CITY / NATURE FOR URBAN RESILIENCE

STORMWATER TOOLBOX

2017 Scan | Design Interdisciplinary Master Studio

University of Washington, College of Built Environments

Non-infiltrating Bioretention Planters

A Creative Solution

Non-infiltrating biofiltration planters are useful when stormwater infiltration cannot be accomplished or is not ideal. This could be due to contextual characteristics, native soils, contaminated soils, building adjacency, or other constraints.

Planters are designed with an impermeable base, (typically concrete or liner) and supporting drainage infrastructure that collects and filters runoff downward through soil, and directs treated runoff through an underdrain pipe.

Flat Planters

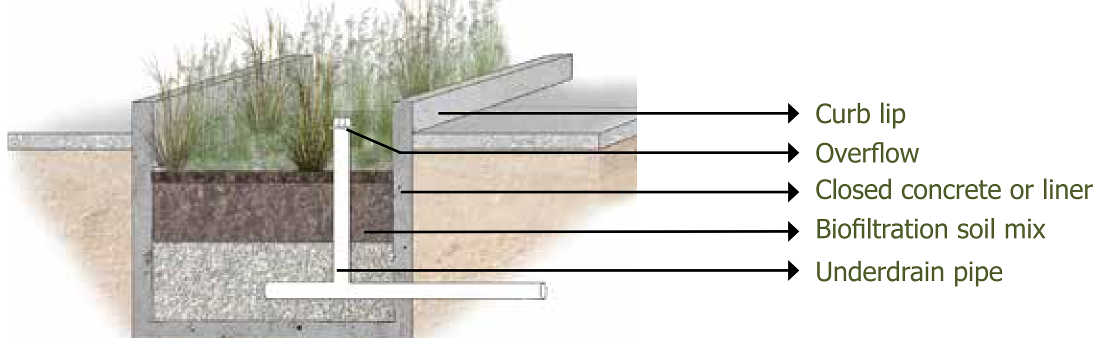


Image by Aaron Parker

Multiple Benefits

- Water quality treatment
- Reduce runoff volume and flow rate
- Able to fit flexibly in limited spaces
- Provide a solution in contexts where infiltration is not desired
- Relatively low maintenance
- Relatively cost-effective stormwater management option
- Educational benefit with stormwater visibility
- Increase air quality, especially if adjacent to streets

Sloped Planters

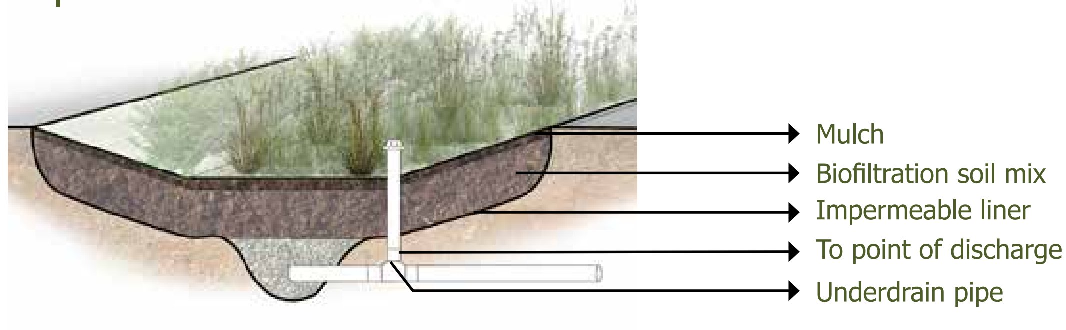
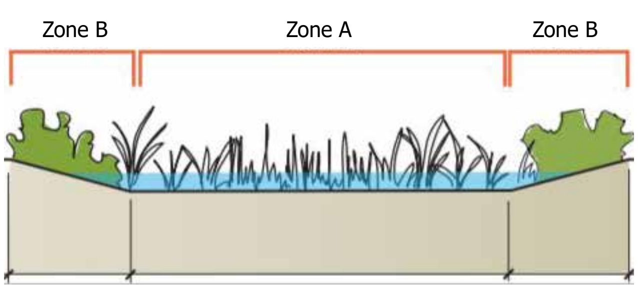


Image by Aaron Parker

Planting Considerations

Varying slope and ponding levels allows for two different moisture zones. The bottom area becomes inundated during storms and the side slopes experience a lower level of moisture.



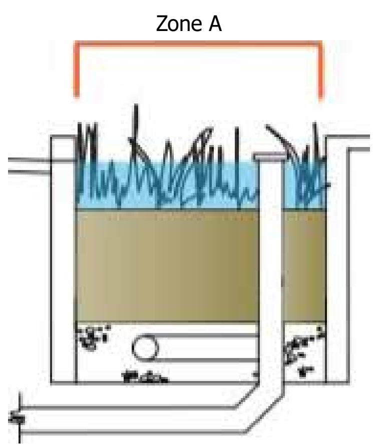


Image by http://ucanr.edu/blogs/slomggarden/blogfiles/10285.pdf

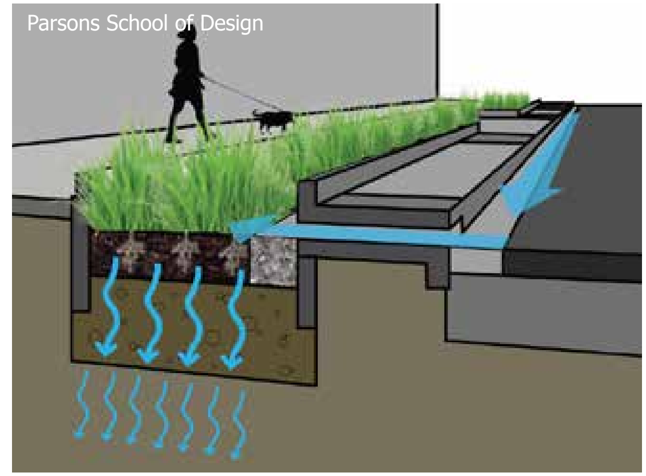
Practical Requirements

- Have a hydraulic restriction layer to prevent infiltration into the soil
- Be equipped with an underdrain
- Drain within 24 to 72 hours
- Soil media should balance meeting stormwater estimations and optimizing pollutant removal potential

Recommendations

- Include seating along planter edges
- Build in areas for pedestrians to cut through to ensure curb access
- Use plants appropriate for the micro-climate that require little irrigation and maintenance

Bioretention Cells (infiltrating)



What is a bioretention cell?

A bioretention cell is a planting cell containing a combination of planting soils, sand, mulch, and plant materials such as trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells allow collected water to directly infiltrate into the ground or utilize an underdrain to carry away excess water.

Why use a bioretention cell?
The chemical, physical, and biological qualities of the plants and soil remove pollutants found in stormwater runoff, such as phosphorous, nitrogen, heavy metals, and suspended solids. The cells also absorb stormwater runoff, reducing and slowing flows into sewer systems. This reduces the costs typical spent on conventional practices. Finally, they can add an element of beauty to the built environment.

When should I use a bioretention cell?

While bioretention planters can be as narrow as 4 feet in width, bioretention cells require a minimum 200' flow path, restricting the ability to use it in tighter urban settings. However, for bioretention swales, the minimum recommended bottom width is 1 foot. Additionally, bioretention cells function best when contributing slopes are between 1-5% , and draw from a drainage area that is less than 2.5 acres.

How much water can I treat with a bioretention cell?

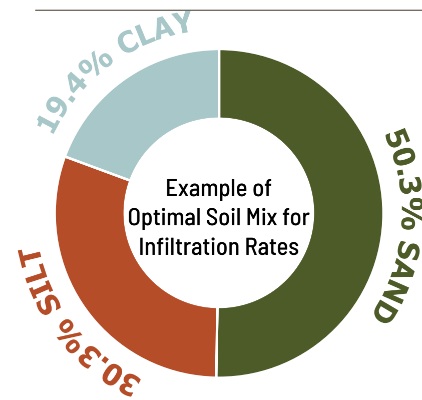
Because soils utilized in bioretention cells receive significantly more stormwater flows than in natural settings, the possibility of clogging is higher. While traditionally the response has been to use a higher percentage of sand to anticipate the particulate collection, studies have found that the presence of roots and invertebrates maintain sufficient soil porosity. As a result, an example of an optimal soil mix for bioretention cells is included to the right, which would result in an infiltration rate of three inches per hour, which also avoids the need for an underdrain. The typical depth of bioretention cells ranges from 6 inches to over 40 inches, with a 6 inch suggested maximum for storage water depth and a 36 inch suggested maximum for biortention soil depth.

According to the Tennessee Permanent Stormwater Management and Design Guidance Manual, a formula for calculating the soil storage volume (ft^3) is equal to the soil area (ft^2) times the soil depth (ft) below the overflow multiplied by the void ratio (which are generally .2 for bioretention soils, .4 for clean-washed aggregate, and .85-.95 for manufactured storage units).

Sources: BMP T7.30, 2014 Stormwater Management Manual for Western Washington (SWMMWW)
Green Stormwater infrastructure in Seattle, Implementation Strategy, 2015-2020

Hydraulic Conductivity by Soil Type

Texture class	Sand	Clay	Saturated Conductivity (in/h)
Sand	88	5	4.3
Loamy Sand	80	5	3.81
Sandy Loam	65	10	1.98
Loam	40	20	0.61
Silty Loam	20	15	0.63
Silt	10	5	0.87



Optimal Infiltration Rate

Soil Storage Volume Equation

$$SSV(ft^3)=SA(ft^2)xSD(ft)xVR$$

Upstate Forever LID fact sheet
Nathalie Shanstrom. www.deeproot.com. 2015.
http://tnpermanentstormwater.org/manual.asp

Grasspave

Invisible Structures

Basic Information

Grasspave, a permeable grass surface that acts like pavement, is a great alternative to cement or asphalt. It can bear heavy loads but is meant to be used infrequently for utility access, additional parking, landing areas and more.

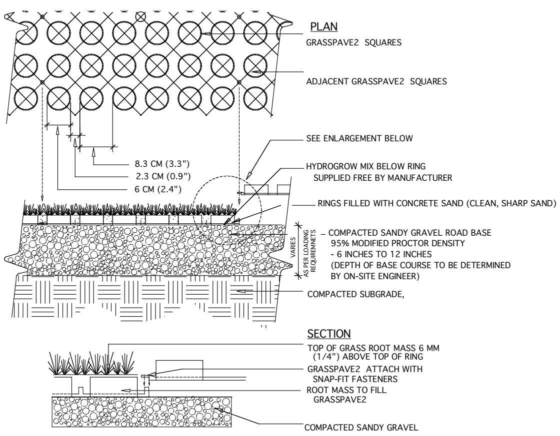
A few important facts before we start: The system size ranges from 6 to 12 inches thick depending on type purchased. 25% of each system is void space and will act as water storage. There is roughly 75,000 square feet of alley space in Belltown.

