EPA CAMPUS RAINWORKS CHALLENGE

US EPA CAMPUS RAINWORKS

INTEGRATING GREEN INFRASTRUCTURE IN CAMPUS PLANNING

APPENDIX: DESIGN TOOLKIT

one architecture new york city amsterdam

Climate Resilience Consulting

SHERWOOD DESIGN ENGINEERS

ABOUT THIS DESIGN TOOLKIT

The intent of this toolkit is to provide campus stakeholders a starting point to identify, discuss, and evaluate common green infrastructure approaches based on their suitability to site conditions. It includes two principal components:

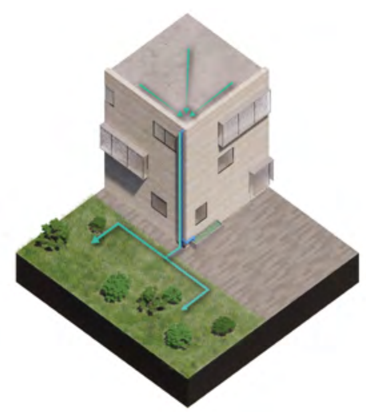
1. A green infrastructure catalogue, which identifies, visualizes, and describes a range of design options that may be applicable for campus environments.

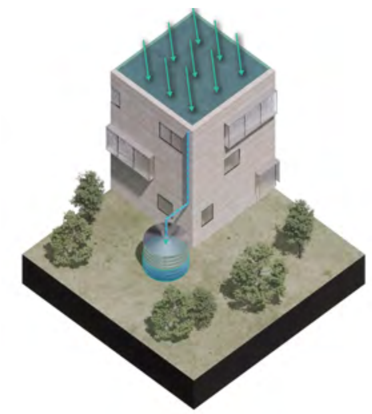
2. A prioritization matrix, which offers an approach to compare potential green infrastructure measures for their applicability and compatibility with campus conditions.

University professors, students and facility managers have successfully used this toolkit to advance implementation of green infrastructure on their campuses while engaging in planning and engagement activities.

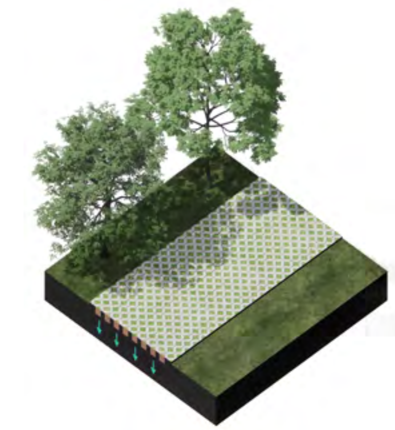
GREEN INFRASTRUCTURE DESIGN OPTIONS

Upper watershed strategies
Middle watershed strategies
Lower watershed strategies

