Briefing Document: Small-Scale Green Infrastructure Best Management Practices

Executive Summary

This document provides a comprehensive synthesis of small-scale Green Infrastructure (GI) and its associated Best Management Practices (BMPs) for stormwater management. Green Infrastructure, also known as Nature-Based Solutions (NBSs) or Low Impact Development (LID), represents a paradigm shift from traditional "gray" infrastructure, which relies on pipes to dispose of rainwater. Instead, GI utilizes natural systems—vegetation, soil, and permeable surfaces—to manage stormwater at its source, mimicking the site's pre-developed hydrology. This approach yields multiple environmental and societal benefits, including flood mitigation, improved water and air quality, groundwater recharge, reduced urban heat, and the creation of recreational space.

The analysis delves into specific GI technologies, including rainwater harvesting systems like cisterns and rain barrels, green roofs, rain gardens (bioretention systems), and pervious paving. For each technology, the document outlines its function, design components, and performance data regarding runoff reduction, pollutant removal, and other benefits such as energy savings.

A significant portion of this briefing is dedicated to the regulatory framework established by the state of New Jersey. The New Jersey Stormwater Management Rules mandate the use of small-scale, distributed GI BMPs to meet standards for groundwater recharge, stormwater runoff quality, and quantity. The core compliance requirements stipulate that stormwater must be managed close to its source, BMPs must be distributed throughout a site, and specific contributory drainage area limitations must be met. Detailed tables outline the specific roles and performance metrics of various BMPs within this regulatory context, providing a clear guide to their application.

1. Foundational Concepts in Sustainable Stormwater Management

1.1. Nature-Based Solutions (NBSs)

Nature-Based Solutions are actions that leverage natural processes and features to address societal challenges while simultaneously enhancing human well-being and biodiversity. Also referred to as "green infrastructure" or "natural infrastructure," NBSs are founded on principles of place-specificity, evidence-based design, integration, equity, and transdisciplinarity.

Key Applications of NBSs:

- **Climate Change:** Mitigation and adaptation.
- **Flood Risk:** Reduction, particularly in coastal areas.

- **Water Quality:** Improvement through natural filtration.
- **Coastal Protection:** Protection of property and stabilization of shorelines.
- **Habitat:** Restoration and protection of wetlands.
- **Urban Environment:** Reduction of urban heat and addition of recreational space.

The International Union for Conservation of Nature (IUCN) framework illustrates that NBSs use ecosystem-based approaches (protection, management, restoration) to address societal challenges, resulting in benefits for both human well-being and biodiversity.

1.2. Green Infrastructure (GI)

Green Infrastructure is an approach that integrates natural processes into the built environment for stormwater management and other benefits. It contrasts with single-purpose gray stormwater infrastructure.

- **U.S. EPA Definition:** The U.S. Environmental Protection Agency (EPA) defines GI as an approach using vegetation and soil to manage rainwater where it falls, providing multiple benefits like flood mitigation and air quality management. The Water Infrastructure Improvement Act of 2019 specifies GI measures as those using natural systems to reduce stormwater runoff, including permeable surfaces, plant or soil systems, stormwater harvesting, and landscaping.
- **Broader Definition:** Also known as Blue-green infrastructure, this concept refers to a network designed to solve urban and climatic challenges by "building with nature." Its components address stormwater management, climate adaptation, heat stress, biodiversity, food production, air quality, and other anthropogenic functions like recreation.
- **New Jersey Definition:** The New Jersey Administrative Code (N.J.A.C. 7:8) defines GI as a stormwater management measure that manages stormwater close to its source by:
    1. Treating runoff through infiltration into subsoil.
    2. Treating runoff through filtration by vegetation or soil.
    3. Storing runoff for reuse.

1.3. Low Impact Development (LID)

Low Impact Development is a site planning and design approach that aims to reduce or prevent adverse runoff impacts. It seeks to preserve or closely mimic a site's natural hydrologic response to precipitation. Rather than treating runoff at a centralized facility, LID techniques interact with the rainfall-runoff process to control stormwater and pollutants closer to their source, promoting the concept of "designing with nature."

1.4. Stormwater Best Management Practices (BMPs)

Stormwater BMPs are a broad category of structural and non-structural measures employed to meet objectives for flood control, pollution reduction, and groundwater recharge.

2. Guiding Principles and Strategies

2.1. Core Objectives of LID and GI

The principles of Low Impact Development and Green Infrastructure share several fundamental goals aimed at sustainable land development and environmental protection:

- Maintain or restore natural hydrology.
- Manage stormwater as close to its source as possible.
- Minimize energy consumption and carbon emissions.
- Minimize secondary pollution.
- Minimize life-cycle costs.

2.2. New Jersey's Nine Nonstructural Stormwater Management Strategies

The New Jersey BMP Manual (February 2004) outlines nine key nonstructural strategies that form the basis for effective stormwater management design:

1. Protect areas providing water quality benefits or those susceptible to erosion.
2. Minimize impervious surfaces and disconnect the flow of runoff over them.
3. Maximize the protection of natural drainage features and vegetation.
4. Minimize the decrease in the pre-construction time of concentration.
5. Minimize land disturbance, including clearing and grading.
6. Minimize soil compaction.
7. Provide low-maintenance landscaping that encourages native vegetation and minimizes lawns, fertilizers, and pesticides.
8. Provide vegetated open-channel conveyance systems that discharge into stable vegetated areas.
9. Provide preventative source controls.

