Stormwater Management

Stormwater Best Management Practices

Pond: permanent pool of water, or a combination of a permanent pool and extended detention, and some characteristics of a shallow marsh. Provides stream channel protection and overbank and extreme flood attenuation.

Wetland: shallow structural practice, also called constructed wetlands which incorporates wetland plants into the design to store and treat stormwater runoff. Pollutants within stormwater flowing through a wetland are filtered out via settling and biological uptake.

Infiltration: detains and temporarily stores stormwater runoff before infiltration into underlying soil layers; most pollutants are trapped in the soils (Center for Watershed Protection, 2007).

Filter: utilizes artificial media, such as sand, peat, grass, soil, or compost to filter out pollutants from stormwater runoff. Stormwater is detained, treated, collected in an underdrain, and returned back to a storm drain. Usually used for small development sites (less than 5 acres). Three broad categories include sand filters and bioretention and vegetated channels (swales). Bioretention is a shallow landscaped depression, with a drainage area of one acre or less. Swales are broken into dry, wet, and grass swales. Swales have moderate pollutant removal capability; can reduce peak runoff volume; and increase groundwater recharge (Center for Watershed Protection, 2007 and 1996).

Native Landscaping: are adapted to managing local site and regional wet weather conditions. Require minimum maintenance and may be used in many different best management practices.

Permeable Pavement: pavement technology that allows stormwater to filter through the media. Open pore space within the pavement material allows for water to move downward. Stormwater percolates and is filtered into the ground recharging groundwater resources. An aggregate base layer acts as a stormwater storage basin. Two forms of permeable pavement include porous concrete and permeable pavers (D. Huffman, 2005).

Figure 7.12: Bioretention cell in urban context (Kevin Robert Perry, American Society of Landscape Architects, 2006)

Figure 7.13: Permeable pavers installed in a parking lot (Iowa Natural Resources Conservation Service, 2008)

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Stormwater Pond and Wetland Examples

Figure 7.14: Natural wetland/pond (Pennsylvania Department of Environmental Protection, 2008).

Figure 7.15: Constructed wetland within a park-like setting (J. Loevy, Los Angeles Times, 2008).

Figure 7.16: Stormwater wetland within an urban area (United States Geological Survey, Western Ecological Research Center, 2007).

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Infiltration systems are used to remove pollutants and infiltrate stormwater into the ground. Pollutant removal occurs via filtration through soil medium, and biological and chemical activities within the soil. Peak runoff rate and volume is reduced by increasing groundwater recharge rates. Highly permeable soils provide temporary storage of stormwater runoff. Outflow occurs through the surrounding soil.

Design guidance includes many variables. Infiltration systems are best when used in conjunction with other stormwater treatment practices. Such pretreatment practices may include: grass channel, grass filter strip, bottom sand layer, and upper sand layer. Water should be delivered and pass through the system at non-erosive velocities. The maximum drainage area should be less than 5 acres. Dense vegetation should be established in pervious areas.

Infiltration systems should be setback 25 feet down slope from structures and 100 feet from water supply wells. They may not be located on slopes greater than 15% or within fill soils. The soil clay content should be less than 20% and the silt/clay content less than 40%. A 6 to 12 inch layer of filter material (coarse sand) should be put on top of the system to prevent build up of impervious deposits on the soil surface.

A portion of the water entering the system should be pretreated; greater than or equal to 25% of the water quantity volume should be pretreated. Pretreatment options include sedimentation and stilling basins. The exit velocities of the pretreatment systems should be non-erosive for a 2-year design storm. The infiltration system should be able to treat the total water quantity volume within 48 hours after the storm.

Design variations include infiltration trench and basin, and porous pavement practices (Center for Watershed Protection and New Jersey Department of Environmental Protection, 2004).

