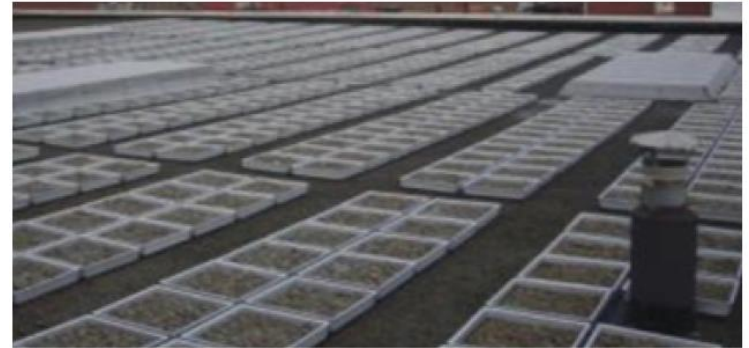
Il ruolo del verde urbano  
Giulio Senes

UNIVERSITÀ DEGLI STUDI DI MILANO  
Dipartimento di Scienze Agrarie e Ambientali



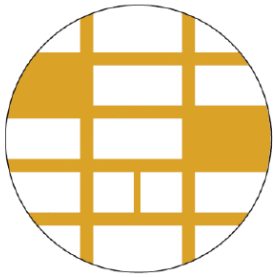


# Blue roofs





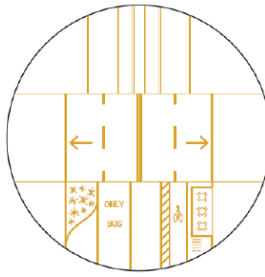
# Complete Streets



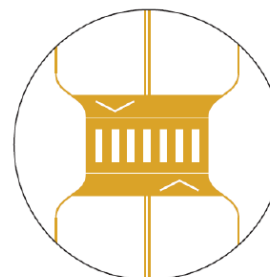
Streets Are  
Public Spaces



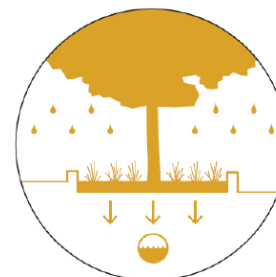
Great Streets are  
Great for Businesses



Streets Can  
Be Changed



Design for  
Safety



Streets are  
Ecosystems



Act Now!



# Complete Streets



## Plazas - Rain Gardens



Source: [www.ann Arbor.com](http://www.ann Arbor.com)



Source: [www.sfbetterstreets.org](http://www.sfbetterstreets.org)

## Planter Strips – Swales, Rain Gardens, Trees



Source: [sfbetterstreets2.szfplanning.org](http://sfbetterstreets2.szfplanning.org)



## Curb Extensions – Rain Gardens



Source: [www.myballard.org](http://www.myballard.org)



Source: [www.blogspot.com](http://www.blogspot.com) on 3.7.2012

## Linked Tree Wells/Curbed Planters



Source: [blog.g8-life.com](http://blog.g8-life.com)