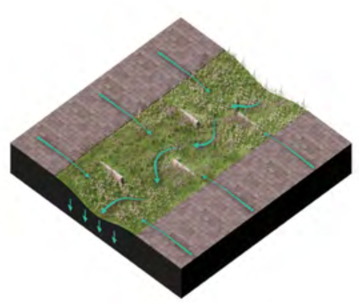

Downspout Disconnect

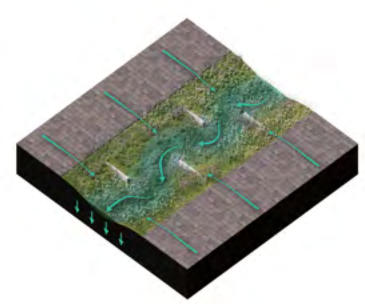

Rainwater Harvesting

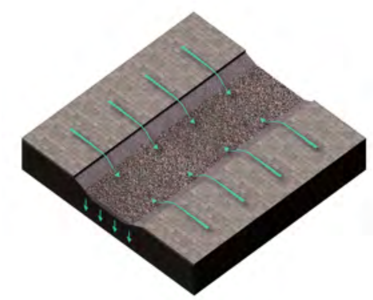

Green Roofs


Permeable Pavers / Surfaces

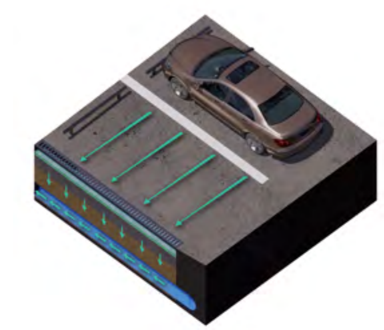

Flow-Through Planters

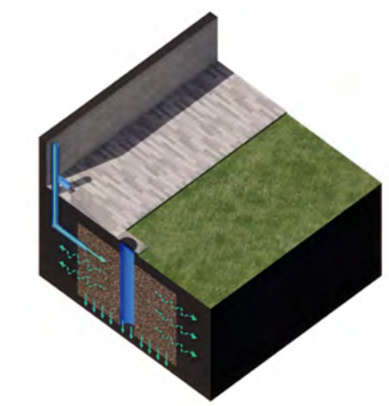

Dry Bioswales


Wet Bioswales


Infiltration Trench


Oil / Grit Separator


Underground Filter


Dry Well

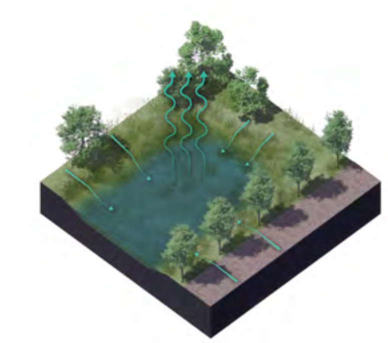

Bioretention


Organic Filter


Surface Sand Filters

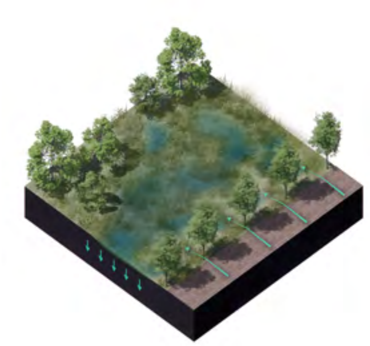

Dry Detention Pond


Extended Dry Detention Pond


Wet Pond

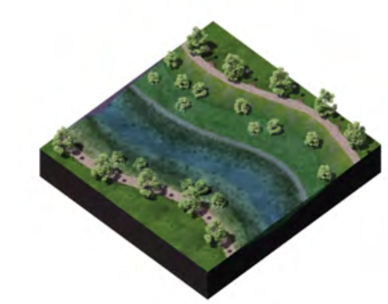

Pocket Pond


Pocket Stormwater Wetland


Stormwater Wetland


Site Reforestation / Revegetation


Stream Restoration

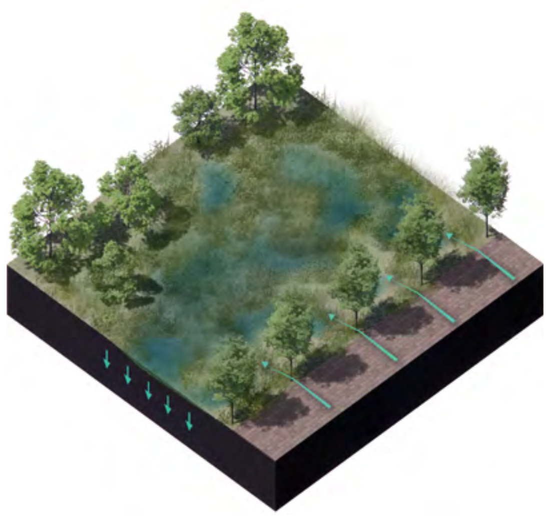

Flood Management Area

Source: One Architecture & Urbanism / Sherwood Design Engineers, 2023

GREEN INFRASTRUCTURE DESIGN OPTIONS

Unless noted, all definitions below are derived from the *Georgia Stormwater Management Manual, Volume 2 Technical Handbook* (2016) (link)

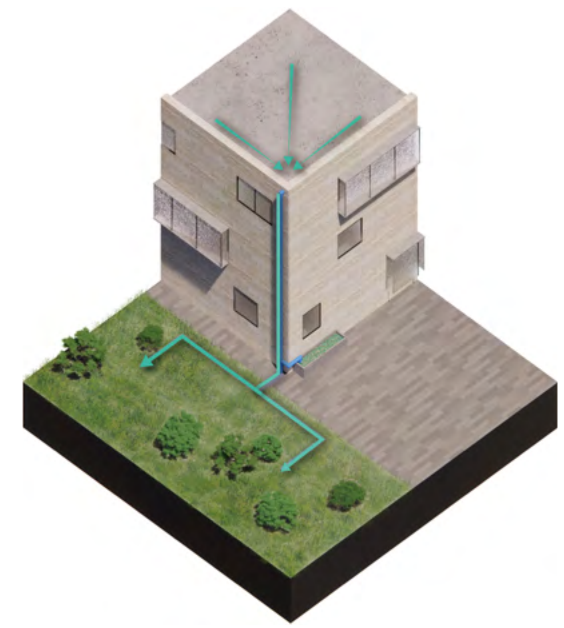
Upper watershed strategies
Middle watershed strategies
Lower watershed strategies



Stormwater Wetland

Stormwater Wetland

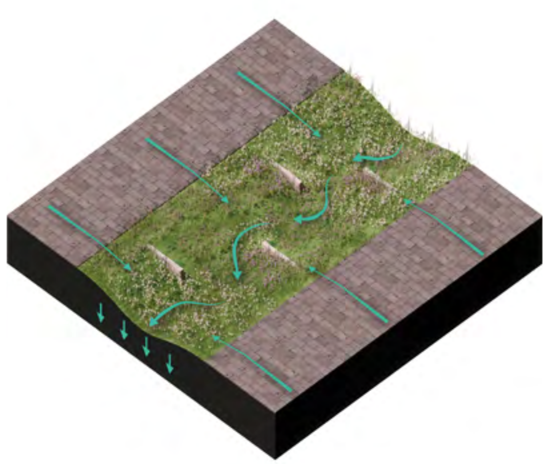
Stormwater wetlands are constructed wetland systems used for stormwater management. Stormwater wetlands consist of a combination of shallow marsh areas, open water, and semi-wet areas above the permanent water surface. As stormwater runoff flows through a wetland,it is treated, primarily through gravitational settling and biological uptake.



Downspout Disconnect

Downspout Disconnect

A downspout disconnect spreads rooftop runoff from individual downspouts across lawns, vegetated areas, and other pervious areas, where the runoff is slowed, filtered, and can infiltrate into the native soils



Dry Bioswales

Dry Bioswale

Dry swales are vegetated open channels that are designed and constructed to capture and treat stormwater runoff within dry cells formed by check dams or other structures. A dry swale is designed to prevent standing water, with or without an underdrain.

