Sustainable Site Design: Stormwater Mitigation Technical Brief

***Green Guide for Health Care™* Sustainable Sites Credits 6.1 & 6.2**

Overview

A sustainable site development plan requires integrated solutions in every aspect of site design and architecture – including roofs, terraces, parking lots, roads, and pathways. A successful development will restore natural drainage patterns and native plant communities within a landscape design that enhances and reveals the inherent beauty of the place. Developed areas of the site should employ sustainable design technologies such as pervious parking lots, infiltration trenches, and underground recharge beds. In landscaped areas, vegetated swales and wet meadows work as biofilters to remove pollutants and facilitate stormwater infiltration. This approach reinforces the natural hydrologic cycle that infiltrates water into the soil, recharges groundwater, and sustains base flow in area streams.

Evolving federal, state and local regulations, such as the National Pollutant Discharge Elimination System (NPDES), require large land holding institutions to mitigate threats to the water quality of streams that lie within their watersheds associated with both old and new development. Other regulations require that contributing watersheds reduce the loads of key pollutants, such as nitrogen and phosphorous, to improve water quality downstream. Silt covered stream bottoms, eroded stream banks and water bodies choked with aquatic vegetation all reflect the problems of stormwater runoff on local drainage. Not surprisingly, impervious surfaces and urban land uses have been identified as the principal root cause of these problems.

GGHC v2.2 Sustainable Sites Credit 6: Stormwater Management recognizes that responsible site design must be coupled with strategies that can capture, reuse, treat, and infiltrate the stormwater runoff resulting from development by increasing the site's total pervious area. Most of the recommendations in this technical brief combine both land and stormwater management strategies because stormwater quantity and quality concerns are significant consequences of site development.

The Challenges

As José Almiñana and Theodore Eisenman discuss in *LEED in the Landscape*, ecological concerns must be incorporated early in a project's integrated design process to be successfully reflected in the final product: "An understanding of ecological context deeply informs the conceptual strategy of the site design and construction process that is striving to restore and maintain healthy, functioning ecosystems. This understanding must be incorporated at the very outset of the project and within a team-oriented approach."[1] The greatest challenge to an integrated approach to stormwater mitigation is often ignorance by project team members of the impact that site design can have on the larger environmental and health goals of the project. Phased construction projects can also make it difficult to establish synergies between site and building design. In fast-tracked projects, the landscape and civil designs might be under construction before the building has moved beyond schematic design. Perceived cost premiums for structural stormwater management strategies, such as green roofs, infiltration beds or pervious

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[1] José Almiñana and Theodore Eisenman, "LEED in the Landscape: Beyond the Box," *Environmental Design + Construction*, January 2003. http://www.edcmag.com

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pavement, may, in fact, prove to provide a cost benefit if reviewed holistically across the project rather than as a line item.

Best Practices

Stormwater Best Management Practices are location-specific stormwater management measures that involve some sort of construction or installation. Their efficiency, cost and overall applicability varies depending on the nature of the site and the scope of construction.

Best management practices should be evaluated on a project-by-project basis, based on their relative effectiveness in reducing stormwater volume through storage and treatment.

The two key criteria used to measure best management practice efficiency are: 1) reduction of runoff volume during design rainfalls; and, 2) reduction of selected non-point-source (NPS) pollutants.

1. Storage/infiltration beds

Most infiltration designs attempt to infiltrate both the natural amount of yearly rainfall and a portion of the site water that is lost annually to evapotranspiration (ET). Conduct a feasibility study that calculates the permeable surface area required to infiltrate the design stormwater volume based on conductivity (the speed of infiltration) and the rate and quantity of rainwater inflow to the site.[2]

Site conditions unsuitable for infiltration include:[3]

- Soil as impermeable as the roofs and pavements that will be placed upon it
- Toxic waste in industrial areas and saline deposits in arid areas that would leach if loaded with additional through flow
- Steep unstable slopes
- Proximity to basements, sensitive structural foundations, water supply wells or septic tanks

The feasibility study should also include an evaluation of all potential site soils and soil infiltration tests in desired bed locations. These tests identify the most suitable horizon (i.e., depth) for infiltration, which, in some cases, can result in very shallow infiltration beds.

