



GREEN INFRASTRUCTURE TECHNIQUES

Rain Gardens, Permeable Pavement, Bioswales,
Rain Water Harvesting, Green Roofs,
Downspout planters, Enhanced Tree Pits
for homes, gardens, and communities



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This Green Infrastructure Guide is designed to educate homeowners, community gardeners and others interested in techniques that help minimize water pollution as it results from rainfall in cities that have combined sewers and other locations that experience flooding and storm water problems. Storm water management techniques include: rain water harvesting, bioswales, rain gardens, downspout planters, green roofs, permeable paving and enhanced tree pits. The photographs, detailed drawings, material lists and descriptions provide a starting point for those interested in utilizing these practices in their homes, gardens and communities. Additional information and resources (videos) can be found in our online toolkit at <http://www.grownyc.org/openspace/green-infrastructure-toolkit>.

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COVER: Rain garden at the University of Minnesota-Duluth with native plants (top); Enhanced tree pit (bottom)

PREFACE

AS MORE AND MORE PEOPLE populate the earth and cluster in cities, environmental sustainability, and building with the environment in mind, is increasingly incorporated in city development. City planners, architects and residents have to look at: how cities work and grow and how this growth stresses city infrastructure. They need to analyze the impacts of design, construction, transportation, building, manufacturing, growing, cleaning, water supply and agriculture. Taking such a holistic approach helps to minimize harmful impacts.



Rain water harvesting setup

The water and plumbing infrastructure of an older, more developed city, like New York, has become overburdened. It can no longer keep up with the population growth of the city because the system is used to handle sewage as well as storm water. This can become a problem when flooding and runoff occur. The answer is not to build a bigger and better sewage system: the answer is to build with the

system already in place. When water naturally falls from the sky and hits the ground most of it gets soaked into the ground, either draining all the way to the water table, or going through transpiration in which the plants absorb it and release it as vapor. The water that does not infiltrate the ground is called run-off. This water runs along the surface of the ground down a slope. The more there are impervious surfaces like paved road and sidewalks, the more run-off. The more run-off, the more pollution we have. With all the city's impervious surfaces, think about how much run-off results in NYC! Best guess? 5 billion gallons of water per one inch of rain. So now what? Find opportunities to build within the existing system, to naturally mitigate harms like pollution runoff into our water bodies. This is where green infrastructure comes in.

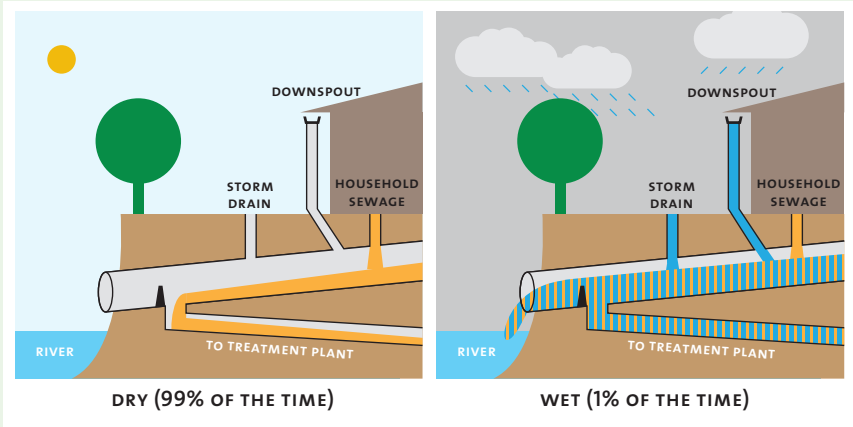
WHY IS GREEN INFRASTRUCTURE IMPORTANT?

GREEN INFRASTRUCTURE PREVENTS HEAT ISLAND EFFECT



Concrete, asphalt, and other building materials absorb heat and hold the heat, making the urban environment much hotter than suburban areas. Trees and other greenery as well as white painted surfaces help to minimize the heat island effect.

GREEN INFRASTRUCTURE PREVENTS COMBINED SEWER OVERFLOW (CSO)



Combined sewers are designed to collect water runoff, domestic sewage, and industrial waste water in the same pipe. During rain events storm water enters the sewer system and causes the system to exceed its intended capacity. In New York City wastewater treatment plants rain events cause all of the water to be directed to the waterways around the city creating what are called Combined Sewer Overflows or CSOs.