Surface Sand Filters

Surface Sand Filters

Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system through an underdrain system, or allowed to partially exfiltrate into the soil.

GREEN INFRASTRUCTURE DESIGN OPTIONS

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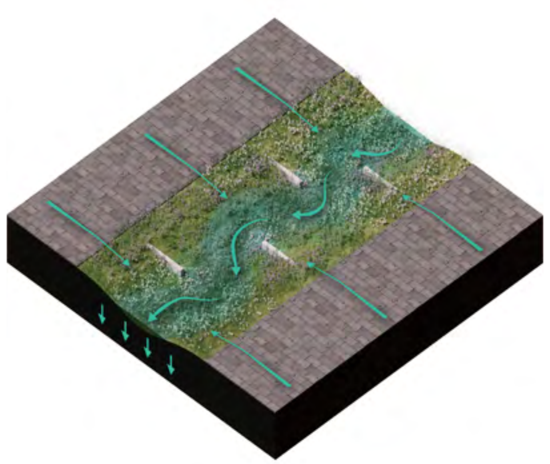
Stream Restoration

Stream Restoration

Stream restoration is often performed to reduce the effects of stressors on the environment and return stream structure and function to pre-disturbance conditions. Often, restoration projects aim to improve water quality and in-stream habitat, manage riparian zones, stabilize stream banks, and allow fish to pass barriers.

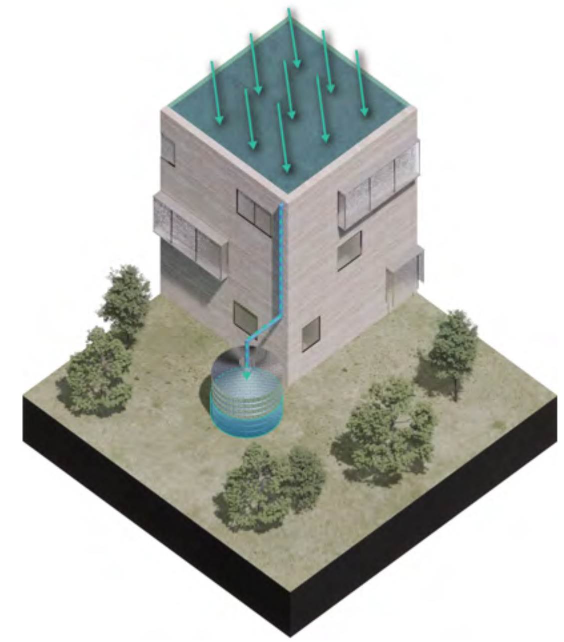
Source: www.enviro.wiki/index.hp?title=Stream_Restoration



Wet Bioswale

Wet Bioswale

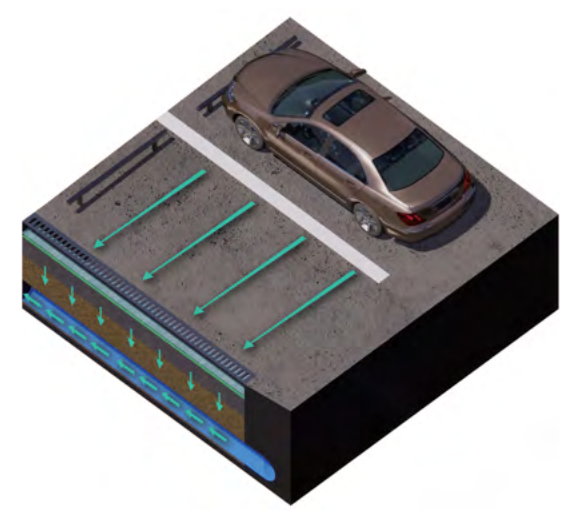
Wet bioswales are vegetated open channels that are designed and constructed to capture and treat stormwater runoff within wet cells formed by check dams or other structures. A wet swale is designed to hold water.



Rainwater Harvesting

Rainwater Harvesting

Rainwater harvesting is a common stormwater management practice used to catch rainfall and store it for later use. Typically, gutters and downspout systems are used to collect the water from roof tops and direct it to a storage tank. Rainwater Harvesting systems can be either above or below the ground. Once captured in the storage tank, the water may be used for non-potable indoor (requires treatment) and outdoor uses.



Underground Filter

Underground Filter

Underground sand filters are concrete structures designed to store and filter rainwater through sand to remove pollutants collected from rooftops, sidewalks, and roads. Water first filters through an oil/grit trap to remove heavy debris, and then flows through layers of sand and gravel before being released through a pipe into local streams or storm drain system.