On-site storage design requirements may face budgetary or space constraints. In some cases, local utilities do not allow on-site storage. If an infiltration bed cannot be designed to handle a large storm event due to an external constraint, it may be feasible to design the infiltration system to handle and treat average stormwater runoff as a water quality measure.

Table 1: Stormwater volume reduction benefit for infiltration/storage beds

Rainfall Event	Benefits
1" Rainfall	Storage/infiltration beds typically store total runoff volume of a 1" rainfall and 1" of additional runoff conveyed from surrounding areas.
2-Year Storm	Storage/infiltration beds typically store total runoff volume of a 2-year storm and equal volume of runoff conveyed from surrounding areas.
Annual Precipitation	95% of annual precipitation in the Eastern U.S. occurs in storm events equal or less than the magnitude of a 2-year storm.

[2] Bruce K. Ferguson, *Stormwater Infiltration*, CRC Press, 1994, p. 177.

[3] Ibid.

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2. Pervious paving with infiltration/storage beds

Pervious pavement with a storage bed is composed of a water permeable pavement surface that is underlain by a storage bed filled with uniform aggregate for structural support. The stone bed provides a 40% void space for stormwater storage. The system assumes that the pavement surface is capable of infiltrating the total amount of rain during 95% of all rainfall events annually. It also assumes that a contiguous area of equal size can be conveyed to the bed and stored until the soil mantle infiltrates it. The infiltration rate should be such that the bed is drained before the next rainfall. For construction, assume an 18" bed of stone with 40% void space capable of storing and infiltrating 7.2" of stormwater runoff per square foot of pervious paving..

Pervious paving offers the potential for substantial volume reduction because of the location of possible bed sites and its extensive surface area.

Effective applications of pervious paving include:

- Locations where redevelopment is anticipated
- Surface parking lots: both new and retrofitted
- Hard surface recreation areas

3. Vegetated Roof Systems

Vegetated roofs are especially valuable in densely developed areas where cost and space constraints make surface stormwater best management practices impractical. Extensive vegetated roofs, which require only 1-4" of growth media, often do not require substantial structural changes to the roof design and can be planted with hardy groundcover species, such as sedums, that do not require a permanent irrigation system. Vegetated roofs can reduce both the volume and rate of stormwater runoff and have a variety of other benefits relating to energy efficiency, roof longevity, heat-island effects, aesthetics, site disturbance, property values, and sound transmission.

Table 2: Stormwater volume reduction benefit for extensive vegetated roofs

Rainfall Event	Benefits
1" Rainfall	An extensive vegetated roof stores runoff volume of a 1" rainfall and 0.7" of additional runoff conveyed from surrounding areas.
2-Year Storm	An extensive vegetated roof captures approximately 50% of a 2-year storm.
Annual Precipitation	Approximately 75% of the annual precipitation in the Eastern U.S. occurs in storm events equal or less than the magnitude of a 2-year storm.

Intensive vegetated roofs, also called roof gardens, require several feet of growth media to support a wider variety of vegetation than extensive vegetated roofs, including trees, shrubs, and grass. They require additional structural support in the roof design, but are also designed for building occupant use and provide additional recreational and aesthetic features for the facility. The stormwater benefits can be equal to or greater than an extensive vegetated roof but the cost per unit benefit is usually much higher (due to the presence of larger vegetation, pathways, maintenance requirements, growth media, structural support, etc.).

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Table 3: Stormwater volume reduction benefit for intensive vegetated roofs

Rainfall Event	Benefits
1" Rainfall	An intensive vegetated roof stores runoff volume of a 1" rainfall and 1.8" of additional runoff conveyed from surrounding areas.
2-Year Storm	An intensive vegetated roof captures approximately 75% of a 2-year storm.
Annual Precipitation	Approximately 90% of the annual precipitation in the Eastern U.S. occurs in storms equal to or less than the magnitude of a 2-year storm.

4. Rain gardens

A rain garden uses native plants and landscaping to soak up rain water (stormwater) that flows from downspouts or simply flows over land during a rain event. Rain gardens reduce the volume of run-off – through rainfall retention and storage – that enters storm drains immediately after a rain event. The first flush of stormwater run-off often contains the highest concentrations of non-point source pollutants that wash off of impervious surfaces. Rain gardens effectively capture and filter these pollutants, improving the quality of stormwater that reaches the municipal wastewater system.