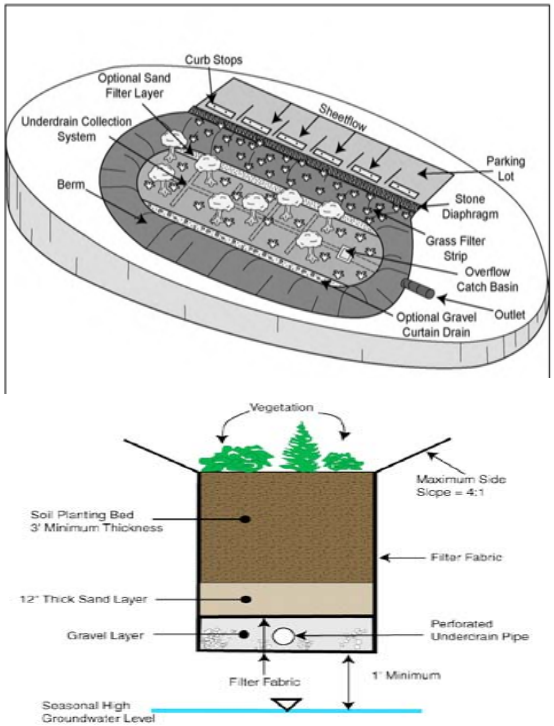

Figure 7.17: Stormwater bioretention design templates (Center for Watershed Protection, 2007 and New Jersey Department of Environmental Protection, 2004); Figure 7.18: Stormwater management strategies will be applied throughout study area.

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Infiltration, Bioswale, and Bioretention Design Examples

Figure 7.19: Infiltration trenches in parking lot and building complex areas (Center for Watershed Protection, 2001 and American Society of Landscape Architects, 2004).

Figure 7.20: Parking lot biorentention cell (Iowa Natural Resources Conservation Service, 2008).

Figure 7.21: Vegetative swale in residential setting (Iowa Natural Resources Conservation Service, 2008).

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Permeable Technologies

Design options include porous asphalt, pervious concrete, and permeable pavers. Voids within the materials allow for infiltration. An underlying stone reservoir temporarily stores surface runoff before it infiltrates into the subsoil. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with interconnected voids. Pervious concrete consists of specific mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has voids that allow rapid percolation through the pavement. Permeable pavers are interlocking concrete blocks or synthetic fibrous grids with voids allowing grass to grow within them. Other grid systems have sand or gravel within the voids. Maintenance and proper installation are necessary to ensure long-term effectiveness.

Areas with medium traffic are ideal for porous pavement application. Benefits include: reduced stormwater runoff rates and volumes, groundwater recharge, filtering of sediments, silt, and pollutants (City of Chicago, Department of Transportation, 2007).

Design Guidelines

1. *Pretreatment*. In porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Frequent maintenance of the surface to prevent clogging includes sweeping or vacuuming . A layer of fine gravel can be laid on top the coarse gravel reservoir for additional pretreatment.

2. *Treatment*. If used, stone reservoir below pavement surface should be composed of layers of small stone laid directly below the pavement surface. Stone bed below the permeable surface should be sized to attenuate storm flows for the designed storm event to be. Porous pavement is sized to treat small storm events for water quality treatment. Water can be stored in the voids of the stone reservoir.

3. *Conveyance*. Water conveyed to the stone reservoir though the surface payment infiltrates into the ground. A geosynthetic liner and a sand layer may be placed below the stone reservoir to prevent desired flow paths and to maintain a flat bottom. Large amounts of stormwater may be conveyed through storm drain inlets set above the surface pavement.

4. *Maintenance Reduction*. Signs should identify porous pavement areas for maintenance needs. An "overflow edge," a trench surrounding the edge of the pavement, may connect to the stone reservoir acting as a backup in case of surface clogs.

5. *Landscaping*. Clogging of the pavement may be prevented by stabilizing the upland drainage area, reducing sediment loads (US EPA, 2006).

Figure 22: Recreational trail with pervious grid system (Iowa Natural Resources Conservation Service, 2008); Figure 23: Permeable paver (Iowa Natural Resources Conservation Service, 2008).

Stormwater Management

Green Roofs

Stormwater runoff may be reduced by installing green roofs on commercial, industrial, and residential buildings. Green roofs absorb, store, and later evapotranspire precipitation, reducing peak flow discharge to storm sewer systems. Soil microbial processes and plant uptake in green roofs may reduce the discharge of nitrogen and phosphorous. Additional benefits include reduction of the urban heat island effect, increased thermal insulation and energy efficiency, and increased durability.

Green roofs are classified as extensive, semi-intensive, or intensive. Extensive green roofs have six inches or less of growing medium; and intensive green roofs have greater than 6 inches of growing medium. Semi-intensive green roofs are a hybrid of intensive and extensive green roofs, where at least 25 percent of the roof square footage is greater or less than 6 inches. Extensive green roofs are designed to be low maintenance and typically not designed for public access. Semi-intensive and intensive green roofs are designed for public or building tenet access.