Calculations

System Size (Depth) x Area of Project x 25% = Water Storage Capacity

1' x 75,000 ft2 x .25 = 15,562.5 ft3

15,562.5 Cubic Feet = **116,415.59 Gallons of Water Storage**



Invisible Structures

Invisible Structures

References:

"Invisible Structures." Invisible Structures. Accessed October 15, 2017. http://www.invisiblestructures.com/.

Green Screens and Facades

Benefits

- biophilic experience
- urban beauty
- building performance
- habitat creation
- usability and adaptability
- cost and speed
- water systems

Performance Figures

- Wisteria can transpire 110 Gallons of water per day
- Vigorous climbing vines can cover 6500 ft2 and grow 10' / year
- Daily temp fluxuation reduced by 50% in shaded buildings
- more eficient than built-in insulation.

Types and Applications

- Wire, trellis, cage, or on-wall
- Vertical / wall based
- Overhead / arbor
- Freestanding Structures
- Combine with water infrastructure
- Planter boxes
- etc.!

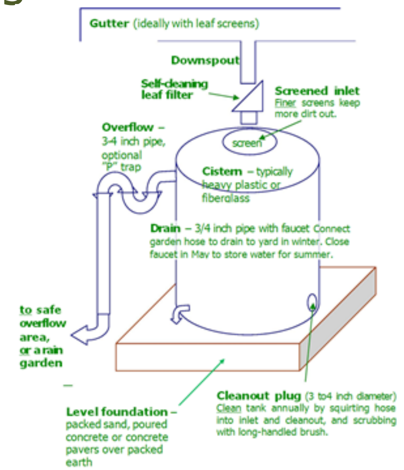
References:

1) http://www.greenscreen.com, Accessed October 15, 2017.

2) Goodwin, C and Hopkins, G. Living Architecture. Collingwood: CSIRO Publishing, 2011.

3) Dunnett, N and Kingsbury, N. Planting Green Roofs and Living Walls. Portland: Timber Press, 2008.

Making Stormwater Management Artful



How much water can be harvested from the 13,150 acres of Rooftop in Seattle during a stypical storm event?

Through the Example of an External Cistern

Stormwater management can be artful, educational, and emotive while it resonsates with the local context. External cisterns are inherently sculptural and so can be easily incorporated into a site's aesthetic design intentions.

Beckoning Cistern

Water as Social Amenity

Growing Vine Street

Rainwater Harvesting

The Ripple Effect

Making Stormwater Management Visible

Considerations:

How much area are you collecting water from?
Which months are you harvesting water from, and which months are you using stored water?
What type of performative aspects can the cistern house?
How can you include local artists or local artistry and craftworks?
What type of educational or informative aspects can be included in a cistern?
> Cost
< Maintenance
> Visibility and use as Social Amenity

Requirements:

1. Level location
2. Solid Base
3. Space for Ingress and Egress
4. Safe place to discharge the overflow
- 5 feet from any structures on slab foundations
- 10 feet from any structures with basement
5. Cannot discharge overflow onto neighboring properties

Resources:

Rainwise Rebates and Cistern Calculators:
http://www.seattle.gov/util/EnvironmentConservation/Projects/GreenStormwaterInfrastructure/RainWise/Rebates/index.htm

Rainwater Harvesting and Connection to Plumbing Fixtures:
http://www.seattle.gov/DPD/Publications/CAM/CAM701.pdf

Cistern Sizing:
http://indytilth.org/Links/CisterSizing.pdf

Green Roof on Historic Buildings

Efficiency Benefits for Historic Buildings:

1. Reducing the urban heat island effect

2. Improving storm water management

3. Improving the energy efficiency and sustainability of the building ...

Check List before Installation on Historic Buildings:

1. Weight Calculation
The most important physical issue to take into account is the increased roof load.

Thin(3-6 inches) Extensive Green Roof=**13 lbs/sf**
Extensive Roof with 3 - 4 inches of Growing Medium=**17-18 lbs/sf**

2. Consider Water/Moisture impact
Green roofs, in many cases, are meant to retain water over a longer period of time to slow stormwater runoff and to nourish the plants. It is important that the roof covering be watertight to prevent leaks into the building. If a proper root barrier or thermoplastic membrane is not included, roots can penetrate through the waterproof layer, allowing moisture to infiltrate the roofing system and damage the structure below.

3. Conduct an Energy Audit
An energy audit will evaluate the building's current thermal performance and identify any repairs that need to be made. (https://www.nps.gov/tps/sustainability/energy-efficiency/weatherization/energy-audit.htm)

Major Sources of Air Leaks(U.S. Department of Energy)

4. Reduce Air Infiltration
Any necessary HVAC upgrades should be carried out, and insulation should be added in appropriate locations

5. Use Energy Model
An energy model should be conducted to predict the potential impact of a green roof. This can assist in deciding whether installing a green roof would be cost effective and if it would provide any added environmental benefits on a historical building.

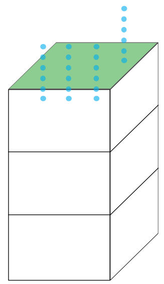
Heinz 57 Center(Stancills Inc.)

Green Roof Construction Code References:

1. The Storm Water Manual
2. International Green Construction Code (IgCC)
3. The Living Future Institute's Living Building Challenge
4. Green Globes, the International Well Building Institute's WELL Standard
5. Passive House and Passive House Institute US (PHIUS)
6. The U.S. Green Building Council's LEED®O+M

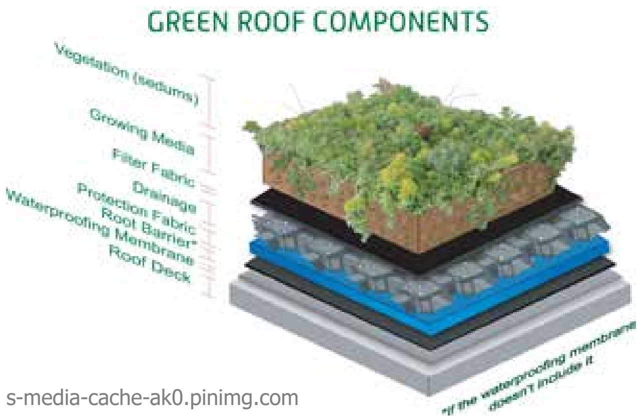
Calculation:

For a three-storey historic office building in Seattle(total building floor area=1500 sf):



For a 3-inch extensive green roof, the building can hold 2,805 gallons of water.

According to the 2030 Stormwater Calculator, the green roof can manage a total of 46% of the stormwater and 12% of the total water.



s-media-cache-ak0.pinimg.com

References:

1) www.nps.gov
2) www.traditionalproductreports.com/
3) forum.savingplaces.org/

Green Walls

Green Walls for Stormwater:
Rachel Wells and Nicky Bloom

Green walls are often cited for their benefits in contributing biodiversity to cities, reducing building energy costs, and reducing the urban heat island effect, but their potential in managing stormwater is just beginning to be explored.

Current measurements apply green roof performance measurements and valuations to green walls. Some sources say that green walls' storage capacity is somewhat less than green roofs. ASLA estimates that average green walls can reduce runoff by 40-60%, while green walls specialized for stormwater specifically estimate runoff reduction at 50-70%, usually due to different planting mediums, increased planting medium volume, and plants selected.

Different strategies for using green walls to manage stormwater include collecting rainwater in a cistern for irrigation, sending runoff collected from the roof directly through the green wall to be absorbed by plants and soil, creating a water filtration system, among others. Whatever the system, green walls delay runoff and are a helpful tool in managing stormwater volume.


GreenWorks

EXPO Center Stormwater Wall:

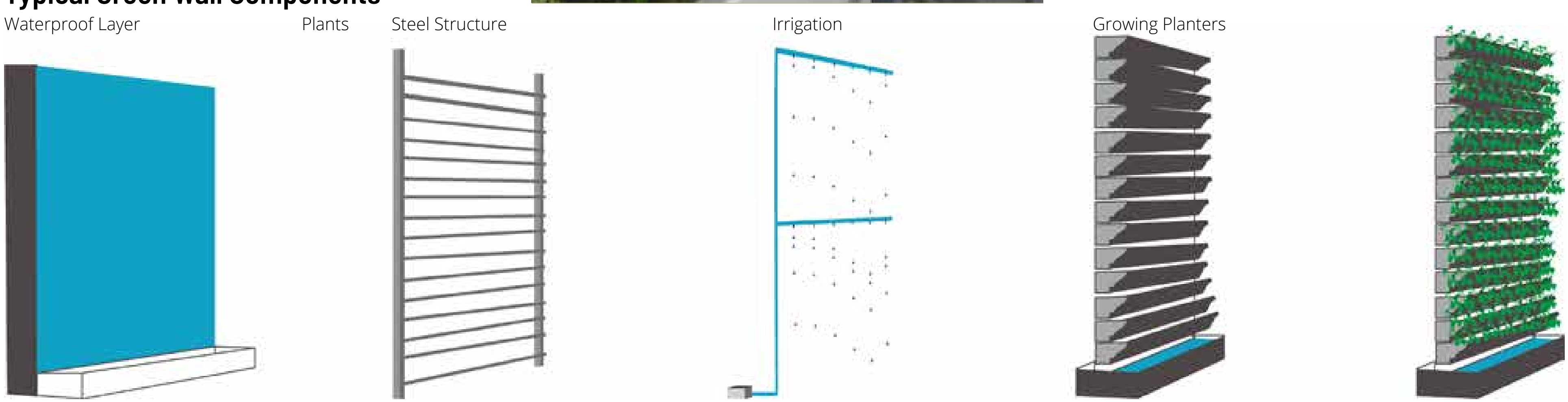
The EXPO Center Stormwater Wall in Portland, Oregon, completed in 2014 by GreenWorks Landscape Architects, is a 30X60 foot green wall specifically designed to treat and retain stormwater and is vegetated by plants and soils native to Oregon's Columbia River Gorge. The project uses gravity rather than the traditional pumps to move runoff through its green wall. City engineers tracking the project estimates that it reduces runoff volume by 50-70% from the 9,400 square foot roof that drains to it.


https://www.portlandoregon.gov/bes/article/505020

Living Wall at The Rubens at the Palace Hotel :

The Palace Hotel in London was retrofitted with a 350 square meter (3,767 square feet) green wall in 2013 by the Green Roof Consultancy and Treebox following a green infrastructure audit. It is designed to be in bloom year round as a pollinator pathway, attracts and traps pollutant particulates, provides urban habitat, and boasts a stormwater storage capacity of 10,000 liters. Stormwater is collected in large cisterns and pumped into the wall gradually, slowing the volume of stormwater flowing into the sewer system.