## Parking Lane – Permeable Paving, Rain Gardens



Source: [www.cityofberkeley.info](http://www.cityofberkeley.info) on 04.12.13



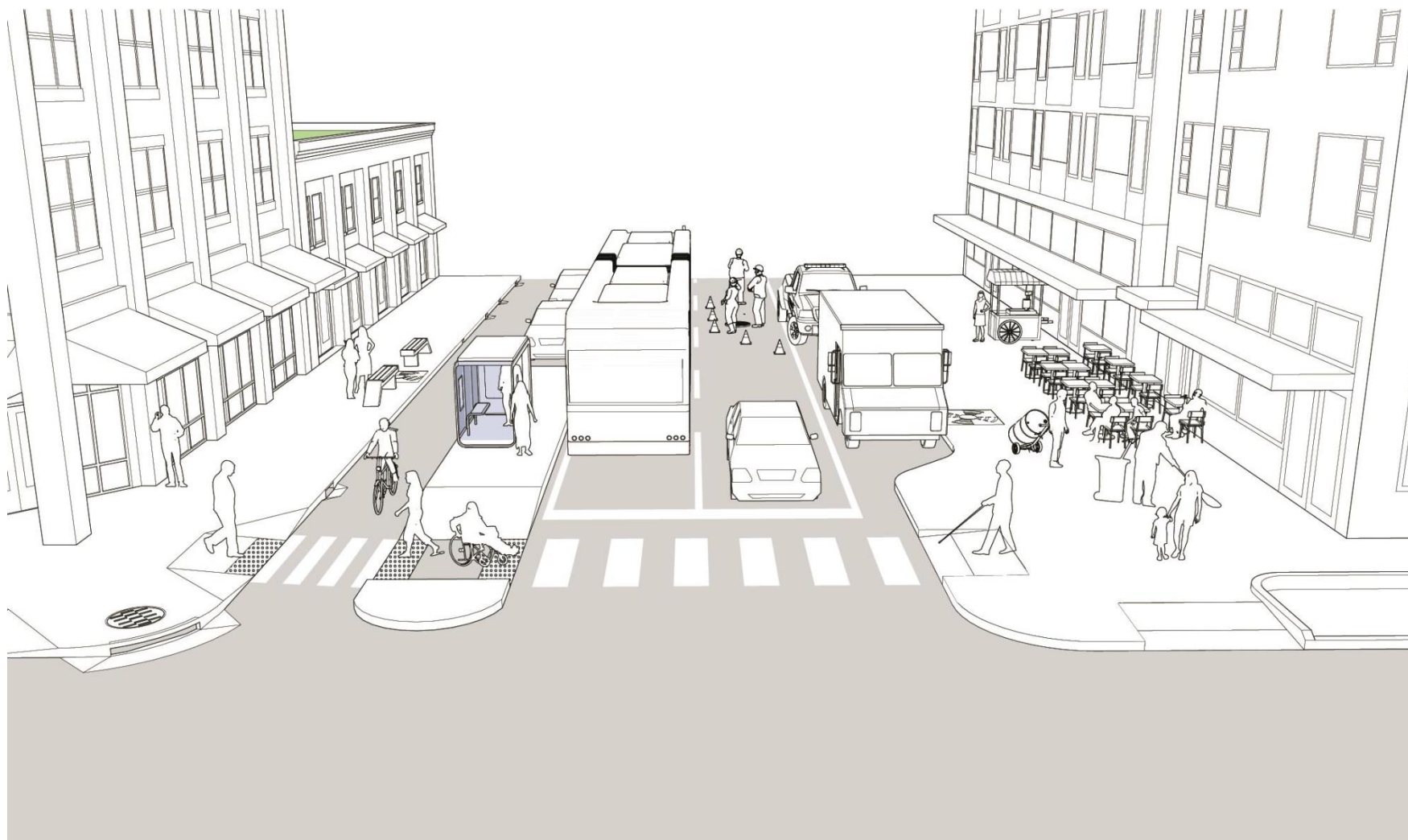
Source: [www.extension.org](http://www.extension.org)