Design Guidelines:

The building has to support the weight of the green roof materials under fully saturated conditions. The stormwater retention of the system will also determine intensive or extensive design options. Green roof materials include a waterproof liner, a soil or substrate layer, and a plant layer. Selected plants need to be adapted to local climatic conditions. Plants on extensive roofs may include sedums, grasses, and wildflowers; and intensive roofs may also include shrubs and small trees.

Green roofs are a useful for retrofitting existing impervious roofs. Most existing flat-roofed buildings may accommodate an extensive green roof without structural modifications (US EPA, 2006).

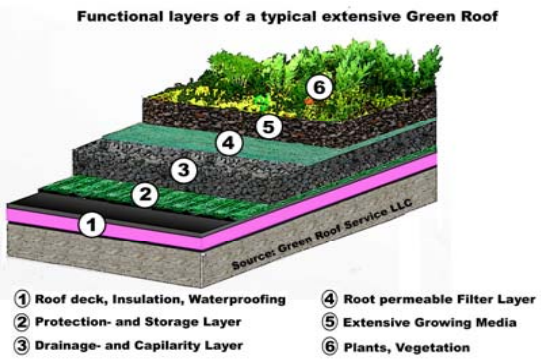

Figure 7.24: Section of a typical extensive green roof (Roof System Consultants, 2008).

Figure 7.25: Green roof systems at the American Society of Landscape Architects headquarters building (American Society of Landscape Architects, 2006).

Stormwater Management

Rain Garden, French Drain, and Dry Wall

Rain Gardens

Capture, filter and infiltrate stormwater runoff from rooftops, sidewalks, parking lots, and other impervious surface areas. They are small vegetative depressions usually 6 to 18 inches deep. The base of the depression is composed of a soil/sand layer. Vegetation includes native woody plants, shrubs, and grasses adapted to wet conditions.

Stormwater is detained for no more than a 24 hour period, until infiltration or evapotranspiration occurs. Benefits of rain gardens include recharge of groundwater, reduced stormwater peak discharges, and pollutant reduction. At least 30% more water infiltrates into the soil compared to conventional lawns.

Design Guidelines

Surface area should be 20% to 30% of the drainage area to detain runoff from 1-inch of precipitation. A minimum of a 1% slope leading to the rain garden is needed to allow adequate stormwater conveyance. Rooftop stormwater runoff may be conveyed to the garden via a downspout extension.

French drains and Dry Wells

Detain and infiltrate stormwater runoff. A swale or downspout may direct stormwater runoff may to the trench. These systems temporarily detain runoff in voids between stones filled within the trench, allowing for infiltration into the soil substrate. A french drain is a shallow underground trench with perforated pipes running along the bottom.

A dry well is composed of a deeper and shorter excavated trench with vertical and horizontal perforated pipes running through the stone layer. French drains are used mainly in residential areas, but dry wells are used at residential and commercial sites. Both systems are used for small drainage areas.

Design Guidelines

Pretreatment should be used to reduce clogging. A screen may be placed on top of rooftop gutters to filter out leaves and debris. An overflow bypass needs to be included to convey excess runoff away from the system during large storm events. The bypass may be an aboveground opening located on the downspout (Center for Watershed Protection, 2007).

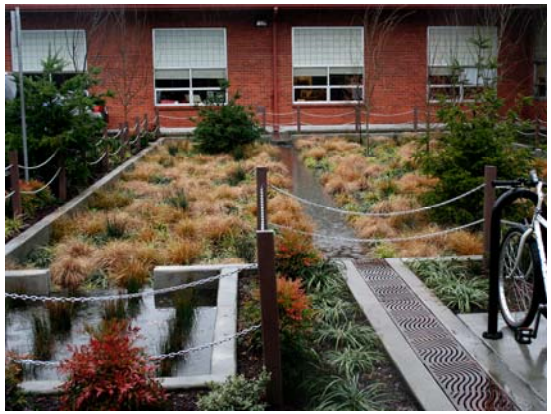

Figure 7.26: Rain garden located in front of a primary educational building. (Kevin Robert Perry, American Society of Landscape Architects, 2007).