Typical Green Wall Components



Green Walls (continued)

Partner Technologies

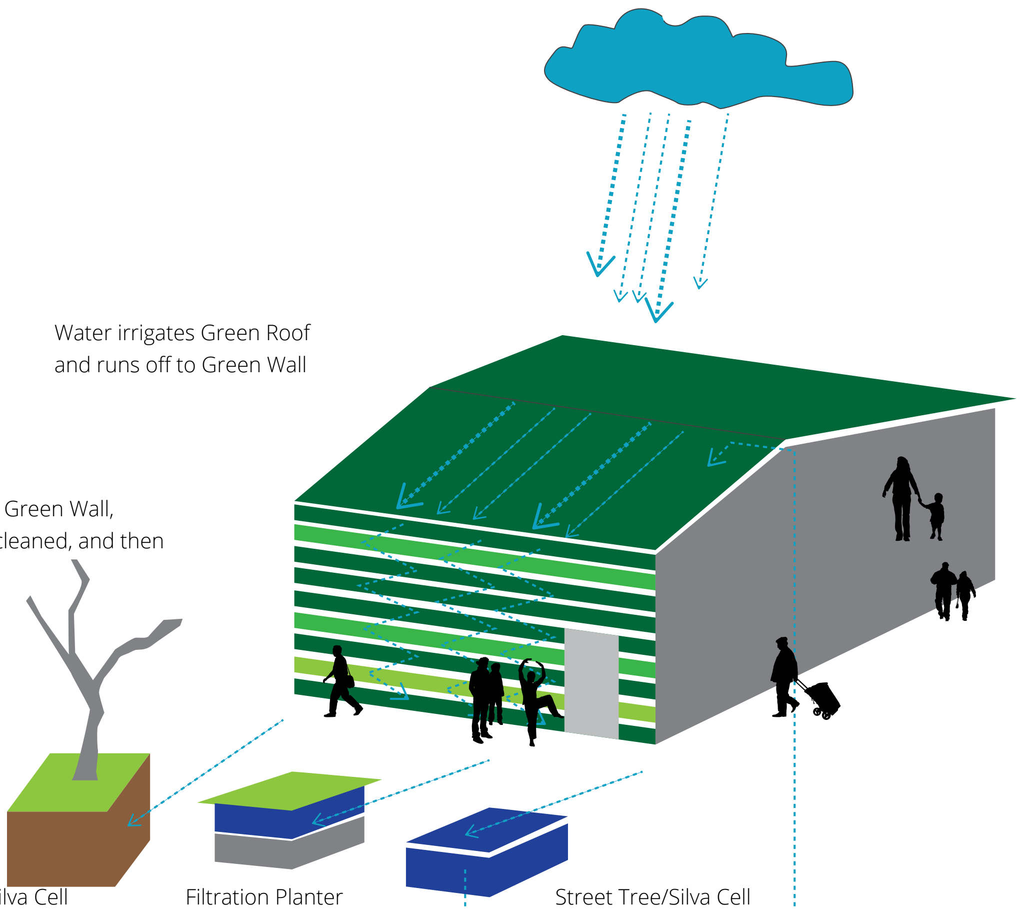


Diagram Content: R Urban + Nicky Bloom

https://www.dezeen.com/2013/08/21/londons-largest-living-wall-will-combat-flooding/

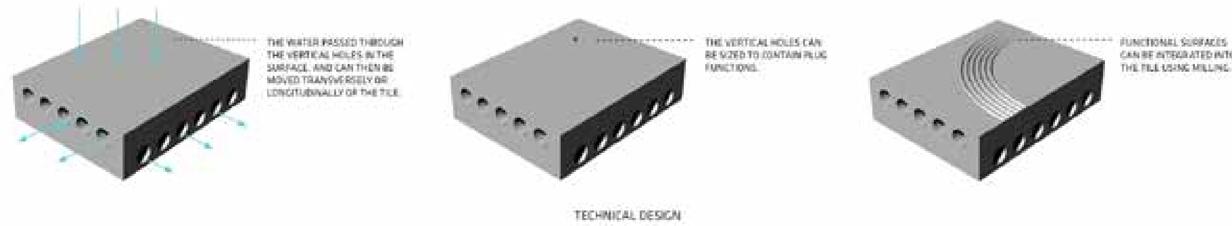
http://www.treebox.co.uk/news/londons-latest-prominent-living-wall--goes-beyond-aesthetics.html

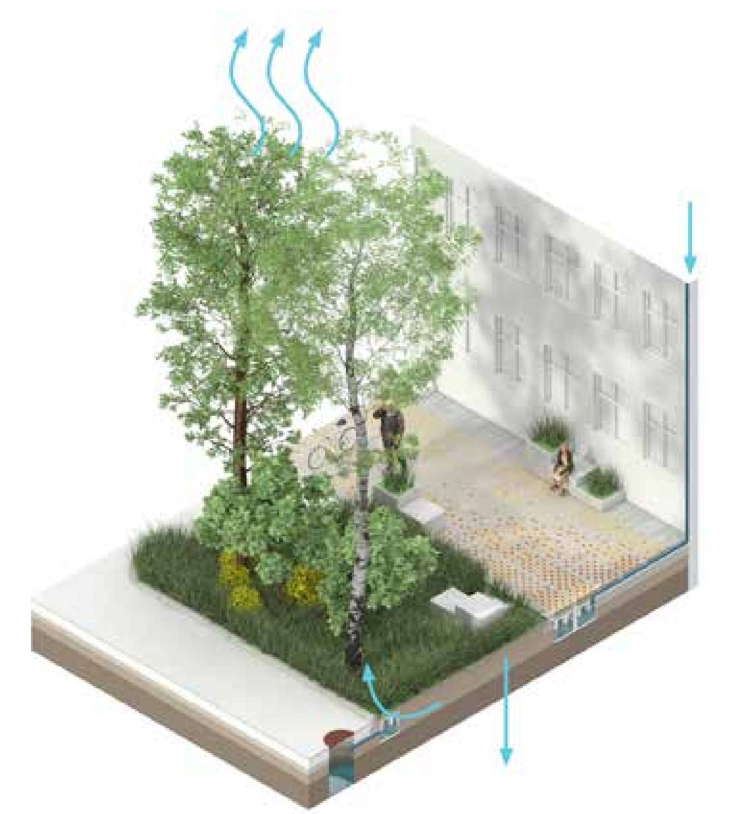
http://www.treebox.co.uk/news/londons-latest-prominent-living-wall--goes-beyond-aesthetics.html

Pervious Pavement

Pervious pavement is a permeable pavement, often with an underlying stone reservoir, that captures rainfall and stores runoff before it infiltrates
into the subsoil.

A Green Sidewalk with CLIMATE TILE (KLIMAFLISEN): A new type of modular tile invented by Danish architecture studio Tredje Natur, to help reduce flooding and increased rainfall in cities due to climate change. The solution offers multi-functional sidewalks that can collect and manage rainwater, and at the same time, the sidewalks become greener, creating new opportunities for experiences, stays and play in the city.



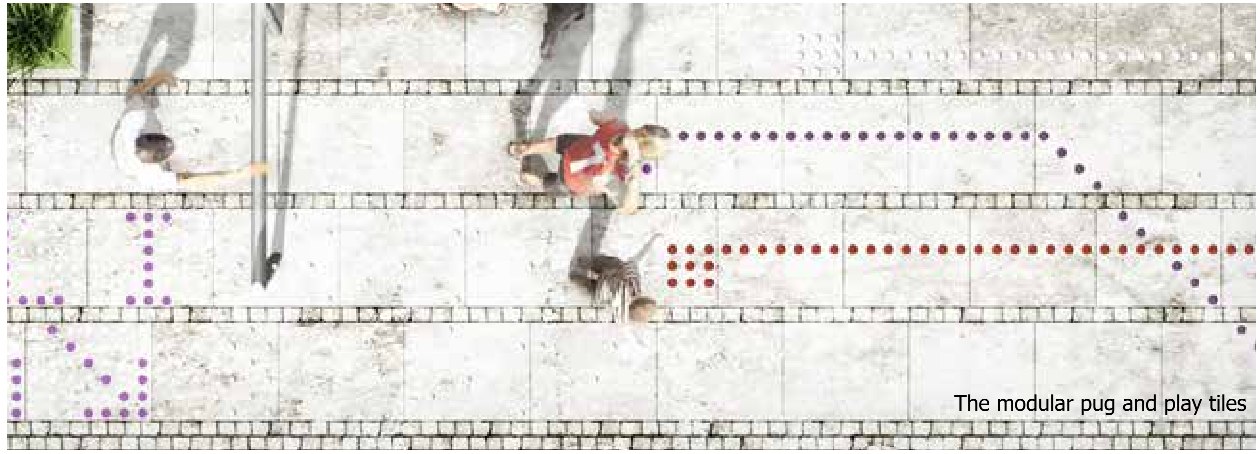


Collecting rain water from roof and pavement and using it in various ways

Underground water management system, and water treated bottom of the tile
Images: http://klimaspring.dk/prejekter-og-projekter/klimaflisen

Pervious Pavement (continued)

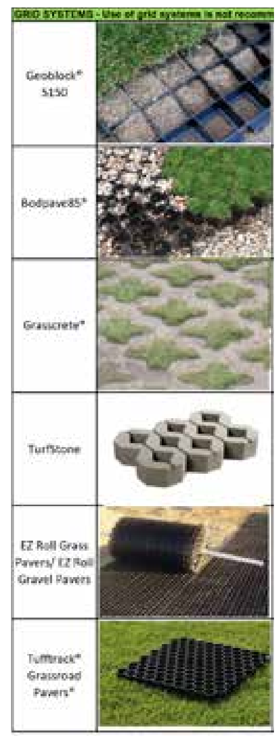
How it works:


The modular pug and play tiles

Climate tile is a modular plug and play system. The pavement tiles are developed with a system of holes, tunnels, and ridges. These collect and manage rainwater through an underground water handling system coupled with playful and green elements on the surface. The tiles handle the rainwater both from roof and pavement areas. The water from the roof is directly channeled to the bottom water-treated part of the tile, while the water from the sidewalk is led to the machine through the spaces between the special edge profiles of the tiles. Underground, rainwater is handled through a combination of storage, delay, or drainage. This is the PLUG part of the system. The PLAY part of the system on the other hand functions on the surface where some of the water is either used or evaporated through irrigation of planting or water pumps, water nozzles, etc. The designers also intend to create plugs for the holes on the surface of the Climate Tile, allowing its uses and catchment patterns to be adapted over time. Some of these will be smart plugs with sensors that measure data about the water supply to enhance awareness among the locals about climate change and adaption.