# Complete Streets

Il ruolo del verde urbano  
Giulio Senes

UNIVERSITÀ DEGLI STUDI DI MILANO  
Dipartimento di Scienze Agrarie e Ambientali



# Green Streets

Il ruolo del verde urbano  
Giulio Senes

UNIVERSITÀ DEGLI STUDI DI MILANO

Dipartimento di Scienze Agrarie e Ambientali





# Green Streets

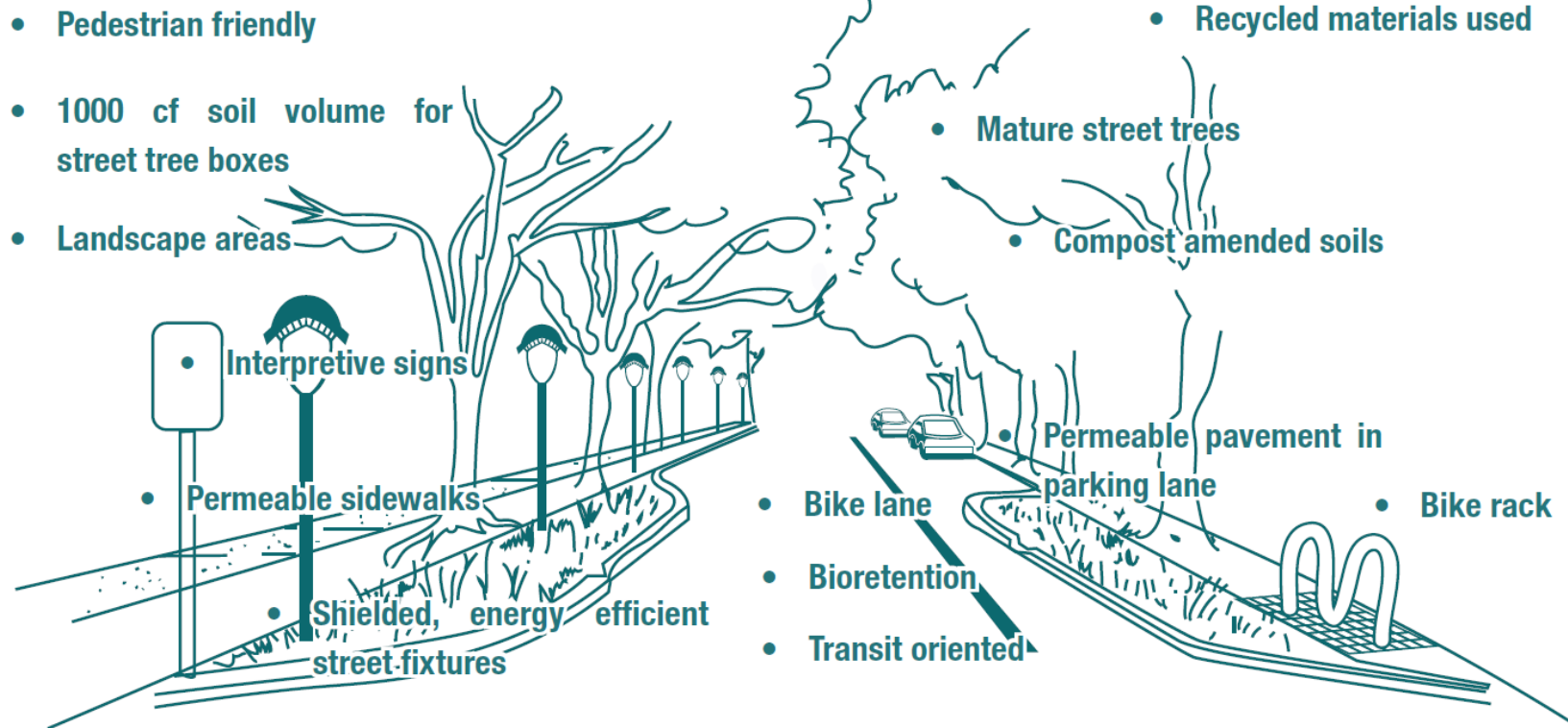


Figure 4.3.1: Anatomy of a Green Street. (Source: Ann English)