Source: www.montgomerycountymd.gov/DEP/Resources/Files/PostersPamphlets/Structural-Underground-Sand-Filters.pdf

GREEN INFRASTRUCTURE DESIGN OPTIONS

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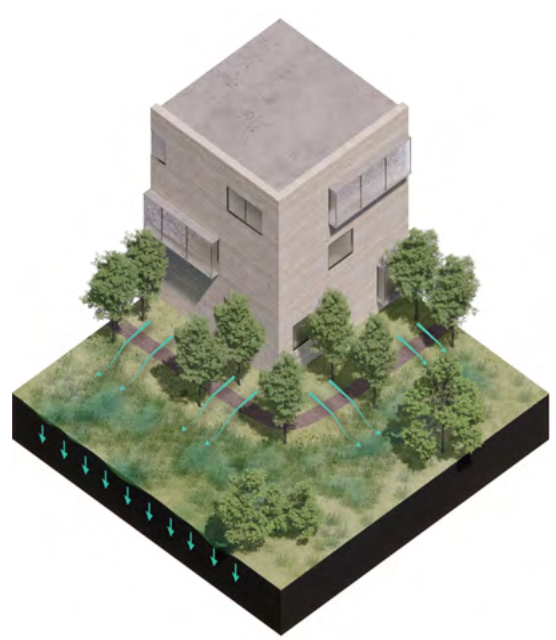
Pocket Pond

Pocket Pond

A pocket pond is characterized by a small drainage area; the water level is sustained by groundwater during dry weather.

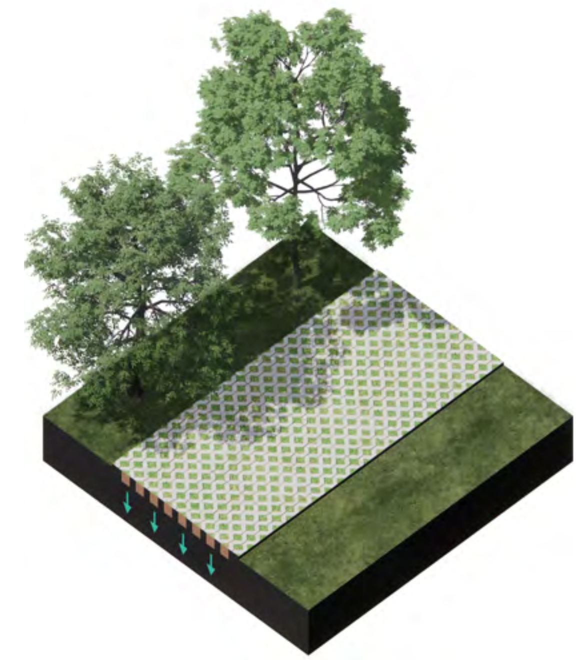


Pocket Stormwater Wetland

Pocket Stormwater Wetland

A pocket wetland is used to capture and treat a specific volume of stormwater runoff. This structure is a shallow wetland with a permanent pool and wetland species added to the bottom to enhance the pollutant removal capability. For this BMP, a high groundwater table is used to maintain the shallow pool and wetland vegetation.

Source: apps.itd.idaho.gov/apps/env/BMP/PDF%20Files%20for%20BMP/Chapter%205/PC-25%20%20Pocket%20Wetland.pdf



Permeable Pavers/ Surfaces

Permeable Pavers / Surfaces

A permeable paver system is a pavement surface composed of structural units with void areas that are filled with pervious materials such as gravel, sand, or grass turf. The system is installed over a gravel base course that provides structural support and stores stormwater runoff that infiltrates through the system into underlying permeable soils.

Organic Filters

Organic Filters

Organic filters are surface media filters that use organic materials, such as leaf compost or a peat/sand mixture,as the filter media. Runoff is filtered through the media prior to discharging through an underdrain system. The Organic media may be able to provide enhanced removal of some contaminants, such as heavy metals.

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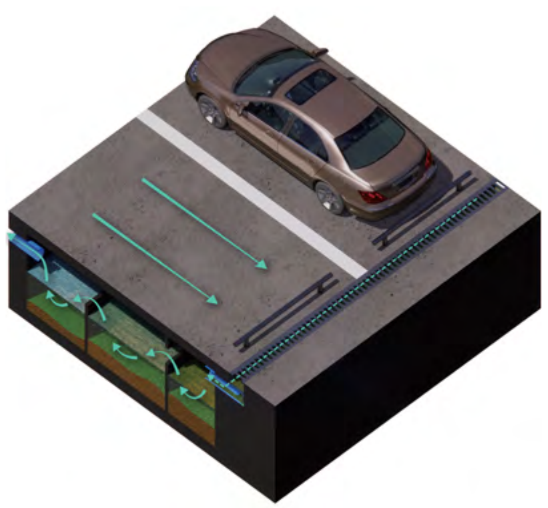
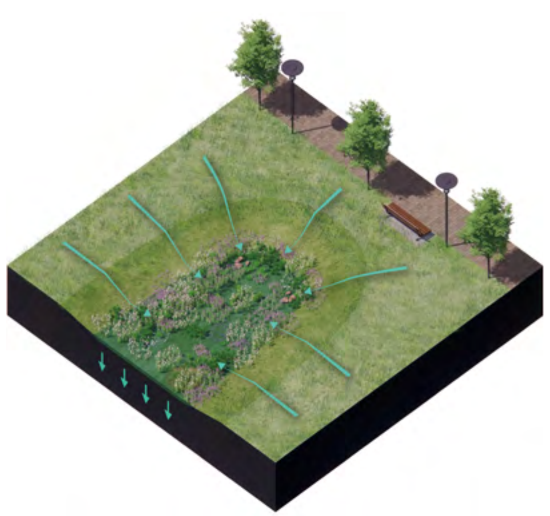