The tiles serve as a supplement to existing drainage systems, easing the stress on sewers at a time when some cities are recording record rainfall. Very soon the streets of Copenhagen will be a testing ground for the Climate Tile. The sidewalk located at Heimdalsgade number 22-24 at Nørrebro in Copenhagen is set for testing the tile; a location has chosen together with the City of Copenhagen municipality – from spring 2017 until 2018. Tredje Natur expects to bring it to the market by late 2018.

City of Seattle has developed a comprehensive guidelines describing allowable permeable pavement materials for different landuse and functions within the city. This also helps to earn storm water credits for new developments in the city.



Allowable permeable pavement options by the city of Seattle, WA

References:
1) Climate tile info and images: http://klimaspring.dk/prejekter-og-projekter/klimaflisen
2) http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2375026.pdf

Silva Cells

Silva Cells are a modular shoring system used to support pavements and create void spaces between the pavement and underlying soils that can then be filled with planting soil or other media to facilitate tree growth as well as water infiltration.

Advantages:

- Root-friendly: Vertically and horizontally contiguous soil ideal for spread of tree roots
- Stormwater in/out: open interior allows for easy movement of water into and out the system
- Utilities/Services: Maximum 14” (355 mm) apertures easily accommodate new or existing utilities
- Flexibility: Independent units allow maximum flexibility around existing or planned site considerations

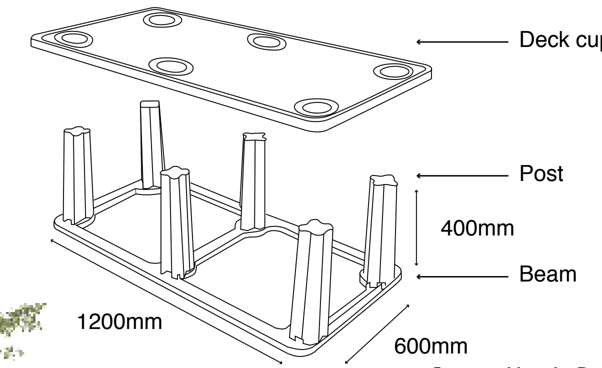


Image: Yunxin Du

Application:

Silva Cells can be used on almost any type of site, including:
- Streets
- Plazas
- Parking areas
- Green roofs/on-structure
- "Break-out" zones

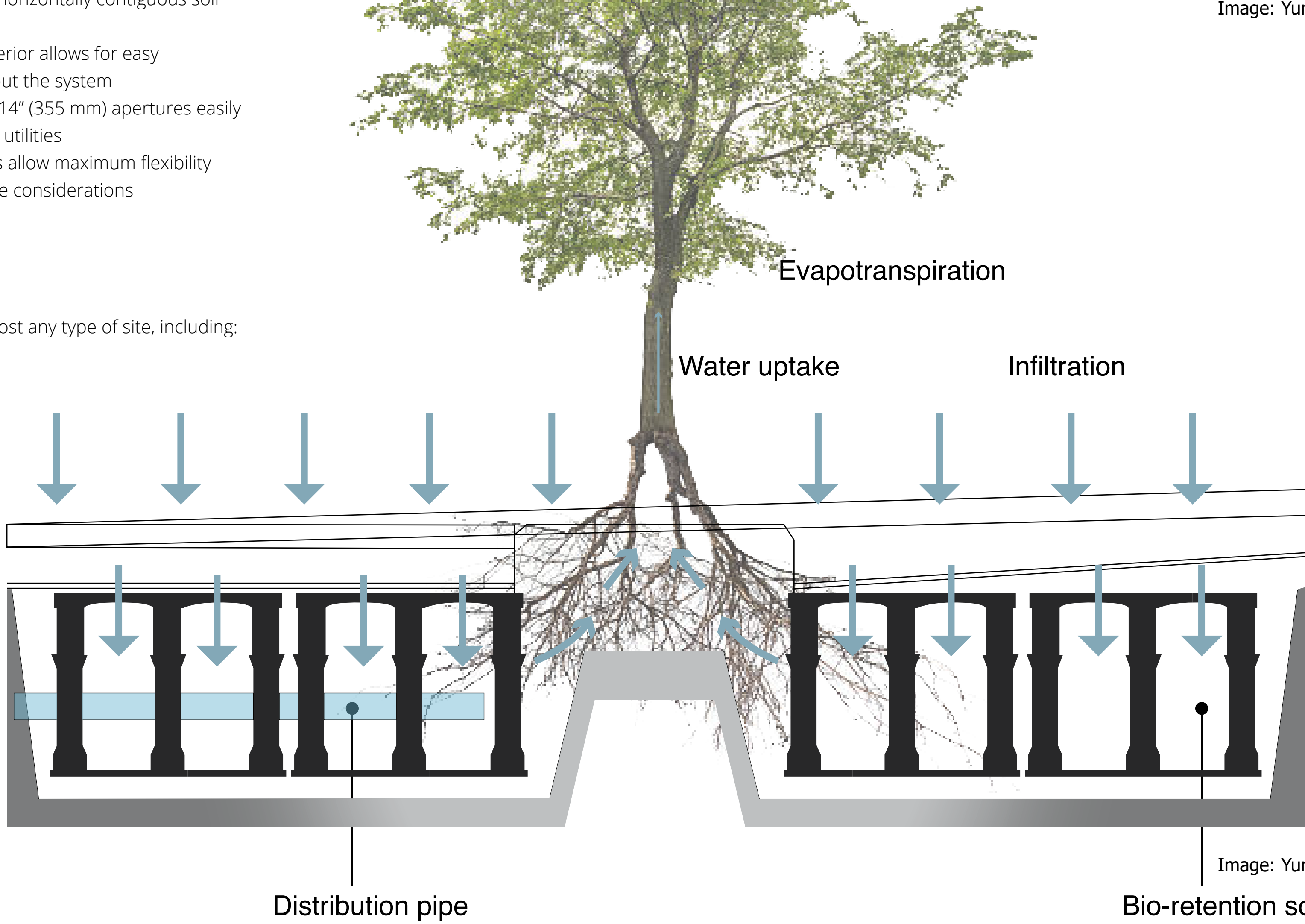


Image: Yunxin Du

Silva Cells (continued)

Image: Yunxin Du

Splash Boxx

Splash Boxx is a portable and adaptable solution for capturing and storing stormwater. These were fashioned for sites that had to treat large polluted areas, such as industrial sites. The boxes are constructed of steel and are comprised of bioretention soil, vegetation, and live storage (ponding). The units are gravity fed from roof downspouts and pumping from oil/water separators. One unit costs between $8,500-9,500.

They are several benefits that come with this solution. The units are pre-engineered to predict the amount of impervious surfaces that can be treated. Splashboxxes are movable and come in seperate units, which make them easily scaleable and adaptable to sites. This also alows them to be easily relocated or replaced.Units are available with seating integrated into the structure. Since they are placed above ground, there is no need for the use of excavation permits typically required when constructing a rain garden.