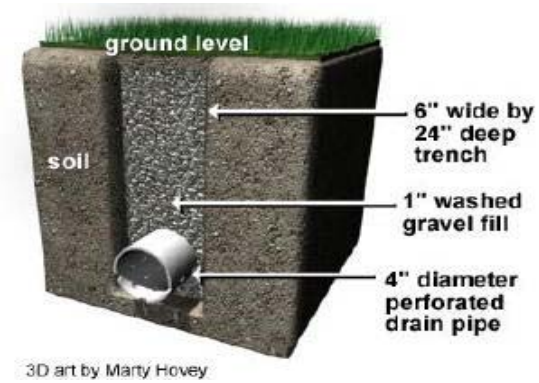

Figure 7.27: Conceptual french drain cross section (Tim Carter, Ask the Builder, 2008).

Heat Island Effect Reduction

Cool Pavements, Buildings, and Roofs

The heat island effect is the process of urban areas absorbing greater solar radiation than surrounding areas with less urbanization. During warm summer days a city may be 6 ºF to 8 ºF hotter than surrounding areas. This occurs because many urban surfaces are composed of materials that absorb solar radiation. Albedo, is a term which means the reflectance of a given material. A high albedo value equals great reflectance, while a low albedo value equals low reflectance. Many urban surfaces have low albedo values, storing solar radiation making urban areas hotter than areas with a lot of vegetation.

Manufactured materials, such as rooftops, sidewalks, parking lots, and roads may be designed to be composed of materials with high albedo values. Other ways to mitigate the heat island effect include: green roofs, increasing tree canopy cover, increasing the amount of park space, and reducing the amount of impervious surface cover. In addition, roofs and parking lots are prime locations for solar panels, wind turbines, and other renewable energy capture devices.

Benefits from mitigating the heat island effect include cooler air temperatures during hot summer days and cost savings from reduced uses of electricity.

Design Guidelines

Impervious surfaces, such as rooftops, pavements, and other building materials may be designed to have high albedo values. Light colored materials are more likely to have higher albedo values, but dark materials may also be designed to have high albedo values. Areas with materials having low albedo values may be shaded by tree canopy cover or other vegetation (green roofs and walls). Shading and evapotranspiration provided by vegetation produces cool air temperatures. Where possible, solar panels, wind turbines, and other renewable energy capture devices should be installed.

Vegetation may be carefully planted around a development site to maximize cooling capabilities. Placing deciduous trees along the south and west sides of a building provide shading and block summer sun. Evergreen trees and shrubs placed on the northwest side of a building may provide protection from winter winds. Trees grouped together protect each other from the sun and wind, increasing their likelihood to grow to maturity and greater longevity (Heat Island Group, US Department of Energy, 2000).

Figure 7.28: Solar panels, wind turbines, and other renewable energy capture devices can easily be installed on parking lots and buildings.

Figure 7.29: Multiple patches of green roofs on in dense urban area (Greenroofs.com, 2008).

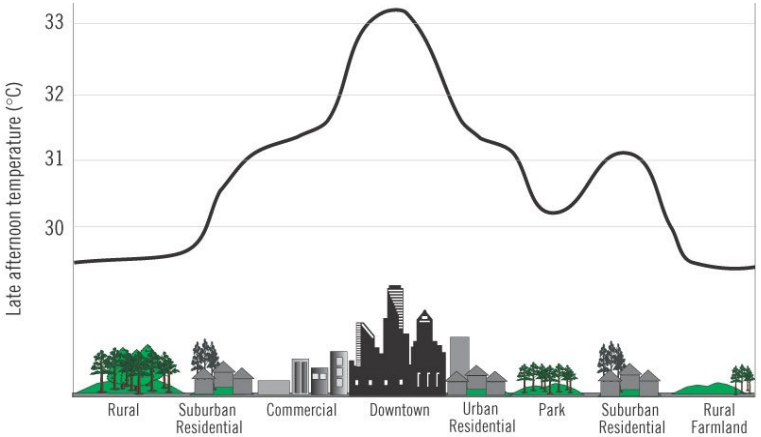

Figure 7.30: General temperature characteristics resulting from the "Urban Heat Island Effect." (Heat Island Group, US Department of Energy, 2000)

Wastewater Management

Living Machine

Human and animal wastewater may be treated with ecologically engineered systems that mimic natural processes of waste decomposition. One such ecologically engineered system is an "eco-machine," originally designed by Todd Ecological Design. In essence the system performs the same wastewater treatment processes as conventional wastewater treatment plants, but with ecologically designed systems.