IS GREEN INFRASTRUCTURE APPROPRIATE FOR MY NEEDS?

THINGS TO LOOK FOR WHEN determining if a site is appropriate for Green Infrastructure techniques—be it rain water harvesting, bioswales, a rain garden and more—include catchment areas (adjacent building roofs, casitas, gazebos), depressions, puddles, slopes, impermeable pavement, and possible planting space, and how captured water can be used.

When devising a plan, consider budget and materials. In some cases simple projects are easy for anyone to install while in other cases permits, plans and contractors may be required. This process may not be linear, but iterative. Make sure that contractors are licensed and have references and that the information you glean comes from credible sources. In implementing your plan, your research may lead you to other techniques or alternative materials to try out, so don't be afraid to experiment in order to find the most functional design for your project.

A group in Northfield, MN constructing a rain garden

WHAT TO LOOK FOR WHEN CONSIDERING GREEN INFRASTRUCTURE

- CATCHMENT AREAS
- TOPOGRAPHY
- INTENDED USE FOR CAPTURED WATER
- BUDGET
- PERMITS (IF APPLICABLE TO YOUR PROJECT)
- NEED FOR A CONTRACTOR



RAIN GARDENS

A **RAIN GARDEN** is a garden of native shrubs, perennials, and grasses that can withstand both drought and occasional flooding, typically planted in a small depression, which is generally formed on the low point of a natural slope. The rain garden is designed to hold and soak in rain water runoff from roofs, driveways, patios or lawns. The rain garden is dry most of the time and typically holds water only for the day following a rainfall event.



MATERIALS

- **SOIL: SANDY LOAM**
- **GRAVEL, SAND**
- **PLANTS (SEE FOLLOWING PAGE)**

When determining where to site a rain garden, look for naturally occurring depressions with slopes on either side. A rain garden can be any size but a typical rain garden is between 100 and 400 feet (but could be smaller if necessary). Rain gardens can be any shape but usually are shaped longer than they are wide and positioned perpendicular to the slope of the land in order to catch the maximum amount of rainfall. Rain gardens should be placed at least ten feet away from building foundations and should not be located where water ponds for an extended period of time (less than 0.5 in. per hour percolation rate). The soil in the interior, lower area of the rain garden should drain well and be amended with sand and gravel to improve drainage. There are specific plants that will thrive in drought conditions and can withstand flooding. Rain gardens are easy to construct, mostly requiring digging in the area in order to add the soil amendments or to increase the depth of the rain garden.

SUGGESTED RAIN GARDEN PLANTS



CINNAMON FERNS



SWAMP MILKWEED



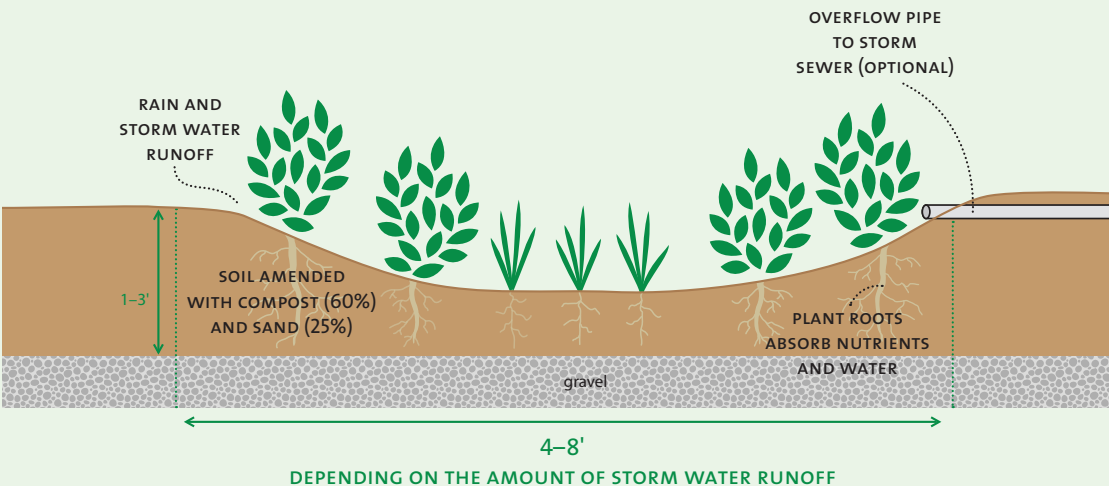
CARDINAL FLOWER

TURTLEHEAD PLANTS

BLACK GUM TREE

OTHER RAIN GARDEN PLANTS

(Brooklyn Botanic Garden has a comprehensive list available at:
http://www.bbg.org/gardening/article/rain_garden_plants)



BIOSWALES

A **BIOSWALE** IS a linear, sloped retention area designed to capture and convey water, while allowing it to infiltrate the ground slowly over a 24 to 48 hour period. The slopes are usually planted with native species similar to a rain garden. A bioswale built into a sloped area can also help prevent erosion.