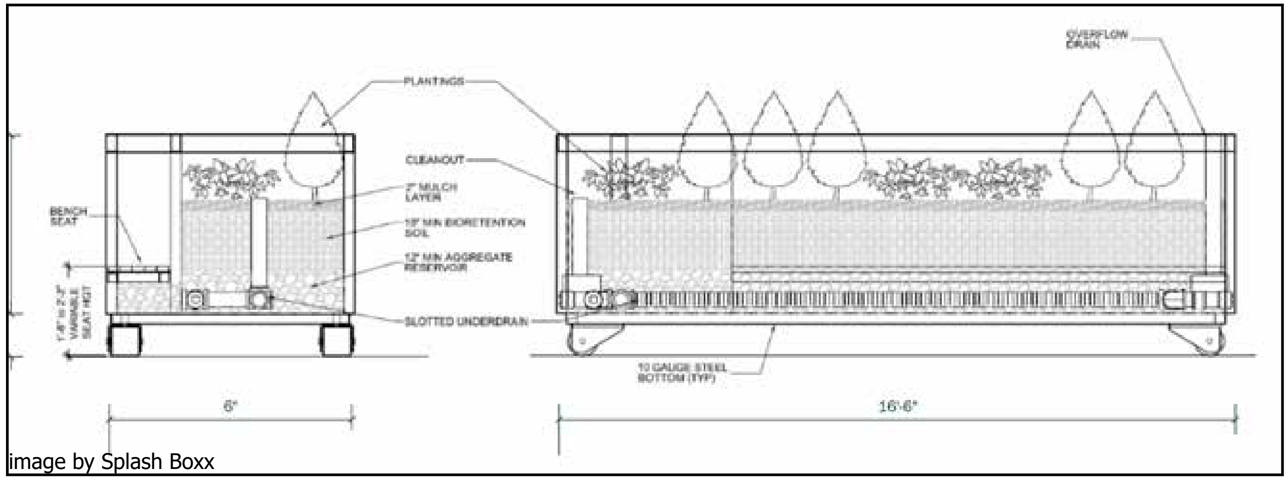


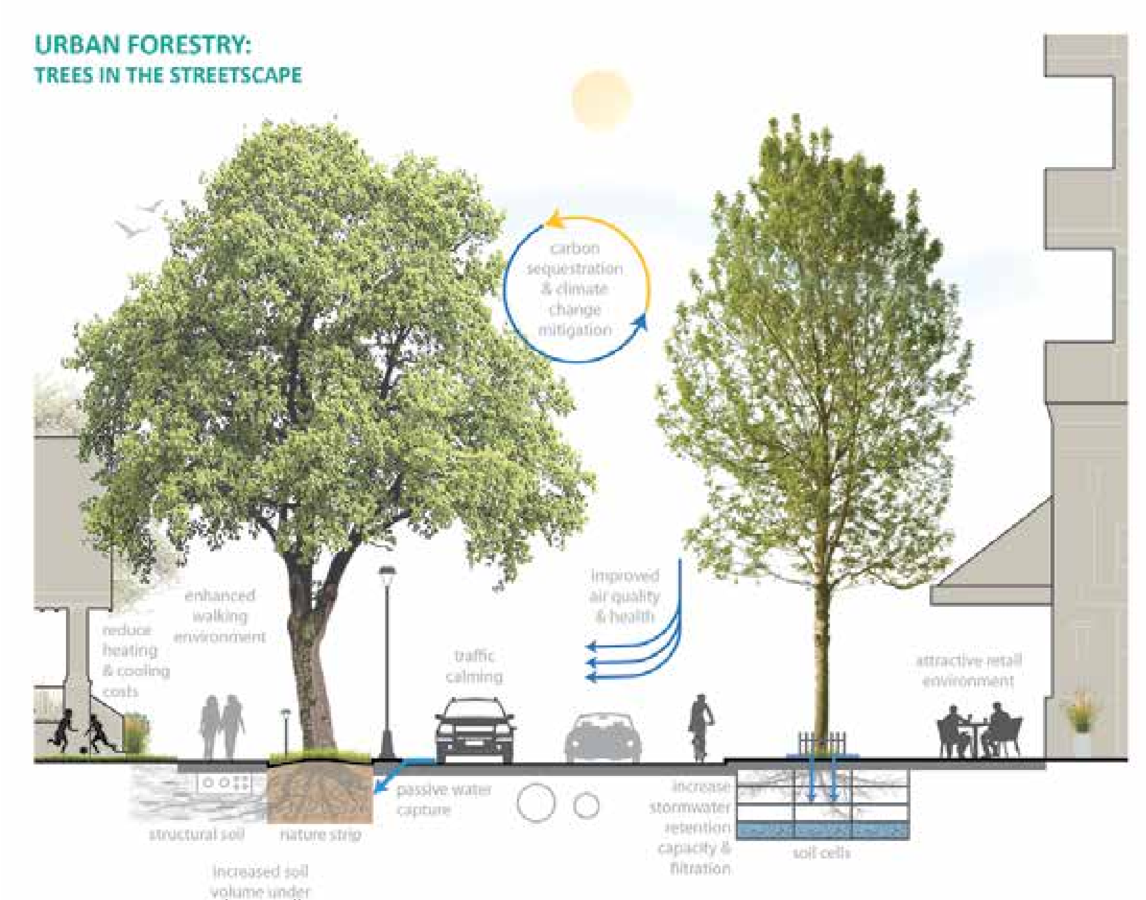
image by Splash Boxx


image by Splash Boxx


image by Splash Boxx


image by Splash Boxx

Urban Trees



Urban Forest Management Plan Toolkit

An urban forest is a compilation of trees in a city, town or suburb. Urban forests and street trees play an essential role in the health of cities.

When it comes to storm water management, trees are a critical part of green storm water infrastructure. Trees help by taking up rainfall and reducing storm water runoff. They also release water back into the atmosphere in a process called transpiration.

Trees also provide economic benefits to urban communities. By shading buildings, street trees can lower cooling costs by reducing energy consumption. Furthermore, shading and evapotranspiration reduces the Urban Heat Island Effect. They also increase property values and the amount of sales at nearby businesses.

Urban forests and street trees are pivotal in reducing air pollution. Trees filter pollution from the air and also reduce particulates in the air. Additionally, trees positively impact climate change through absorbing carbon dioxide.

Street trees better the quality of life in urban environments. Besides reducing noise pollution, they also have a positive effect on human health. Trees have been proven to reduce stress and help people recovering from serious health issues like heart attacks.

Seattle's Urban Forest Plan

Seattle values benefits provided by urban trees and forests. In 2013 the city released an Urban Forest Stewardship Plan to set up a guiding document for urban forestry in Seattle. Within the document is a long-term plan to increase Seattle's canopy cover to 30 percent by 2037. This plan also establishes a framework to support this mission of government departments, nonprofits and community groups.

Tree Canopy

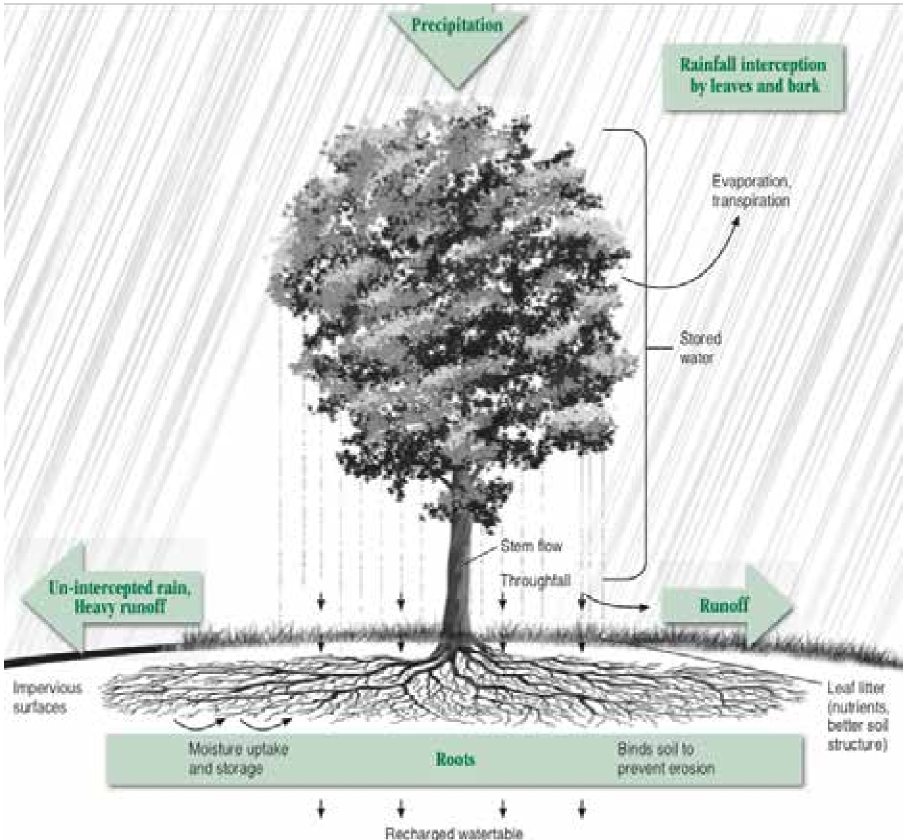


Image: Moss Architecture

Images: Google

Tree Canopy in Belltown

Image: Jiyoung Park

The role of Tree Canopy

Mature trees improves air quality
A tree can absorb up to 48 pounds of carbon per year.

Absolving the stormwater
Trees absorb the frist 30% of most precipitation through their leaves and another nearly 30% at the roots. This absorption reduces run-off, compensates for the drainage problems.

Cooling the temperature
Outdoor areas under the tree shade are 5 to 15 degrees cooler (Ameri canforests.org).

Mature trees improves air quality
A tree can absorb up to 48 pounds of carbon per year.

City of Seattle

Green Roof & Blue Roofs

2012 Seattle Building Code

Typical Roof Load:20 PSF

Green Roof Load: 100 PSF

Pitches up to 2:12 without special stabilization

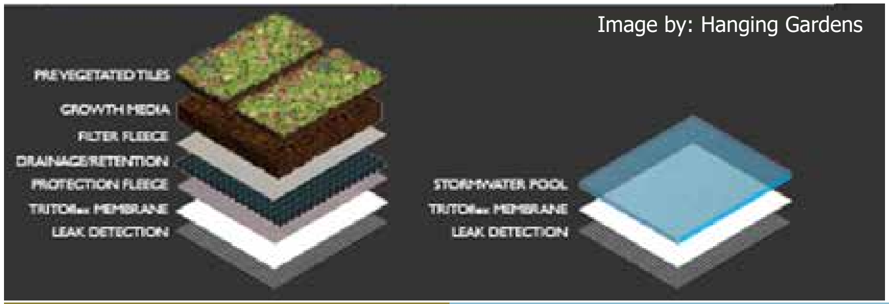
Standard Membrane

Cost: $$

15 Years Life Expectancy

Weight of Water:

62.42lbs/cubic foot



Green Roof	Blue Roof
Vegetated living or eco roof installed on a roof surface. Depth varies depending on the types, extensive. Pitches up to 2:12 (16.7%) without special stabilization	Non-vegetated control storm water. Flow Controls is used at the roof's downspouts to regulate storm water discharged while creating temporary ponding.
$$$$	$$
Life Expectancy: 40+ Year with Maintenance	Life Expectancy: 35+ Year with Maintenance
Roof Load Bearing Requirement: 10 psf-500psf	Roof Load Requirement: 20psf
Depth: 3-34 Inch	Depth: 2-4 Inch
Environmental • Storm water management • Improve air quality and filter air pollution • Reduced Heat island • Habitat for wildlife and urban biodiversity	Environmental • Prevent sewer surcharge and overflow
Social • Provide open space • Improve attention (micro break attention) • Improve roof vistas and aesthetics • Increase worker Satisfaction and Productivity	
Economic • Urban food production • Thermal buffer, reduce energy budget • Government incentive • Increase Building Value • Increase Roof Life time • Lower burning heat load • Noise Barrier • Eva transpiration from vegetation cool the panes increased efficiency of Solar Panels • LEED Points • Add property value	Economic • With light color materials, it reduced heat island and cooling the roof lowering facility operating cost • Does not require lots of excavation compare to ongrade stormwater management

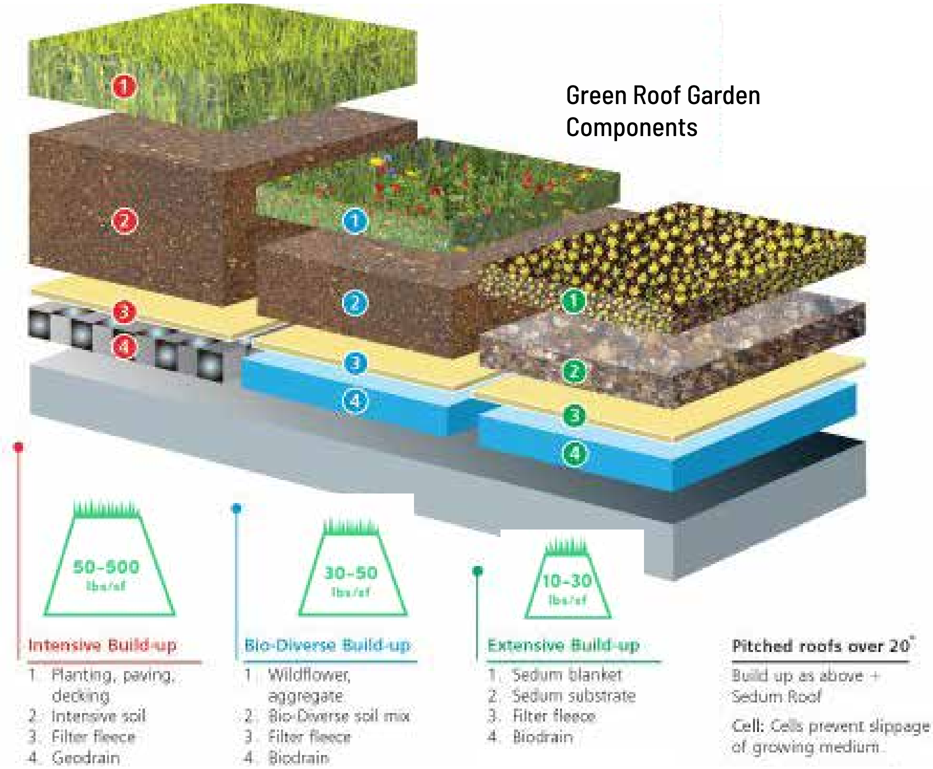


Image by: CEFI UK

Image by: PWD Plan review

Roof assembly can be combination of blue roof and green roof, in some other it was built stepping down to slow down the water.