Oil Grit Separator

Oil / Grit Separator

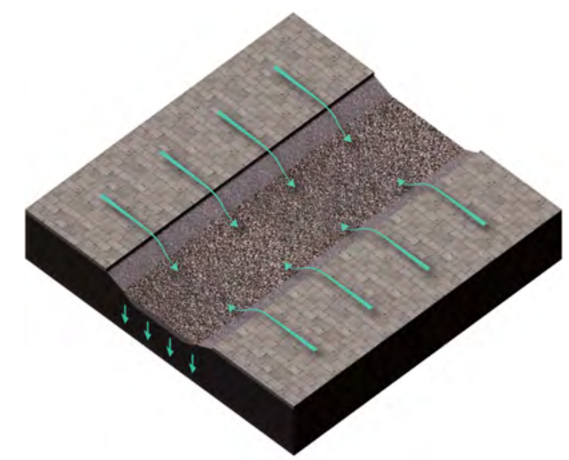
Oil / grit separators are hydrodynamic controls that use the movement of stormwater runoff through a specially-designed structure to remove target pollutants. They are typically used on smaller, impervious, commercial sites and urban hotspots.



Bio Retention

Bioretention

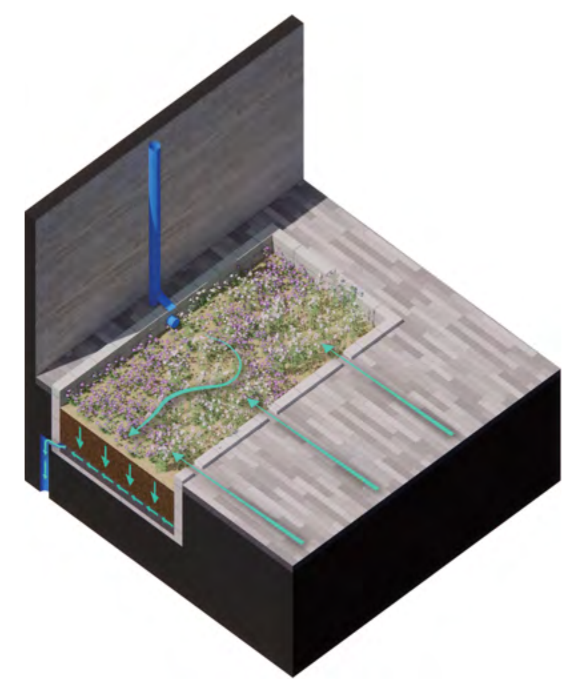
Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered soils and vegetation to capture and treat stormwater runoff. Bioretention areas may be designed with an underdrain that returns runoff to the conveyance system or designed without an underdrain to exfiltrate runoff into the soil.



Infiltration Trench

Infiltration Trench

An infiltration trench is a shallow excavation, typically filled with stone or an engineered soil mix, which is designed to temporarily hold stormwater runoff until it infiltrates into the surrounding soils. Infiltration practices are able to reduce stormwater quantity, recharge the groundwater, and reduce pollutant loads.



Flow Through Planter

Flow-Through Planter

Flow-through planters are structures placed above ground with impervious bottoms that are filled with soil and vegetation which allow stormwater to infiltrate through the soil before being discharged. The bottom of a planter contains a porous pipe that drains the stormwater after it has filtered through the soil and vegetation. Planters are typically installed next to buildings or common open areas to treat stormwater from rooftops.

Source: www.waterboards.ca.gov/publications_forms/publications/factsheets/docs/planters_fs.pdf

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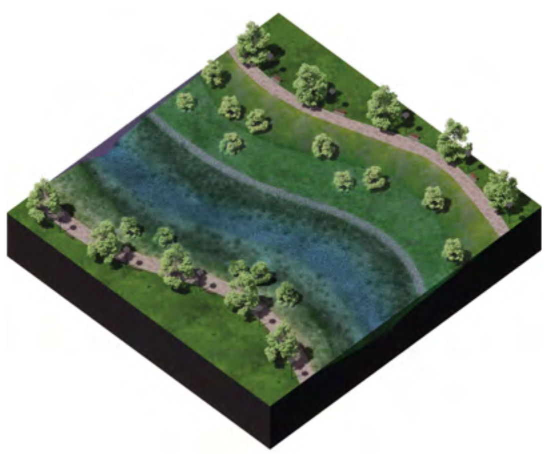
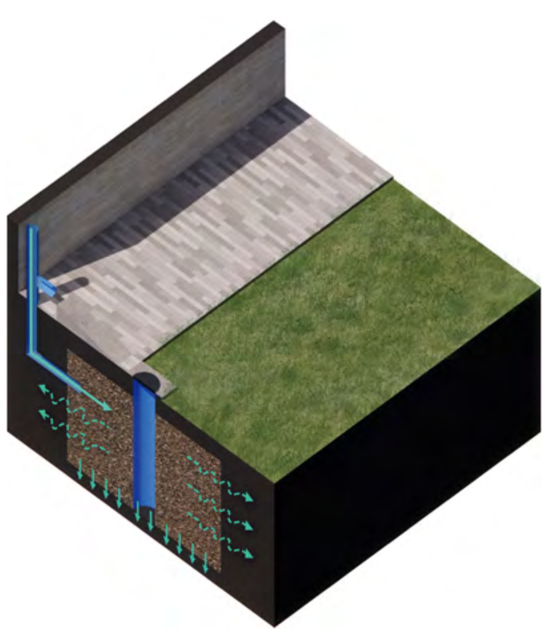


Flood Management Area

Flood Management Area

Flood management areas retain and buffer the effects of heavy rainfall and protect economic activities and communities from flood damage. Natural management areas like flood plains have an important role to play in reducing flood risks and are also the natural habitat of many endangered species. However, they can also be man made areas that can are used for detention such as lowered playing fields.