# Green Streets

## Una strada per le auto . . .





# Green Streets

## Una strada per la gente . . .





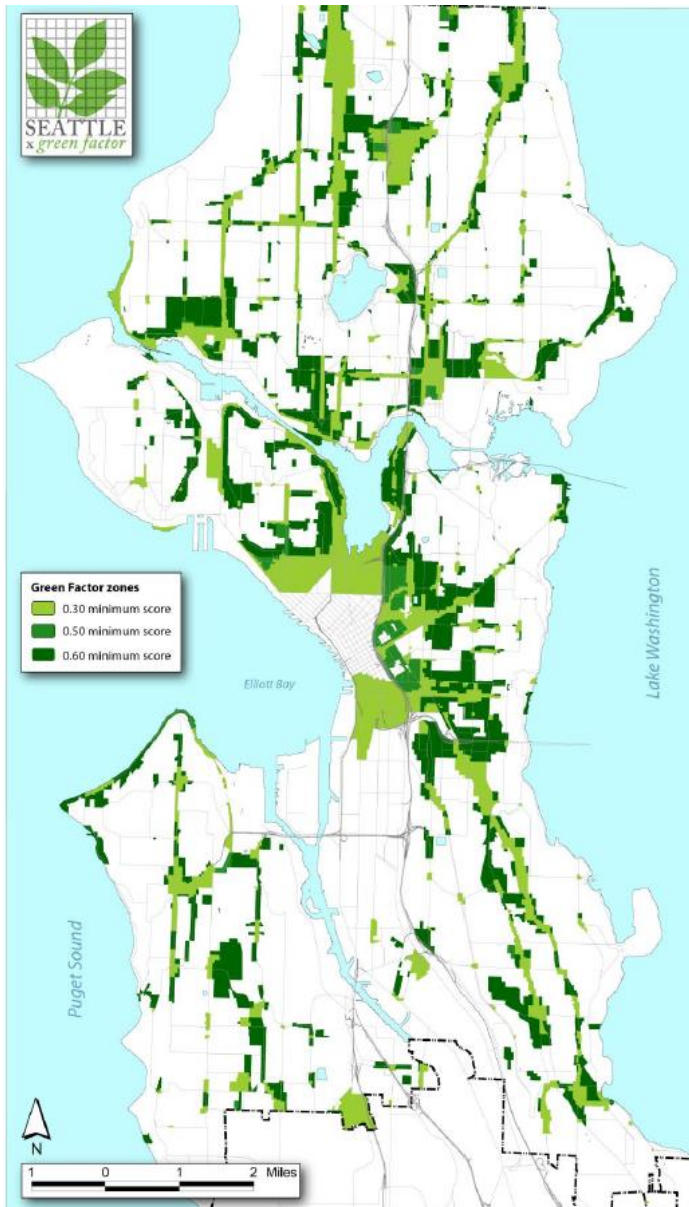
# Green Streets

## Una strada per l'acqua . . .





# Seattle Green Factor



Revised 4/8/09

## Green Factor Score Sheet

SEATTLE *green factor*

Project title: \_\_\_\_\_

Parcel size (enter this value first) \*  enter sq ft of parcel  minimum score determined by zone **SCORE 0.618**

Landscape Elements**		Totals from GF worksheet	Factor	Total
<b>A Landscaped areas (select one of the following for each area)</b>				
1	Landscaped areas with a soil depth of less than 24"	<input type="text" value="enter sq ft"/>	0.1	-
2	Landscaped areas with a soil depth of 24" or greater	<input type="text" value="4314"/>	0.6	2,588.4
3	Bioretention facilities	<input type="text" value="160"/>	1.0	160.0
<b>B Plantings (credit for plants in landscaped areas from Section A)</b>				
1	Mulch, ground covers, or other plants less than 2' tall at maturity	<input type="text" value="4314"/>	0.1	431
2	Shrubs or perennials 2'+ at maturity - calculated at 16 sq ft per plant (typically planted no closer than 18" on center)	<input type="text" value="253"/> enter number of plants 4048	0.3	1,214
3	Tree canopy for "small trees" in the Green Factor tree list or equivalent (canopy spread of 15') - calculated at 50 sq ft per tree	<input type="text" value="3"/> enter number of plants 150	0.3	45
4	Tree canopy for "small/medium trees" in the Green Factor tree list or e	<input type="text" value="0"/> enter number of plants 0	0.3	-
5	Tree or eq	<input type="text" value="5"/> number of plants 750	0.4	300.0
6	Tree or eq	<input type="text" value="0"/> number of plants 0	0.4	-
7	Tree with l	<input type="text" value="0"/> inches DBH 0	0.8	-
<b>C Green</b>				
1	Over	<input type="text" value="0"/> enter sq ft 0	0.4	-
2	Over	<input type="text" value="1350"/> enter sq ft 1350	0.7	945.0
<b>D Vegeta</b>				
		<input type="text" value="2960"/> enter sq ft 2960	0.7	2,072.0
<b>E Approv</b>				
<b>F Permea</b>				
1	Perm	<input type="text" value="0"/> enter sq ft 0	0.2	-
2	Perm	<input type="text" value="404"/> enter sq ft 404	0.5	202.0
<b>G Structu</b>				
		<input type="text" value="0"/> enter sq ft 0	0.2	-
Total of sq ft = 18,450				
<b>H Bonus</b>				
1	Drou	<input type="text" value="2200"/> enter sq ft 2200	0.1	220.0
2	Land throu	<input type="text" value="160"/> enter sq ft 160	0.2	32.0
3	Lands public	<input type="text" value="4,448"/> enter sq ft 4,448	0.1	445
4	Lands	<input type="text" value="0"/> enter sq ft 0	0.1	-
Green Factor numerator =				8,655