Image by: Hanging Gardens

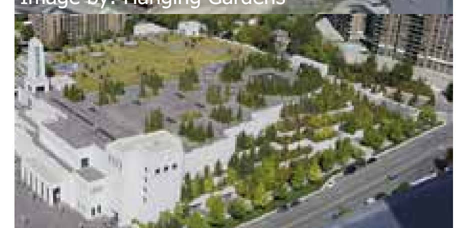


Image by: Utelite

Rainwater Harvesting and Re-use

Rainwater Harvesting is the capture and storage of rainwater and is considered the cleanest form of harvested water.

Through rainwater harvesting we can:
- Provide self-sufficiency water supply.
- Reduce potable water use and related costs.
- Reduce off-site flooding and erosion.
- Prevent CSO and reduce the amount of pollutants into our natural water bodies.
- Reduce salt accumulation in the soil and increase the drought tolerance of plants.

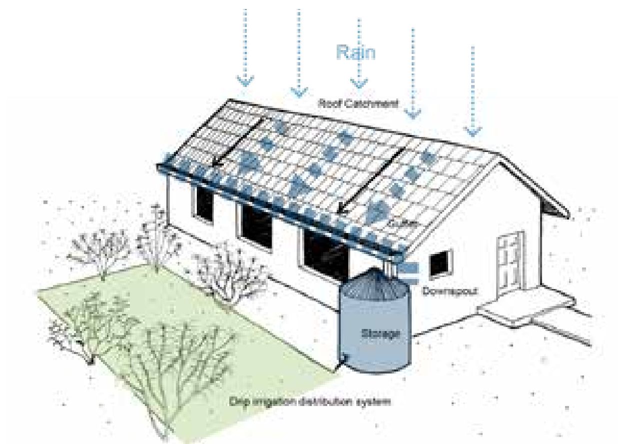


Image by: Parricia H. Waterfall + Yutong Hu

Rainwater Harvesting and Re-use in Private House

Rainwater Harvest System Components

- Collection systems: gutters,downspouts,piping
- Cistern/storage system: barrels, tanks
- Initial water quality treatment: leaf screens
- Delivery/distribution system: pumps, pipes
- Final water quality treatment: screen systems, basic mechanical filtration

Cisterns are storage tanks for rainfall that has been collected from a roof or some other catchment area. Although usually located underground, cisterns may be placed at ground level or on elevated stands either outdoors or within buildings.

HOW MUCH WATER CAN WE CAPTURE?

To determine the amount of rain the roof catches, multiply roof's width by its length (in feet) to estimate its footprint. Then estimate the portion of this area that drains to the downspout that will be using to catch rainwater.

Rain caught (gallons) = (inches of rain) x 0.6* x (portion of building footprint).

*One inch of rain falling on a square foot of surface yields approximately 0.6 gallons of water.

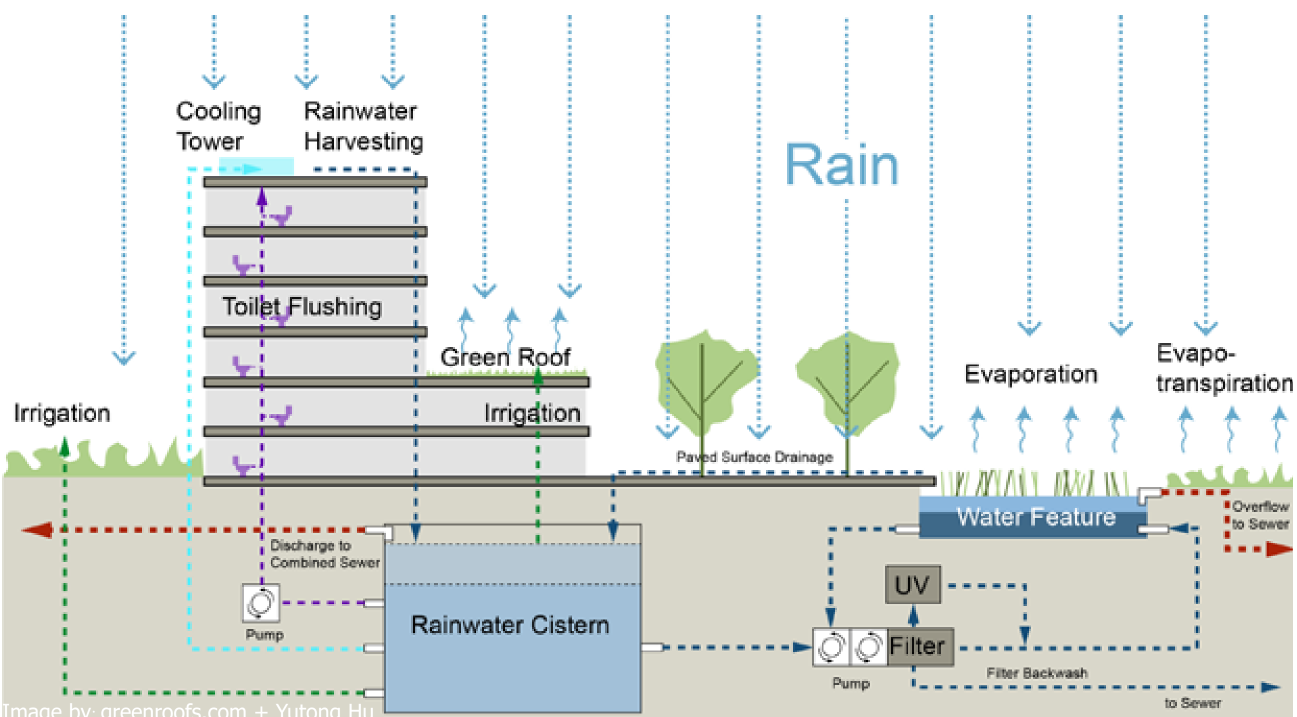


Image by: greenroofs.com + Yutong Hu

Rainwater Harvesting and Re-use in Residential Buildings

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2) Ray A. Bucklin, "Cisterns to Collect Non-Potable Water for Domestic Use"

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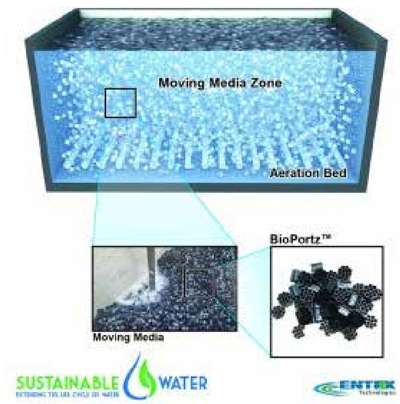
Blackwater Treatment

Moving Bed Biofilm Reactor

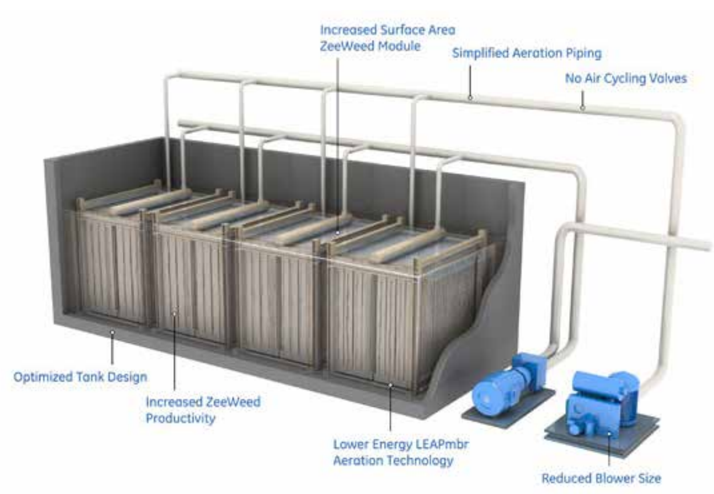
MBBR blackwater filtration systems circulate growth medium in aerated treatment reactors to create treatment biofilms. MBBR reactors can be used for aerobic and anaerobic processes. The growth media has a high surface area and surface charge, as well as waste-treating micro-organism communities, that make it suitable for industrial wastewater reuse. Though the MBBR does have a higher energy input than Living Machines, the system has the capacity to be more efficient in gallons of water filtered and reused per day.