Rain gardens can take many forms. The rain garden's distinguishing characteristic is the inclusion of a rainfall volume capture device within the planting bed. Rain gardens also slow the infiltration and evapotranspiration processes that plantings perform naturally. Areas of turf and/or planting beds that typically convey run-off via sheet flow to the stormwater infrastructure system are converted to dispersed shallow basins for small-scale storage and should be carefully designed to enhance the character of the existing landscape. Grading creates depressional areas that are strategically placed to intercept the first flush of run-off from adjacent impervious surfaces such as roofs, roads and parking lots.

Table 4: Stormwater volume reduction benefit for rain gardens

Rainfall Event	Benefits
1" Rainfall	A rain garden's soil medium has a moisture capacity of 15% of total soil volume, capable of storing total direct rainfall for a 1" storm.
2-Year Storm	A rain garden captures approximately 50% of a 2-year storm.
Annual Precipitation	Approximately 70% of annual precipitation in the Eastern U.S. occurs in storm events equal or less than the magnitude of a 2-year storm.

5. Tree trench

Continuous tree trenches are structured planting areas (typically 2.5' deep) that provide adequate growing space for tree roots and an opportunity to capture stormwater. Enhanced systems incorporate sub-surface storage that allows groundwater infiltration wherever soil and sub-surface utilities allow.

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Table 5: Stormwater volume reduction benefit for tree trenches

Rainfall Event	Benefits
1" Rainfall	A tree trench's soil medium has a moisture capacity of 15% of total soil volume, capable of storing total direct rainfall for a 1" storm.
2-Year Storm	A tree trench captures approximately 50% of a 2-year storm.
Annual Precipitation	Approximately 70% of annual precipitation in the Eastern U.S. occurs in storm events equal or less than the magnitude of a 2-year storm.

6. Runoff, capture and reuse

Runoff, capture and reuse systems collect rainfall in the immediate vicinity of impervious surfaces, store it onsite and use it in some fashion that can offset the use of treated potable water. Possible uses for reclaimed rainwater include: irrigation and non-potable process uses, such as mechanical and medical equipment cooling. Close to 100% of stormwater pollutants are removed through filtration and treatment prior to reuse, preventing direct conveyance of surface pollutants to receiving stream systems.

Table 6: Stormwater volume reduction benefit for runoff, capture & reuse

Rainfall Event	Benefits
1" Rainfall	A runoff, capture, reuse system stores total runoff volume for a 1" storm.
2-Year Storm	A runoff, capture, reuse system captures 50% of a 2- year storm.
Annual Precipitation	Approximately 70% of annual precipitation in the Eastern U.S. occurs in storm events equal to or less than the magnitude of a 2-year storm.

Benefits

Health

The use of fertilizer and pesticides in landscaping, and petroleum deposits from parking lots, can pollute local water systems if allowed to enter the stormwater sewer or regional waterways without prior filtration and treatment. In 2000, the U.S. EPA's National Water Quality Inventory Report found that 39% of river and stream miles, 45% of lake acres, and 51% of estuarine square miles did not meet the ambient water quality standards required by the Clean Water Act. Most of these pollutants are not removed during the water treatment process and enter the drinking water system essentially intact. Longer-term, low-level pesticide exposure has been linked to an array of chronic health problems including: cancer, birth defects, neurological, reproductive, and behavioral effects, and impaired immune system function.

Ecologic

Stormwater best management practices reduce the quantity and pollutant concentration of site runoff attributable to constructing impervious surfaces and structures. Conventional landscaping practices, such

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as extensive lawns, can lead to erosion and non point source contamination of regional waterways through the use of chemical pesticides and fertilizers. Related environmental benefits of low impact landscaping and stormwater best management practices include atmospheric reduction of CO_2, reduced evapotranspiration, and enriched habitat value.

Economic

While stormwater best management practices can increase a project's landscaping budget, they often reduce the overall civil budget by reducing or even eliminating the need to install on-site stormwater piping or connect to the municipal storm sewer. In many cases, best management practices lead to expedited environmental site assessments. They are also designed as low-maintenance landscaping features, reducing facility operations costs after project completion.