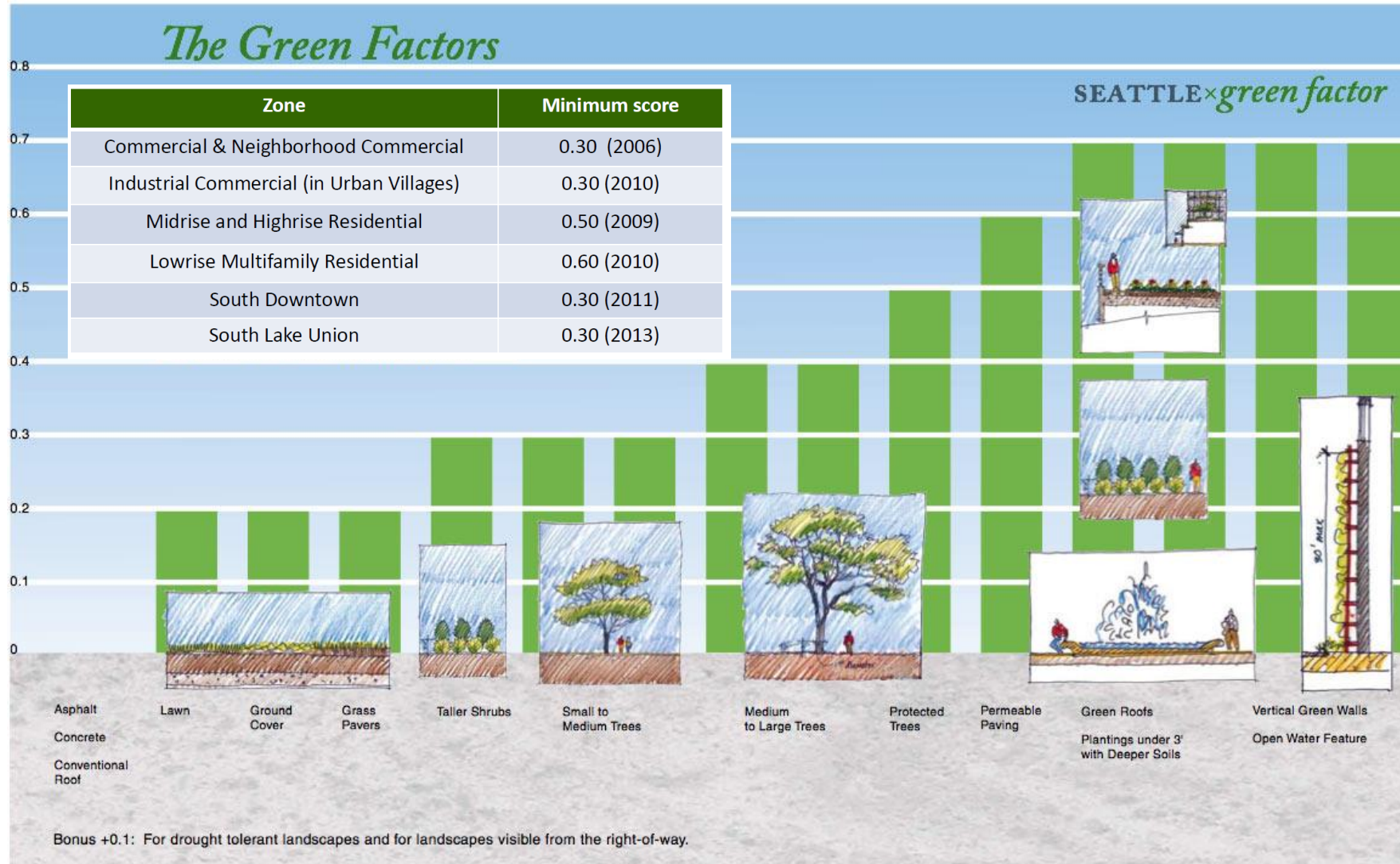
\* Do not count  
\*\* You may  
land must c  
\*\*\* Permeable paving and structural soil together may not qualify for more than one third of the Green Factor score.

parcel. All landscaping on private and public

## Score sheet

- Applicant enters number and/or square footage of landscape features
- Score sheet multiplies each feature by a factor (from 0.1 to 1.0)
- Total divided by parcel size, translates to % or Green Factor score
- Favors layered plantings, right-of-way improvements, and "bonuses"

# Seattle Green Factor



Seattle's Green Factor requires 30 percent parcel vegetation in business districts. Property owners can use various practices to reach the 30 percent threshold, with bonuses for rainwater harvesting, drought tolerant plants, tree preservation, green roofs and more. Image from the City of Seattle.





# UNIVERSITÀ DEGLI STUDI DI MILANO

Dipartimento di Scienze Agrarie e Ambientali

## Il ruolo del verde urbano

*Giulio Senes*

SEMINARIO DI APPROFONDIMENTO

### PROGETTARE PER L'INVARIANZA

REGOLAMENTO REGIONALE N. 7 DEL 23.11.2017:

CRITERI E METODI PER IL RISPETTO DEL PRINCIPIO DELL'INVARIANZA IDRAULICA E IDROLOGICA

AI SENSI DELL'ART. 58 BIS DELLA L.R. 12/2017



COMUNE DI  
MONZA



PROVINCIA  
MONZA BRIANZA



INU Lombardia  
Istituto Nazionale di Urbanistica

ordine degli architetti  
pianificatori, paesaggisti  
e conservatori della provincia  
di monza e della Brianza



Collegio Provinciale  
Geometri e Geometri Laureati  
di Monza e Brianza



11 Aprile 2018 - Sala Congressi Assolombarda - Confindustria Milano Monza e Brianza, via Petrarca 10 - Monza