Headworks International; Sustainable Water

(Left) Enlarged growth medium, (Right) MBBR system components

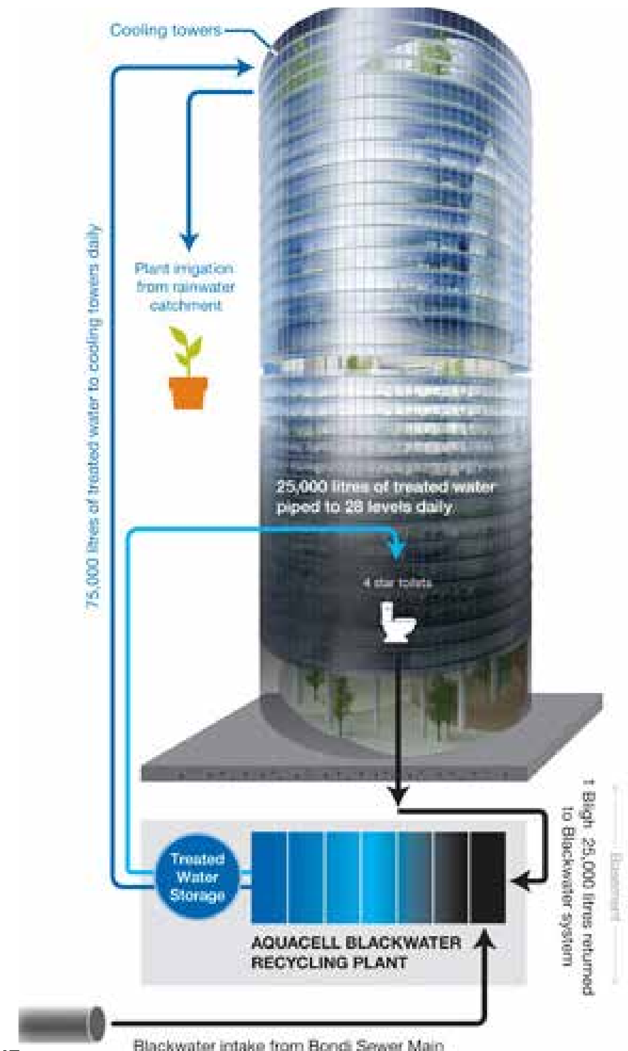
Membrane Bioreactor



American Membrane Technology Association

Membrane bioreactors use submerged membranes to remove solids from blackwater, making them efficient and compact.

Bligh Tower (left), a 29 storey residential and office building in Sydney, uses an MBR to filter both building sewage and city sewage, which its system taps into, producing 90% of the building's required water. UV disinfection follows the MBR filtration process. An MBR can have 99% yield.



ASME.org

Blackwater Treatment

Living Machines™

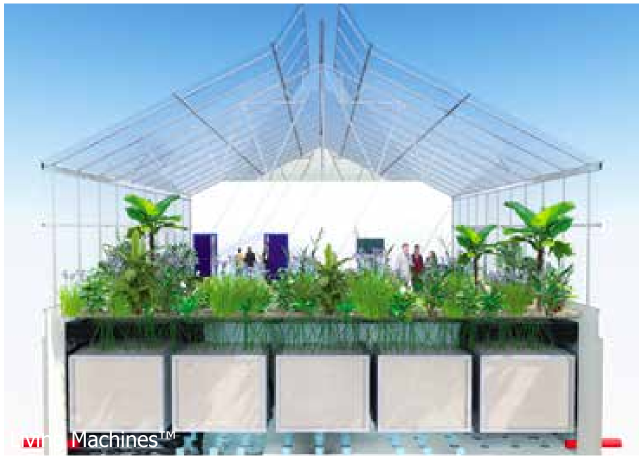
Hydroponic Living Machine System

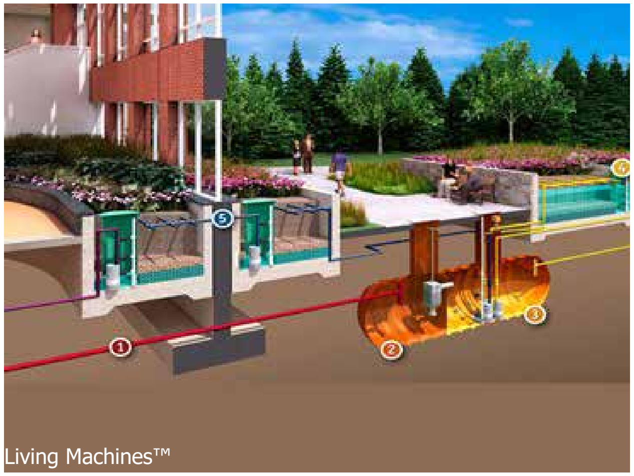
This blackwater filtration system is generally located in a building or greenhouse. Water passes through a series of tanks (Hydroponic Reactors) filled with a textile and covered with vegetation aerated by bubble diffusers. Roots of vegetation provide surfaces for microbial population growth, and the vegetation itself provides habitat for beneficial insects or organisms that consume the microbial biomass. Lightweight expanded shale aggregate with bacteria to remove residual odor compounds is placed on top of racks as a natural biofilter.

Tidal Flow Wetland Living Machine System

The Tidal Flow Wetland system can be used in exterior landscaping or built into buildings or greenhouses. Comprised of a series of flexible basins (wetland cells) filled with special gravel that promotes the development of micro-ecosystems a series of wetland cells, or basins, filled with special gravel, the constructed wetland promotes the development of micro-ecosystems. Cells are alternately flooded and drained, mimicking natural wetlands, to filter wastewater. Nutrients and solids are removed from the wastewater, resulting in high quality effluent. In the final stage, water is filtered and disinfected for non-potable uses. Online sensors monitor water quality and chlorine levels to ensure water safety.

A number of Living Machine systems have been in operation since the early 1990s, several of them federally funded wastewater treatment operations. The larges can handle flows of up to 80,000 gallons per day.





(Top) Living Machine in use at Old Trail School, Bath, OH

(Middle) Hydroponic LMS in greenhouse

(Bottom) Example of Tidal Flow system incorporated into construction of new buildings

Greywater Recycling

Shared Neighborhood Greywater Recycling System for Mixed-Use Areas

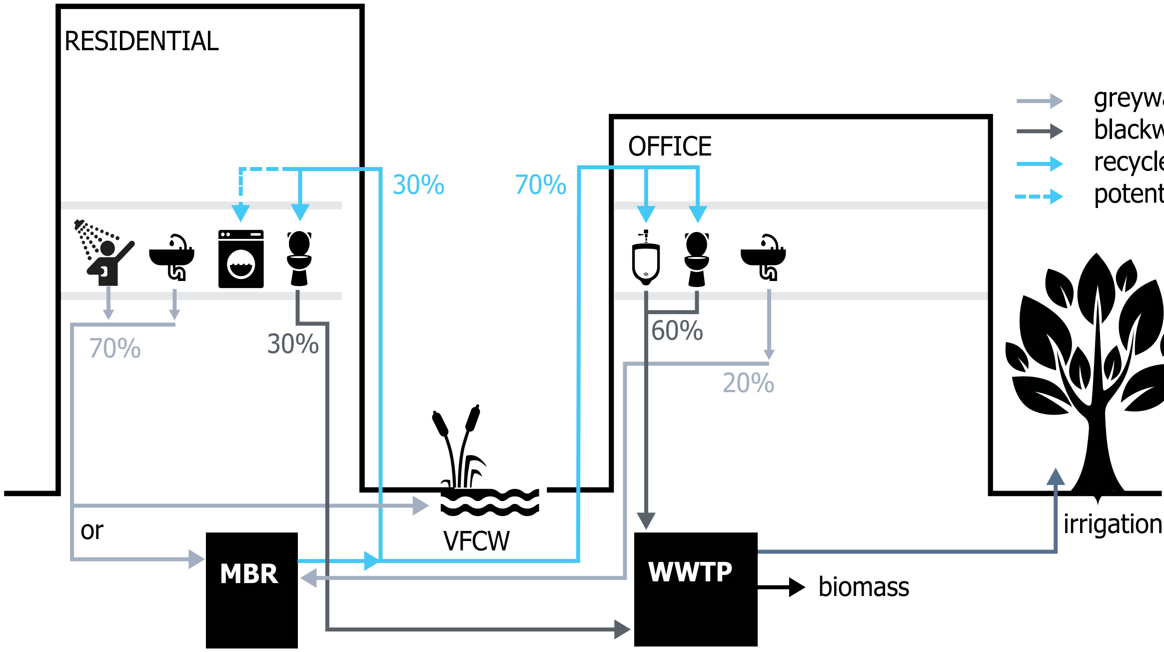
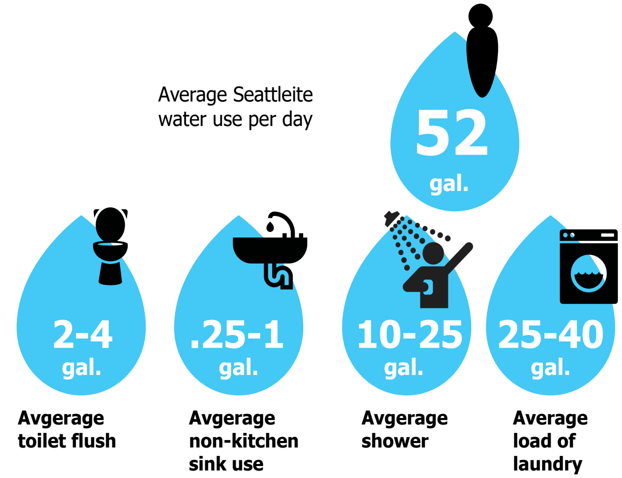
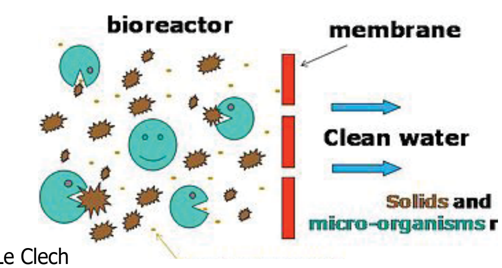


Diagram adapted from Sara Moslemi Zadeh, "Neighborhood-Scale Greywater Recycling for Non-Potable Reuse in Mixed-Use Urban Areas". Numbers from Zadeh et al. 2013[2]. Graphic by Roxanne Glick. Icons from the Noun Project by Bohdan Burmich, Dan Hetteix, Arthur Slain, Alena Artemova, Nikita Kozin, Adrien Coquet.



Data from USGS and Flotender

Membrane bioreactor (MBR) set-up



Pierre Le Clech

MBR process diagram

Greywater Recycling

Greywater recycling reduces potable water use and also wastewater discharge from buildings. It's main advantage is conserving water as a resource, while it's biggest disadvantage is the cost of infrastructure and maintenance.[1] Ways to make the infrastructure more cost-effective are considering the water and energy nexus of biomass.[1] Another method is shared greywater recycling system among commercial and residential units in a mixed-use area or buildings.