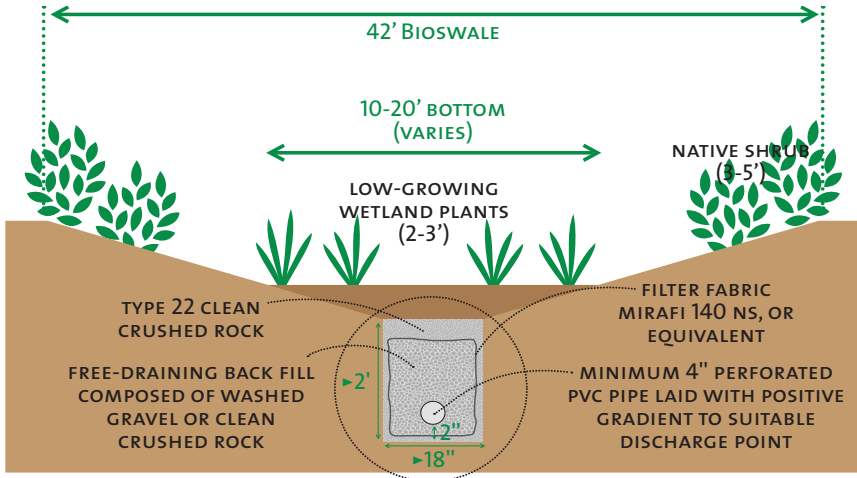


ABOVE: Bioswale

MATERIALS



- **SOIL TEXTURE: SANDY LOAM**
- **LANDSCAPE FABRIC**
- **GRAVEL**
- **PERFORATED PIPE**
- **PLANTS (SEE FOLLOWING PAGE)**

This type of infrastructure is usually found on larger sites. Look for a sloped linear depressed area. Bioswales are used to convey water to plants, rain gardens, or storm drains, while allowing the water to infiltrate into the soil and be soaked up by the vegetation, therefore reducing flooding. The slope should be gradual and planted with native species to minimize erosion and the velocity of water flowing, and to allow for maximum infiltration. For the sloping sides of the bioswale, a rise in the slope of 1 foot for every 2 feet of length or run is a good rule of thumb to use. It is best to follow the contour of the slope for a bioswale to be most effective. A lot of hand digging is required to create the depression. In some cases mechanical digging equipment may be necessary. In order to increase the water retention capacity, a perforated pipe can be placed in the trench similar to a French drain (see callout in diagram below left). This also allows excess flow to be directed where you want it to go. Landscape fab-



A FRENCH DRAIN, OFTEN INCORPORATED IN CONSTRUCTING A BIOSWALE, IS A TRENCH COVERED WITH GRAVEL OR ROCK, USUALLY CONTAINING A PERFORATED PIPE THAT DIRECTS GROUNDWATER AWAY FROM AN AREA

ric is used to cover the perforated pipe to keep the soil from washing in and clogging the pipes. Larger plant material like berry bushes or fruit trees can be planted at the top of the bioswale to provide additional protection against erosion.

SUGGESTED BIOSWALE PLANTS	
 <p>BLACK GUM TREE 9-10 FT TALL</p> <p>CARDINAL FLOWER</p> <p>SWAMP MILKWEED</p>	 <p>TURTLEHEAD PLANTS</p> <p>CINNAMON FERNS</p> <p>OTHER PLANTS</p>