An "eco-machine" has three main processes or systems within the treatment train, which are described below.

1.) Aerobic reactors, composed of a variety of aquatic plants and aerators treat sewage influent. Within the wastewater influent, levels of biochemical oxygen demand (BOD), total suspended solids (TSS), and ammonia nitrate are reduced after being processed through the aerobic reactor cells.

2.) After the first stage of treatment, the influent wastewater passes through a clarifier. The solids within the wastewater settle out as they pass through the clarifier.

3.) The final treatment process is another aerobic cell, which allows for nitrification and suspended solid digestion to occur. The final effluent is a clean water which may be used for irrigation purposes.

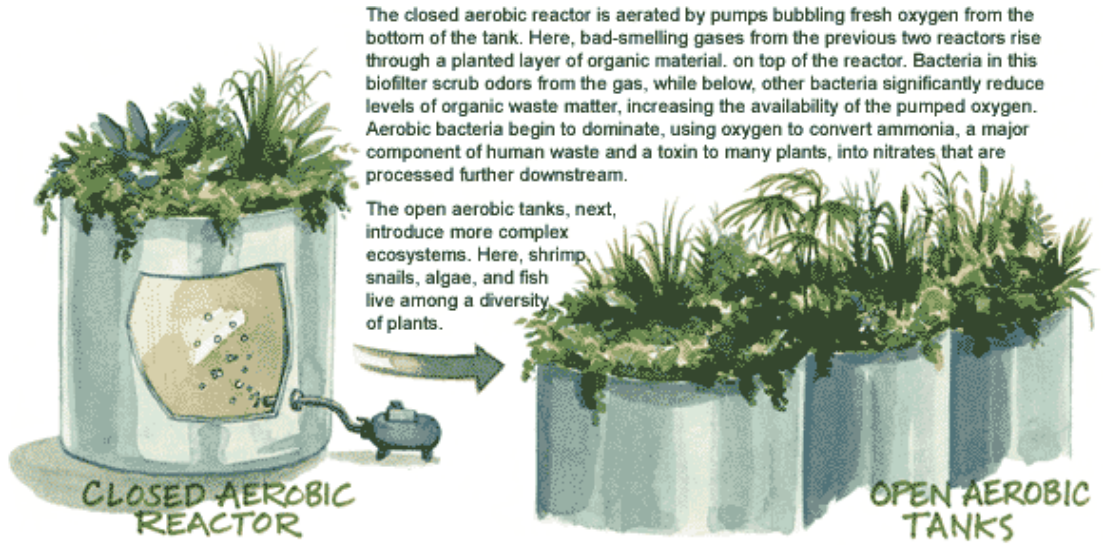

Figure 7.31: Eco-machine aerobic treatment cell (Todd Ecological Design, Inc., 2008).

The "eco-machine" is cost competitive and more aesthetically pleasing than conventional wastewater treatment technologies. Strong odors associated with conventional wastewater treatment practices are absent from the eco-machine system (Todd Ecological Design, Inc., 2008).

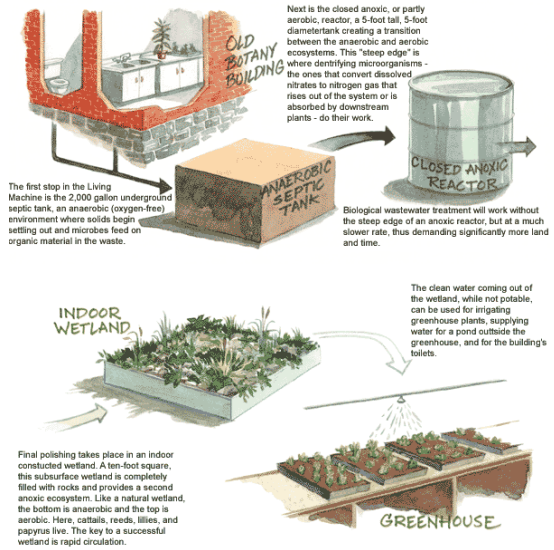

Figure 7.32: Illustrations of Living Machine by Penn State Center of Sustainability. http://www.rps.psu.edu/0009/machine.html