The premise of greywater recycling is that with relatively light treatment, water from showers, sinks and other household water uses can be used for toilet flushing and irrigation and potentially other non-potable uses. Domestic water use yields more reusable water than commercial or retail uses due to washing tasks. While graywater recycling generally does not make sense for commercial buildings alone, domestic uses only need to reuse about 30% of their greywater supply and the surplus can be used for flushing toilets in commercial buildings with a shared system.[2]

There are several technologies available for decentralized water treatment. Vertical Flow Constructed Wetlands (VFCWs) being cost effective but space intensive. Membrane bioreactors (MBRs) are more space effective and can become cost effective in dense urban areas where land is expensive and with larger buildings. Unlike VFCWs, MBRs function with economies of scale.[2] Other processes include a rotating biological contactor and treatment with disinfectant

1. Sabino De Gisi. "The Reuse of Grey Water in Buildings" LinkedIn Slideshare. https://www.slideshare.net/SabinoDeGisi/the-reuse-of-grey-water-in-buildings. Published Oct 28, 2014. Accessed Oct 13, 2017.
2. Sara Moslemi Zadeh, Dexter V.L. Hunt, D. Rachel Lombardi and Christopher D.F. Rogers. "Shared Urban Greywater Recycling Systems: Water Resource Savings and Economic Investment" Sustainability. July 3, 2013. PDF.

Can you use greywater directly for irrigation?
Greywater with only mechanical filtration can be used for irrigation that does not come into contact with people such as drip irrigation or simple gravity -fed pipes. Bits of organic material would clog pipes and attract rodents. (Flotender, greywateraction)

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Green and Blue Roofs

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2) Hanging Garden, "Traditional Vs. Blue. Vs Green" Image. http://www.hanging-gardens.com/stormwater. Accessed October 15,2017.
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2) Living Machine Systems. http://www.livingmachines.com. Accessed October 14, 2017.
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4) Sustainable Water, "Moving Bed Biofilm Reactor". http://sustainablewater.com/mbbr/. Accessed October 14, 2017.
5) WQP Magazine, "Drought Solutions Down Under". https://www.wqpmag.com/drought-solutions-down-under. Accessed October 15, 2017.
6) American Membrane Technology Association, "Membrane Bioreactors for Wastewater Treatment." https://www.amtaorg.com/Membrane_Bioreactors_for_Wastewater_Treatment.html Accessed October 15, 2017.

Blue and Green Roofs Ctnd.

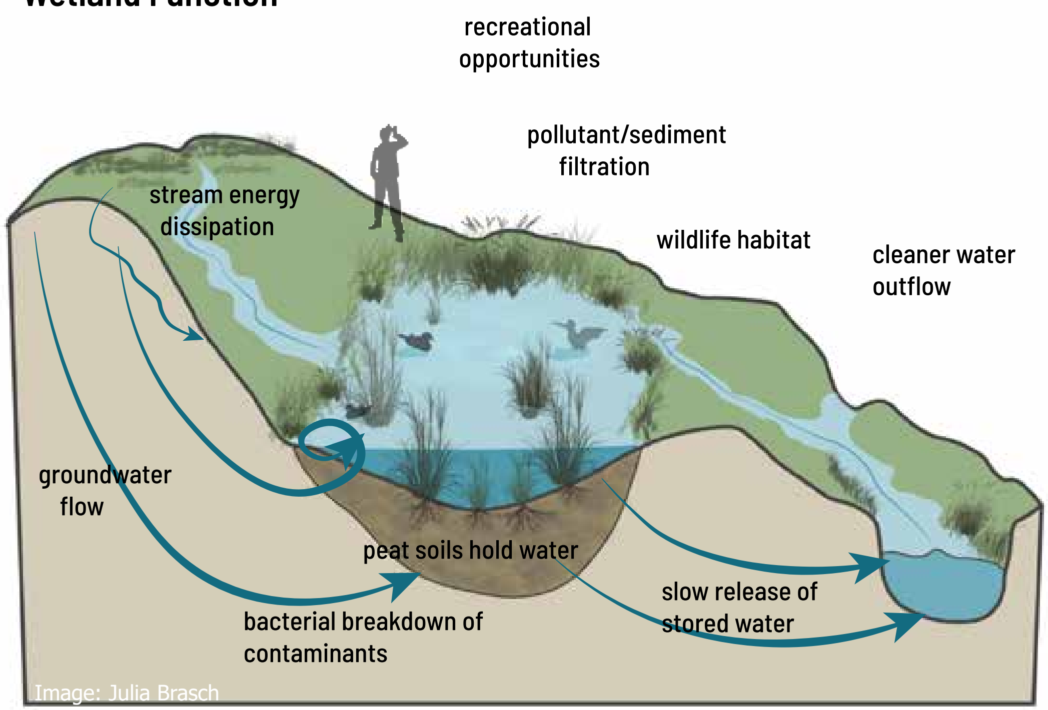
1) Philadelphia Water Storm Plan Review, Chapter 3, "Site design and storm water management integration." Figure 3.5-8 "Full Build Out Example, Green Roof/Blue Roof" Image. https://www.pwdplanreview.org/manual/chapter-3/3.5-integrated-stormwater-management-examples

Greywater Recycling Data Sheet Sources:

1) Sabino De Gisi. "The Reuse of Grey Water in Buildings" LinkedIn Slideshare. https://www.slideshare.net/SabinoDeGisi/the-reuse-of-grey-water-in-buildings. Published Oct 28, 2014. Accessed Oct 13, 2017.
2) Sara Moslemi Zadeh, Dexter V.L. Hunt, D. Rachel Lombardi and Christopher D.F. Rogers. "Shared Urban Greywater Recycling Systems: Water Resource Savings and Economic Investment" Sustainability. July 3, 2013. PDF.

Natural Wetlands

Wetland Function



What is a wetland?

Wetlands are areas where water covers soil all or part of the time, among the most productive ecosystems in the world. They can be either tidal or inland. Inland wetlands are most common in floodplains and other low-lying areas. Wetlands play an integral role in watershed function and perform invaluable ecosystem services.

What benefits do they provide?

Filtration: Wetlands improve water quality by intercepting surface runoff and removing or retaining inorganic nutrients such as nitrogen and phosphorous, processing organic wastes and pollutants, and reducing suspended sediments that would otherwise clog open waterways.

Flood Protection: Some wetlands contribute to hydrological regulation by maintaining stream flow during dry periods and replenishing groundwater. Due to their depressional topography, wetlands store and slowly release water. Plants help slow water movement and prevent erosion. Wetlands within and downstream of urban areas are particularly valuable to counteract the increased rate and volume of surface-water runoff from impervious surfaces.

Habitat: The U.S. Fish and Wildlife Service estimates that 43% of threatened/endangered species rely on wetlands for their survival. Some animals live in wetlands for their entire lives, some for part, and others just for feeding. In the Pacific Northwest, some wetlands release cooler water to salmon-bearing streams and rivers.

Recreation/Education:
Most people enjoy being on or near water, which makes wetland environments a valuable recreation opportunity. Wetlands are often studied in conjunction with environmental programs, and used as outdoor laboratories or research sites in post-secondary education.

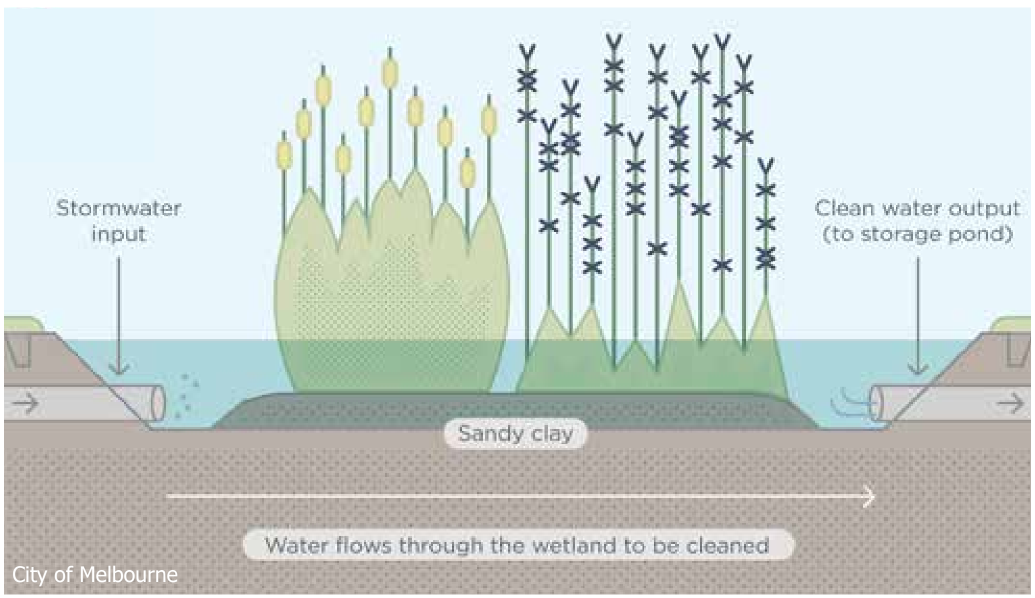
When to use a wetland?

Due to their integral relationship with their surrounding watershed, it is not possible to create a natural wetland where its watershed environment has been extensively modified and degraded, such as in highly urbanized places. In general, natural wetlands can only be preserved or restored.

Sources: U.S. Fish and Wildlife Service. U.S. Environmental Protection Agency.

Constructed Wetlands

Virginia's Soil and Water Conservation Districts



City of Melbourne

Source: United States Environmental Protection Agency, Storm Water Technology Fact Sheet: Storm Water Wetlands

What are constructed wetlands?

They are technology that replicates the ecological processes found in natural wetlands in areas where natural wetlands do not occur. They utilize wetland soils, plants, and microorganisms to remove contaminants from wastewater. This includes Biochemical Oxygen Demand (BOD), suspended solids, and metals such as iron and lead. There are two basic types: Free Water Surface (FWS) and Vegetated Submerged Bed (VSB). FWS constructed wetlands more closely resemble natural wetlands and alternate between fully vegetated areas and open water, while VSB systems occupy a more contained area and feature a gravel bed that does not require vegetation to function (although it can be included for aesthetic and habitat purposes).

Why use constructed wetlands?

They provide simple, effective, and cost-saving treatment of wastewater and stormwater. Up to 80% of suspended sediment and phosphorus can be removed in these systems. They have low operating costs, consisting mostly of weekly water sampling and replacement of plants and soil every several years. They provide pleasant scenery, attract wildlife, and offer educational opportunities.

When to use constructed wetlands?

Most constructed wetlands are used as a tool for wastewater treatment in small communities and rural areas. However, they can also be utilized in urban areas for the purpose of stormwater storage and treatment. The fact that they are aesthetically pleasing makes them useful in highly visible areas.

How much water can they treat?

The following equations are used to determine the treatment volume (Vt) in cubic feet:

(1) $Rv = 0.05 + 0.009 (I)$

Rv: storm runoff coefficient

I: % (as decimal) site imperviousness

(2) $Vt = [(1.25)(Rv)(A)/12](43{,}560)$

A: contributing area (acres)