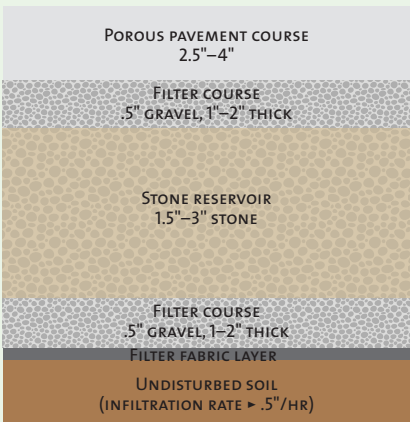
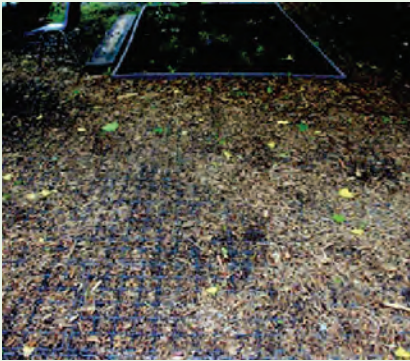
PERMEABLE PAVEMENT

PERMEABLE PAVEMENT is a material designed to allow percolation or infiltration of stormwater through the surface into the soil below where the storm water is naturally filtered and pollutants are removed. Permeable concrete, permeable asphalt and other engineered systems are used depending on the amount and type of foot or vehicle traffic. In contrast, normal pavement is an impervious surface that repels rainfall and associated surface pollutants, forcing water to run off paved surfaces directly into nearby storm drains and then potentially contributing to Combined Sewer Overflows (CSOs).



ABOVE: Permeable paving installed under an arbor at a community garden in Brooklyn

Look for paved areas that frequently have flooding or puddles. This pavement is usually impervious or solid, not allowing water to percolate through it into the ground. Permeable pavement allows water to naturally seep through and back to the water table. Because permeable pavement is not as solid as impermeable pavement and



TOP: Permeable pavement detail **MIDDLE:** Permeable pavement at work in a community garden in Brooklyn **BOTTOM:** A cross-section diagram of the components of installed permeable pavement

cannot bear the same load, it should not be used on heavily vehicle trafficked areas, but should be limited to parking or foot traffic. It should not be placed at the end of slopes in order to minimize flooding. The existing soil underneath the permeable pavement should drain well. Some types of permeable pavement like geogrids can be installed by a do it yourselfer, but follow manufacturer’s instructions. Paving blocks that are permeable can also be easily installed by a homeowner or gardener while other types of permeable paving like permeable concrete or permeable paving using aggregates like crushed glass will require a contractor.

MATERIALS

- PAVERS
- COMPACTING MACHINE
- FILTER FABRIC
- GRAVEL
- MASONRY SAND
- GEOGRID MATERIAL

GREEN ROOFS

A **GREEN ROOF** is a vegetative layer grown on a rooftop. Green roofs hold rain water and reduces temperatures in a home by removing heat from the air through evapotranspiration. Green roofs can be ornamental and low profile or be used to grow vegetables and larger plant material on rooftops.



ABOVE: Example of an intensive green roof (>2" of soil) at Via Verde, an apartment building in the Bronx

GREEN ROOFS NEED flat or nearly flat roofs to work. It is also important to know the weight bearing capacity of the roof. Often additional structural support is necessary in order to hold the additional weight of soil and water. In most cases the planters or planting medium is separated from the roof by membranes that protect the roof. Check zoning codes that may limit the amount of roof area that can be covered by a green roof. Extensive green roofs use as little as 2 inches of soil and grow mainly grasses and sedums. This type of roof will weigh much less than an intensive green roof but provide the same temperature reduction benefits and require much less maintenance.

An intensive green roof will have greater than 2 inches of soil and can support much larger plant material. Some green roofs are urban farms growing vegetables for sale. Wet soil can weigh more than 120 pounds per cubic foot but the climate of



LEFT: Before and after, a Manhattan roof garden using low-cost materials



MATERIALS

- WEATHERPROOF MEMBRANE
- ASPHALT ROOFING FELT
- PLANTERS, GRID SYSTEM
- DRAINAGE LAYER, GRAVEL
- GROWING MEDIUM, SANDY LOAM
- PLANTS

a rooftop can be hotter than at street level and more windy which will tend to dry out soil and desiccate plants.

A drip irrigation system can help insure that the soil does not dry out. There are commercially available systems for green roofs which supply fabrics or membranes as well as grid and modular systems. An inexpensive green roof can be made with recycled planters. Before you decide on a green roof, consult with a structural engineer or architect, to address structural, safety, and other concerns.