Dry Well

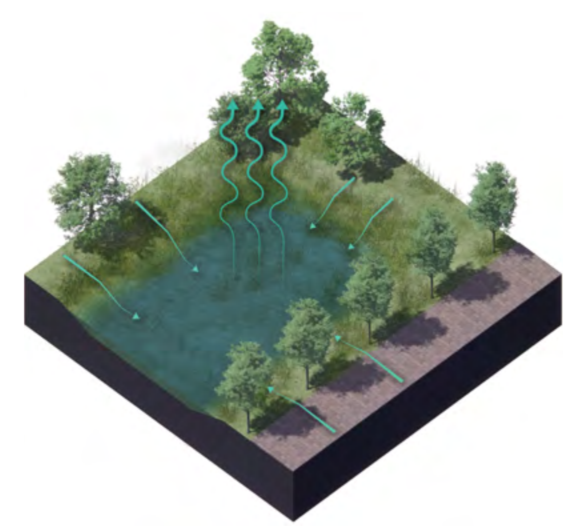
Dry Well

Dry wells are shallow excavations, typically filled with stone, that are designed to intercept and temporarily store post-construction stormwater runoff under the ground surface until it infiltrates into the underlying and surrounding soils. If properly designed, they can provide significant reductions in post-construction stormwater runoff rates, volumes, and pollutant loads on development sites.

Water Squares

Water Squares

When sub-surface crates are full, sunken playgrounds fill up temporarily with additional stormwater run-off. These water squares reduce damage, increase water quality due to combined stormwater reduction and increase recreational activities.



Stormwater Pond/ Wet Pond

Stormwater Pond / Wet Pond

Stormwater ponds are constructed stormwater retention basins that have a permanent pool (or micropool) of water. Some runoff reduction is achieved within a stormwater pond or detention system through evaporation and transpiration. Stormwater ponds provide water quality treatment through sediment precipitation in the permanent pool.

Source: mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/Fact%20Sheets/MDE_Fact_Sheet_S_WetPonds.pdf

GREEN INFRASTRUCTURE DESIGN OPTIONS

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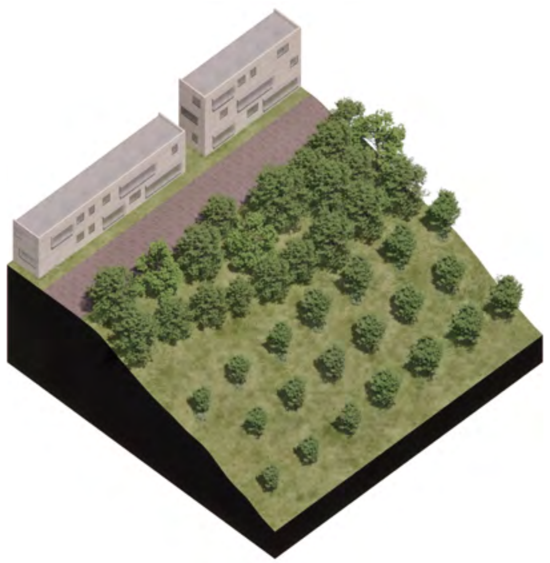


Site Revegetation

Site Reforestation / Revegetation

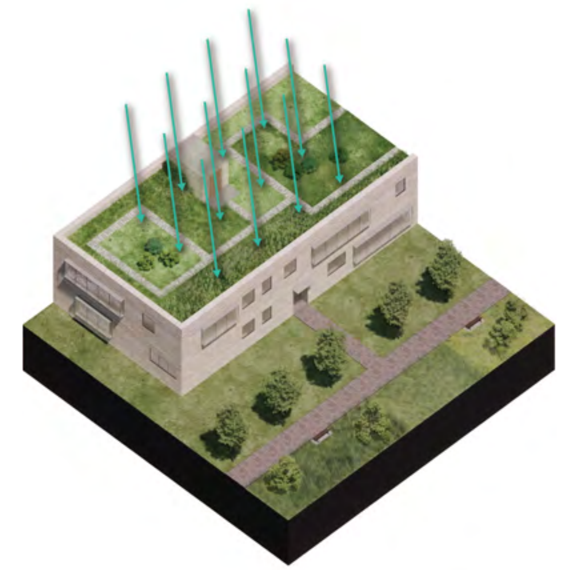
Reforestation or revegetation is a process of planting trees, shrubs, and other native vegetation in disturbed pervious areas to restore the area to pre-development or better conditions. The process can be used to establish mature native plant communities, such as forests, in pervious areas that have been disturbed by clearing, grading and other land disturbing activities. These plant communities intercept rainfall and slow and filter the stormwater runoff to improve infiltration in the ground. Areas that have been reforested or revegetated should be maintained in an undisturbed, natural state over time. These areas must be designated as conservation areas and protected in perpetuity through a legally enforceable conservation instrument (e.g., conservation easement, deed restriction).

Extended Dry Detention Ponds

Extended Dry Detention Ponds

Extended dry detention basins are modified conventional dry detention ponds, designed to hold stormwater for at least 24 hours to allow solids to settle and to reduce local and downstream flooding. Extended dry detention basins may be designed with either a fixed or adjustable outflow device. Pretreatment is a fundamental design component of an extended dry detention basin to reduce the potential for clogging. Other components such as a micropool or shallow marsh may be added to enhance pollutant removal.