Case Study

Kaiser Permanente Modesto Medical Center, Modesto, CA

Kaiser Permanente, an integrated health care system operating in nine states and the District of Columbia, is very interested in improving the environmental footprint of their facilities' construction and operation. The changes they make generally impact the entire health system. As a result, they perform on-site testing and extensive cost analyses before approving changes to their standard procedures. By thinking outside of the general narrow interpretation of construction costs and by integrating the work of the civil engineer, the architect, and the owner early in the project, the project team was able to realize substantial cost savings.

One example of this methodology is the introduction of porous paving on Kaiser Permanente's Modesto project. Porous paving is concrete or asphalt with little or no fine aggregate. As a result, stormwater can filtrate into the site rather than being channeled into stormwater sewers that direct the water off the site. The foundation under the porous pavement filters out the pollutants in the stormwater, reducing the possibility of depleting the water table.

Porous pavement is not appropriate for all soil types or all climates. On Kaiser Permanente's Modesto project, the project team evaluated the project first and the life cycle cost of installing porous pavement, rather than treating it as a line item in the budget. They discovered that installing sufficient porous pavement on the site's impervious surfaces had a cascading effect. They installed porous pavement on the development's parking lots. Despite the fact that porous pavement costs more than traditional asphalt and concrete alternatives, the team found first cost savings through eliminating the fees associated with connecting to the municipal water system, avoiding the cost of installing an on-site stormwater piping system, and speeding up the environmental review of the project.

Resources

In addition to the resources noted in the Green Guide for Health Care, the following may offer additional guidance:

Almiñana, José and Theodore Eisenman. "LEED in the Landscape: Beyond the Box," *Environmental Design + Construction*, January 2003. http://www.edcmag.com

Dramstad, W. E., James D. Olson, and Richard T.T. Forman. *Landscape Ecology Principles in Landscape Architecture and Land Use Planning*. Harvard University, Graduate School of Design. Island Press, Washington, D.C., 1996.

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Elston, S. 2000 "Green Rooftop Technology Saves Energy, Cools Air." *Environmental News Network.* http://www.enn.com/news/enn-stories/2000/12/12302000/rooftops_40979.asp

Ferguson, Bruce, K. *Porous Pavements*. CRC Press, 2005.

Ferguson, Bruce, K. *Stormwater Infiltration*. CRC Press, 1994.

Forman, Richard T.T., and Michel Godron. *Landscape Ecology*. John Wiley & Sons. New York, NY, 1986.

Franklin, Carol, Teresa Durkin and Sara Pevaroff Schuh. "The Role of the Landscape in Creating A Sustainable Campus," *Planning for Higher Education* v. 31 (2003): p 142-149.

Green Building Rating System, Version 2.1. U.S. Green Building Council. Washington, D.C., November 2002.

"LEED-CS Pilot Precertification Submittal for Leigh Valley Cedar Crest East Medical Office Building." *Leigh Valley Hospital and Health Network*, October 10, 2005.

Leopold, A. *A Sand County Almanac*. Oxford University Press. New York, NY, 1949.

McHarg, I. *Design With Nature*. John Wiley & Sons, Inc. New York, NY, 1967.

Morelli, S. (leedinfo@usgbc.org). Email to T. Eisenman (eisenmant@andropogon.com), "Re: LEED Info," 20 May 2003.

Ndubisi, Forster. "Managing Change in the Landscape: A Synthesis of Approaches for Ecological Planning." *Landscape Journal*, Vol. 21, pp. 138-155. University of Wisconsin Press. Madison, WI, 2002.

Pennsylvania Stormwater Best Management Practices Manual. Pennsylvania Department of Environmental Protection, December 2006. www.dep.state.pa.us/dep/

Sorvig, Kim. From "LEEDing the Way," by Meg Calkins. *Landscape Architecture*. American Society of Landscape Architects. Washington, D.C., May 2001.

Thompson, William J., and Kim Sorvig. *Sustainable Landscape Construction*. Island Press, Washington, D.C, and Covelo, CA, 2000.

U.S. DOE. "Landscaping for Energy Efficiency." *Energy Efficiency and Renewable Energy Clearinghouse*, April 1995. DOE/GO-10095-046 FS 220.

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