DOWNSPOUT PLANTERS

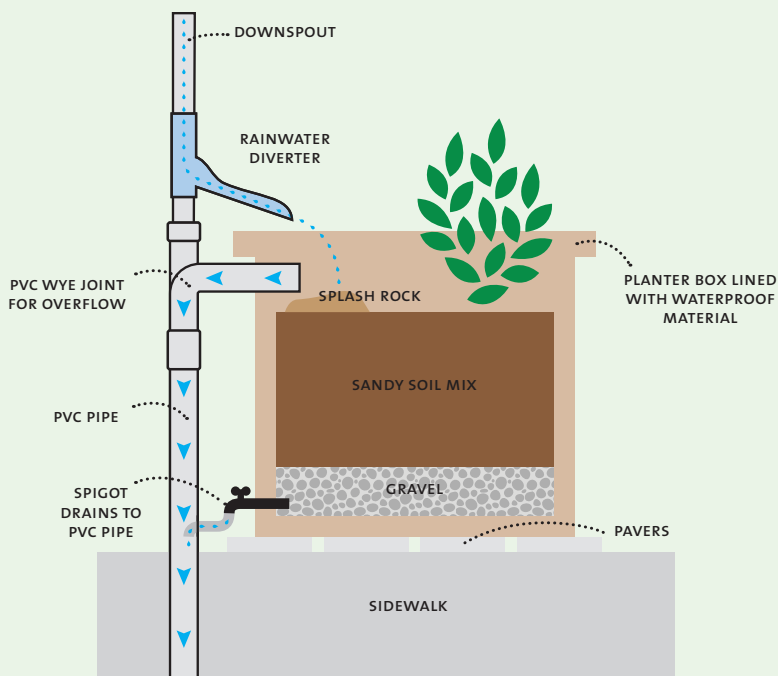
SIMILAR TO A RAIN GARDEN downspout planters place plants along or at the end of a downspout to capture the water before it enters the sewer. They range from very simple planters on the ground to one or more planters along the downspout. Rainfall is captured by the planter allowing for infiltration and capture of pollutants.

WHEN SPACE IS LIMITED a downspout planter is a good solution. It can be as simple as placing a large pot or planter at the bottom of, or next to, your downspout. A planter box will last longer if it is lined with plastic, as the moist soil tends to rot unprotected wooden planters. Plastic lumber is an option as it will last for many seasons as it does not rot like wood. You'll need to install an overflow outlet in order to drain excess water. This is important as the planter will be close to the building and could cause moisture problems if the overflow is not directed away from the building.

Downspout planters can also be installed somewhere along the downspout to



LEFT: Drainspout planter by the side of a house



slow down the flow of water, to act as a bio-filter, or to take advantage of vertical planting options. This type of solution, also called an inline planter, should be properly secured, considering the weight of moist soil. If the planter will be inaccessible, low maintenance plants like grasses will work best.

MATERIALS

- PLANTER
- PLASTIC LINER
- WELL DRAINED SOIL
- CARDINAL FLOWER
- SWAMP MILKWEED
- TURTLEHEAD PLANTS
- INLAND SEA OATS
- SEDGES

ENHANCED TREE PITS

AN ENHANCED TREE PIT collects rain water by diverting runoff from the street into a cut into the curb. Enhanced tree pits are specially engineered with soils and native plant species to absorb water and filter associated pollutants. In some enhanced tree pits, storage chambers hold additional runoff, available for plant uptake or ground water recharge.



ABOVE: Enhanced tree pit in Brooklyn

FOR MOST PEOPLE installing an enhanced tree pit themselves will not be an option. However, if sidewalks, streets or curbs are being redone, you can request an enhanced tree pit by contacting your city government (in New York City, a good place to start is your local Community Board). The most effective tree pits include an underground storage tank to increase the amount of stormwater retained. In order to work properly, the soil should be amended in order to accommodate inflow of large amounts of water. Both of these improvements will



ABOVE: Enhanced tree pit detail in the Bronx showing the stormwater inlet

BELOW: Enhanced tree pit in Philadelphia

require heavy equipment as well as permits and approvals. A homeowner or a community gardener that has a tree in their garden could direct rain water that runs along an impervious surface in the garden or backyard toward that tree as a simple do it yourself project. As with all Green Infrastructure techniques, some allowance has to be made for overflow in heavy rains.