Source: megamanual.geosyntec.com/npsmanual/drydetentionbasin.aspx



Green Roof

Green Roof

Green roofs represent an alternative to traditional impervious roof surfaces and typically consist of underlying waterproofing, drainage systems, and an engineered planting media. Stormwater runoff is captured and temporarily stored in the engineered planting media, where it is subjected to evaporation and transpiration before being conveyed back into the storm drain system. There are two different types of green roof systems. Intensive green roofs have a thick layer of soil, can support a diverse plant community, and may include trees. Extensive green roofs have a much thinner layer of soil that is comprised primarily of drought tolerant vegetation.

Dry Detention Pond

Dry Detention Pond

A dry detention pond is an impoundment or excavated basin for the short-term detention of stormwater runoff from a completed development that allows a controlled release from the structure at downstream, pre-development flow rates. Conventional dry detention basins typically control peak runoff for 2-year and 10-year 24-hour storms. They are not specifically designed to provide extended dewatering times, wet pools, or groundwater recharge. Sometimes flows can be controlled using an outlet pipe but this approach typically cannot control multiple design storms.

Source: megamanual.geosyntec.com/npsmanual/drydetentionbasin.aspx

GREEN INFRASTRUCTURE DESIGN OPTIONS PRIORITIZATION MATRIX

	ECOLOGICAL CONSIDERATIONS		ECONOMIC CONSIDERATIONS		COMMUNITY CONSIDERATIONS				
GREEN INFRASTRUCTURE DESIGN OPTIONS (MEASURES, BMPs)	**Location in Watershed**	**Ecological Co-Benefits**	**Relative Initial Cost**	**Relative Maintenance Cost**	**Integration with Surroundings**	**Environmental Stewardship**	**Aesthetic Value & Placemaking Potential**	**Permitting / Coordination Complexity**	**Benefit to MS4 Compliance**
	Upper, Middle, Lower	Low, Medium, High	$ / $$ / $$$	$ / $$ / $$$	Low, Medium, High	Low, Medium, High	Low, Medium, High	Low, Medium, High	Low, Medium, High
Green Roofs	All	Medium	$$$	$$$	Medium	Medium	High	Medium	Medium
Rainwater Harvesting	All	Low	$$	$	Medium	High	Medium	Medium	Medium
Oil/Grit Separator	All	Low	$	$$	Medium	Medium	Low	Medium	Low
Downspout Disconnect	All	Low	$	$$	Medium	High	Low	Low	Low
Site Reforestation/Revegetation	All	High	$$$	$	High	High	High	Low	High
Infiltration Trench	Upper	Medium	$	$$	Low	Medium	Medium	Low	Low
Permeable Pavers/Surfaces	Upper	Medium	$$$	$$	Low	Low	High	Medium	Medium
Organic Filter	Upper	Medium	$$	$$	Low	Medium	Low	Low	Low
Surface Sand Filters	Upper	Low	$$	$$	Low	Low	Low	Low	Medium
Bioretention	Upper/Middle	High	$$$	$$	Medium	High	High	Medium	High
Flow-Through Planters/Landscape Infiltration	Upper/Middle	Medium	$$	$	Medium	Medium	High	Low	Medium
Dry Well	Upper/Middle	Medium	$$	$$	Low	Low	Low	Medium	Low
Dry Bioswales	Middle	Medium	$$$	$$	Medium	Medium	High	Medium	Medium
Wet Bioswales	Middle	Medium	$$$	$$	Medium	Medium	High	Medium	Medium
Dry Detention Pond	Lower	Medium	$	$$	Low	Medium	Medium	Medium	High
Extended Dry Detention Pond	Lower	Medium	$	$$	Low	High	Medium	Medium	High
Wet Pond	Lower	High	$	$$	Medium	High	Medium	High	High
Pocket Pond	Lower	Medium	$	$$	Low	Medium	Medium	Medium	Low
Underground Filter	Lower	Low	$$	$	Low	Low	Low	Medium	Medium
Flood Management Area	Lower	Low	$	$	Low	Medium	Medium	Medium	Low
Stormwater Wetland	Lower	High	$$	$	High	High	High	High	Medium
Pocket Stormwater Wetland	Lower	Medium	$$	$	Medium	High	Medium	Medium	Low
Stream Restoration	Lower	High	$$$	$	High	High	High	High	Low

Source: One Architecture & Urbanism / Sherwood Design Engineers, 2023

GREEN INFRASTRUCTURE DESIGN OPTIONS PRIORITIZATION MATRIX NOTES

The matrix describes a way to compare green infrastructure strategies and provides select technical criteria as a starting point for analysis. All measures are industry-standard practices. Guidance is taken from the Georgia Stormwater Management Manual (GSMM), which is considered by EPA as one of the leading guidance documents for green infrastructure in the nation, in the absence of specific EPA guidance.

Ecological Considerations characterize design criteria and recognize the importance of co-benefits for the natural environment. They include position in the watershed based on the framework of general applicability or specific applicability to the upper, middle, or lower watershed. This category also gives an indication of the ecological co-benefits that green infrastructure can deliver, including making a contribution to the restoration of the natural environment or the provision of habitat.

Economic Considerations evaluate the relative cost for both one-time installation and recurring maintenance costs. Unit costs are relative due to uncertainty around site-specific conditions and the changing fiscal context, driven by inflation and supply-chain operations. Still, green infrastructure interventions are generally found to be cheaper to maintain than traditional "gray infrastructure" solutions (i.e. subsystem pipe networks) due to the self-sufficiency of the vegetation within green infrastructure.