RAIN WATER HARVESTING

ALL GREEN INFRASTRUCTURE techniques capture rain water in some way. Rain water harvesting (RWH) generally means collecting and storing rain water in large, durable containers, typically collecting from rooftop gutters. RWH systems come in a variety of shapes and sizes. Simple systems can be installed by a do-it-yourselfer. Larger and more complicated systems may require a skilled contractor.



ABOVE: Rain water harvesting structure in a Manhattan school garden

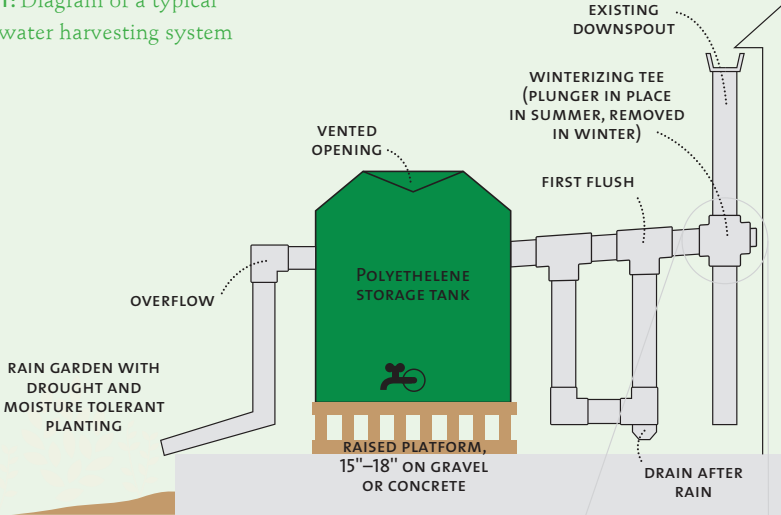
RAIN WATER HARVESTING SYSTEMS are fairly easy to construct. Rain water collected from the downspout of an adjacent building or shed in the garden is redirected to the water storage area in the garden. Tanks can be above ground or underground and range in size from as small as 50 gallons to as large as 10,000 gallons. Most rain water harvesting systems can capture about $\frac{1}{2}$ gallon of water for each square foot of roof per one-inch of rainfall. Care should be taken to size your tank properly according to roof size and how much water you will want to use. Without special treatment, rain water is

most often used for non-potable needs such as irrigation or washing sidewalks.

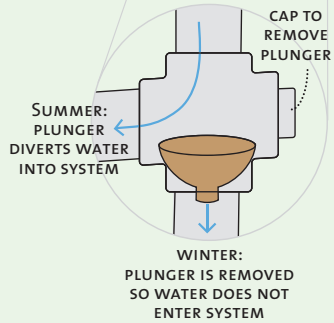
The RWH system includes the collection area or roof, piping to deliver the rain to the storage tank, the first flush or filter, the tank and the overflow pipe.

In most rainfall events, water flows from the gutter into the downspout and then to the sewer. Instead of the water going into the sewer system, a rain water harvesting system diverts the water into pipes. Any type of diverter can be used. The diverter shown consists of a winterizing tee with a plunger in place during the summer. This plunger keeps the water from entering the downspout and forces it to flow into the harvesting system. The plunger is taken out in the winter when rain water is no longer collected and to prevent freezing.

RIGHT: Diagram of a typical rain water harvesting system



The pipes lead to a roof washer system which is a containment area for the first few gallons of water. Since the initial flushes of water contain rooftop debris and leaves, the roof washer acts as a filtering system by separating the dirty water from the cleaner water. Once the roof washer is full, the cleaner water enters the rain tank. Other types of screens and filters can be used to keep pollutants out of the storage tank. As soon as the tank is full, excess water flows into the overflow pipe. The overflow can then be diverted to an adjacent rain garden (a plot containing hardy plants that can survive both saturated and dry soil). Alternatively, overflow water can be diverted to where the downspout originally drained, or piped underground.



- MATERIALS**
- STORAGE TANK
 - GUTTERS
 - PIPING
 - PLATFORM

GLOSSARY

AGGREGATES Mineral materials such as sand, gravel and crushed stone that are used with a binding medium (water, bitumen, Portland cement, lime, etc.) to form compound materials, for example asphalt or concrete.

BIOSWALE A linear, sloped retention area designed to capture and convey water, while allowing it to infiltrate into the ground slowly over a 24 to 48 hour period. The slopes are usually planted with native species similar to a rain garden. When built into a sloped area a Bioswale can help prevent erosion.