Community Considerations evaluate the societal implications of green infrastructure, including the impacts that interventions have on the campus's integration with surrounding neighborhoods, the collective campus's environmental stewardship, contiguous campus character, compliance with governmental regulations. Evaluation of considerations related to permitting/coordinating correspond to the level of inter-organizational coordination and scale of the project. Metrics that are evaluated in this category, with their associated considerations, include:

- City-Campus Integration: The degree to which the green infrastructure facilitates benefit to surrounding neighborhoods or provides connections between the campus and neighborhoods
- Environmental Stewardship: The degree to which an intervention contributes to the Campus's overall sustainable use and protection of the natural environment
- Aesthetic Value & Placemaking Opportunity: The degree to which green infrastructure offers additional benefits to the campus in terms of improving aesthetics, facilitating continuous campus character, and orienting infrastructure around the campus employees and students.
- Permitting/Coordinating: The degree to which extensive permitting or inter-organizational coordination is necessary, as a result of the scale or complexity of the measure.
- Benefit to MS4 Compliance: The degree to which the green infrastructure advances the Campus towards MS4 compliance by either reducing the amount of impervious area that exists or by increasing the amount of impervious area runoff that is treated by green infrastructure.

Green infrastructure strategies are evaluated based on their relative benefit to the campus or surrounding communities.

Stormwater Management & Cloudburst Mitigation

The strategies that apply to managing moderate rain events can also apply to managing cloudbursts, or extreme rainfall events. A layered approach that introduces a hierarchy of flooding can ensure capacity for a range of rainfall volumes. For example, measures such as green roofs and infiltration trenches can hold a certain amount of water as rain accumulates, and as they reach capacity, stormwater could flow to and be detained in larger areas (e.g., bioretention features, detention ponds, flood management areas).

Application of the Matrix

The matrix is deliberately non-determinant; it is a tool that could be used alongside and in concert with other technical and value-based evaluation frameworks and inputs to explore the range of green infrastructure strategies that might be suitable for a given location on campus. The utility of the matrix builds on the cloudburst visioning process, which remains the fundamental step to envision the benefits and scale of green infrastructure projects.

GREEN INFRASTRUCTURE DESIGN OPTIONS
TECHNICAL CRITERIA

GREEN INFRASTRUCTURE DESIGN OPTIONS (MEASURES, BMPs)	TECHNICAL CRITERIA		
	Maximum Drainage Area	Pressure Head Needed	Maximum Slope
	Acres	Feet	%
Green Roofs	100% of BMP size	0.5 - 1	10
Rainwater Harvesting	N/A	N/A	2
Oil/Grit Separator	5	4	6
Downspout Disconnect	0.06	N/A	6
Site Reforestation/Revegetation	0.25 Min	N/A	N/A
Infiltration Trench	5	1-3	6
Permeable Pavers/Surfaces	300% of BMP size	N/A	0.5
Bioretention	10	5-8	6
Flow-Through Planters/Landscape Infiltration	10	2-6	6
Dry Bioswales	5	N/A	5
Wet Bioswales	0.06	2	6
Dry Well	0.06	2	6
Organic Filter	5	3-5	4
Surface Sand Filters	5	1	4
Dry Detention Pond	10 Min.	N/A	15
Extended Dry Detention Pond	10 Min.	N/A	15
Wet Pond	25	6-8	15
Pocket Pond	10	6-8	0
Underground Filter	5	2-5	4
Flood Management Area	N/A	N/A	N/A
Stormwater Wetland	25	3-5	8
Pocket Stormwater Wetland	5	2-3	0
Stream Restoration	N/A	N/A	N/A

Source: One Architecture & Urbanism / Sherwood Design Engineers, 2023

NOTES

Guidance for industry-standard practices are taken from the Georgia Stormwater Management Manual (GSMM), which is considered by EPA as one of the leading guidance documents for green infrastructure in the nation, in the absence of specific EPA guidance.

Location in watershed
Based on the priorities listed for each portion of watershed. Upper Watershed: Infiltrate, Convey Downstream; Middle Watershed: Slow Water Flows through storage, Divert Flows from Problem Areas, Convey Downstream; Lower Watershed: Absorb and Store

Ecological co-benefits
Evaluation considers the ancillary benefits associated with the incorporation of Green Infrastructure on campus, including the provision of habitat within the Green Infrastructure and the mitigation of Urban Heat Island Effect through the decrease of impervious area or the increase of tree canopy.

Economic considerations
Due to the unavailability of data from the federal government on Green Infrastructure standards, costs were taken from Volume 2 of the Georgia Stormwater Management Manual (2016) and NOAA Guidance for Cost Estimations of Nature Based Solutions (2020). Costs are considered in terms of price per square foot (SF) that is treated by the green infrastructure measure / design option.

Benefit to MS4 Compliance
Evaluation based on the degree to which the GI either reduces the amount of impervious area or treats the stormwater that generates from impervious area on campus.

Technical criteria
(maximum drainage area; pressure head needed; maximum slope)
In absence of explicit technical guidance for national-level agencies, technical information was supplemented from the Georgia Stormwater Management Manual Volume 2 (2016) which is listed on EPA's website as a resource for GI guidance and is commonly regarded among the nation's leading stormwater guidance documents.

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