COMBINED SEWER Sewers that are designed to collect water runoff from rainfall, domestic sewage, and industrial waste water in the same pipe.

COMBINED SEWER OVERFLOW During rain events storm water enters the sewer system and causes the system to exceed its intended capacity. In New York City wastewater treatment plants rain events will cause all of the water to be directed to the waterways around the city creating what are called Combined Sewer Overflows or CSOs.

DOWNSPOUT A pipe to carry rainwater from a roof to a drain, water storage tank or to ground level planter.

EROSION The process by which the surface of the earth is worn away by the actions of water, glaciers, winds, and other elements.

EXTENSIVE GREEN ROOF A type of green roof that uses as 2 inches or less of soil and grows mainly grasses and sedum. This type of green roof weighs much less than an intensive green roof but provides the same temperature reduction benefits and requires much less maintenance.

FRENCH DRAIN A ditch lined with rocks, gravel, or a perforated pipe that redirects surface and groundwater towards or away from an area.

GREEN INFRASTRUCTURE Sustainable solutions that enable natural process to work more smoothly. Some of these techniques include rain gardens, bioswales, permeable pavement, green roofs, downspout planters, enhanced tree pits, and rain water harvesting.

GEOGRID A type of permeable pavement, usually a synthetic material characterized by woven bands of narrow elements in a regular, grid-like pattern with large voids between the woven bands. The tensile strength of the woven bands and the voids between those bands lend stabilizing strength to the projects where they are used.

GROUNDWATER RECHARGE Movement of water out of an area of saturated soil. In well drained soils rainwater seeps into the ground and moves downwards through the soil until it reaches the water table.

IMPERVIOUS Not able to pass through.

INFILTRATION The process by which water landing on the surface of the ground enters the soil.

INTENSIVE GREEN ROOF A green roof with greater than 2 inches of soil which can support much larger plant material. Some intensive green roofs are urban farms growing vegetables for sale.

NON-POTABLE WATER Water that is not of drinking water quality, but which may still be used for many other purposes, such as irrigation, depending on quality.

MITIGATE To make changes or improvements in order to alleviate or lessen the severity of a problem or issue, e.g. stormwater management techniques

PERCOLATION The slow movement of water through the pores in soil or permeable rock.

PERENNIAL PLANT A plant that lasts or is active for many years.

PERFORATED PIPE A pipe with holes along the pipe walls designed to help ease soggy yards, flooded fields and wet basements by dispersing water evenly.

PERMEABLE Allows liquids or gas to pass through.

RAIN GARDEN A garden of native shrubs, perennials, and grasses which can withstand both drought and occasional flooding, typically planted in a small depression, which is generally formed on a low point of a natural

slope. The rain garden is designed to hold and soak in rain water runoff from roofs, driveways, patios or lawns. The rain garden is dry most of the time and typically holds water only for a day following a rainfall event.

ROOF WASHER Acts as a filtering system by capturing the first few gallons of the dirtiest water, in a Rain Water Harvesting System.

SANITARY SEWER A sewer to dispose of waste water from homes and businesses but not water from rainfall.

SOIL AMENDMENT Elements added to the soil, such as compost, peat moss, or fertilizer, to improve the soils capacity to support plant life.

STORM SEWER a sewer for carrying off rainfall drained from paved surfaces, roofs, and other places that don't absorb water.

STORMWATER MANAGEMENT Anything associated with the planning, maintenance, and regulation of facilities which collect, store or convey storm water.

TRANSPIRATION Process by which water absorbed by plants, usually through the roots, evaporates into the atmosphere from the surface of the leaves through the leaf pores.

WATER RETENTION CAPACITY The ability of a particular type of soil to hold water against the force of gravity. Different types of soils have difference capacities.

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ABOUT GROWN NYC

FOUNDED IN 1970, GrowNYC is a hands-on non-profit which improves New York City's quality of life through environmental programs that transform communities block by block and empower all New Yorkers to secure a clean and healthy environment for future generations.

GrowNYC operates Greenmarket farmers' markets, engages New Yorkers in recycling education and resources, builds and maintains green spaces and engages young people in hands-on education. Reaching three million New Yorkers every year, we are helping residents make ours the most sustainable city in the world.

Donate, volunteer or get involved at www.grownyc.org



**New York State
Pollution Prevention Institute**

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