3. Technical Deep Dive into Key GI Technologies

A variety of small-scale measures are used to implement GI and LID principles. Common measures include amended soil, bioretention cells (rain gardens), cisterns and rain barrels, green roofs, planter boxes, pervious paving systems, grassed swales, and vegetative filter strips.

3.1. Rainwater Harvesting

Rainwater harvesting is the practice of collecting and storing rainwater for reuse. It can significantly reduce household demand for potable water; one source indicates it can cut consumption by half. Key methods include rain barrels, cisterns, green roofs, and rain gardens.

Rain Barrels and Cisterns

These systems collect runoff from roofs and other catchment areas, storing it for non-potable uses like irrigation. Cisterns are typically larger than rain barrels.

- **Yield:** A one-inch rainfall event on a 1,000-square-foot roof can yield approximately 600 gallons of water.
- **Challenges:** A 2009 study of systems in North Carolina by Jones & Hunt found that they were often underutilized. Potential reasons include negative public perception, under-informed personnel, suboptimal cistern location, changes in facility use, or inadequate storage capacity for homeowners.
- **Design:** Systems can be installed above ground (surface) or below ground (subsurface). Diagrams in the NJ BMP Manual show components like downspouts, first flush diverters, roof washers, and overflow connections.

3.2. Green Roofs

Green roofs are vegetated roof systems that provide significant stormwater management and energy benefits.

Construction and Types

A typical green roof consists of several layers: a vegetation layer, soil layer, webbing/geotextile filter, and drainage material, all installed over a waterproofed roof structure with a root barrier.

- **Extensive Green Roof:** Features a thin substrate layer (less than 6 inches) with low-level, drought-resistant plantings like Sedum.
- **Intensive Green Roof:** Has a deeper substrate layer (6 inches or more) that can support plants with deeper roots, including shrubs and trees.

Performance in Runoff Management

Green roofs substantially reduce the volume and peak flow of stormwater runoff compared to traditional impervious roofs.

- **Runoff Volume:** Data shows intensive green roofs have the lowest annual runoff (median ~25%), followed by extensive green roofs (~50%), gravel roofs (~75%), and traditional roofs (~85%).
- **Water Retention Factors:**
  - **Substrate:** Depth and type are primary influences.
  - **Slope:** Retention is greatest at the lowest slope (85%) and least at the highest slope (75%).
  - **Rainfall Intensity:** High-intensity rainfall is retained less effectively than low-intensity rain.
  - **Temperature:** Higher evapotranspiration in warmer seasons regenerates water-retaining capacity more quickly.

- **Runoff Quality Factors:** The quality of runoff from a green roof is influenced by numerous factors, including materials used, soil thickness, drainage type, maintenance chemicals, vegetation type, local pollution, and precipitation dynamics.

Energy Benefits

Green roofs act as insulators, reducing energy consumption for heating and cooling.

- **Summer Cooling:** They can reduce heat gain by 70-90% compared to a bare roof.
- **Winter Heating:** They can reduce heat loss by 10-30%.
- **Effectiveness:** These energy savings are most significant in older buildings with poor insulation.

3.3. Rain Gardens (Small-Scale Bioretention Systems)

Rain gardens are landscaped depressions planted with native shrubs, perennials, and flowers designed to temporarily hold and infiltrate runoff from impervious areas like roofs and driveways.

- **Groundwater Recharge:** Rain gardens can provide 30% more groundwater recharge than a conventional lawn.
- **Pollutant Removal:** They are highly effective at treating stormwater runoff. Studies have shown they can:
    - Remove up to 97% of E. Coli.
    - Remove the majority of Zinc in urban runoff.
- **Design:** A typical system includes an inflow area, an optional vegetative filter strip, a soil bed (18-24 inches deep, composed of 85-95% sand), an outlet control structure, and a connection to a downstream collection system.

3.4. Pervious Paving Systems

Also known as porous pavement, these systems allow stormwater to infiltrate through the surface into the ground below, reducing runoff. They typically consist of aggregates and a Portland cement binder.

- **Applications:**
    - Vehicular and pedestrian access
    - Parking lots
    - Bicycle and equestrian trails
    - Slope stabilization and erosion control
    - Land irrigation

4. Regulatory Framework: New Jersey Green Infrastructure Standards

The New Jersey Stormwater Management Rules (N.J.A.C. 7:8), amended in March 2020, mandate the use of GI to mimic the natural hydrologic cycle. Compliance requires satisfying standards for groundwater recharge, stormwater runoff quality, and quantity.

4.1. Core Requirements for Compliance

To meet the state's GI standards, a design must be assessed against three fundamental questions:

1. **Is the stormwater managed close to its source?**
2. **Are the BMPs distributed throughout the site?**
3. **Are the contributory drainage area limitations met?**

4.2. Maximum Contributory Drainage Area Limitations

To ensure BMPs are small-scale, the rules specify maximum drainage areas for several types of GI measures.

Best Management Practice	Maximum Contributory Drainage Area
Dry Well	1 acre
Manufactured Treatment Device	2.5 acres
Pervious Paving Systems	Area of additional inflow cannot exceed three times the area occupied by the BMP
Small-scale Bioretention Systems	2.5 acres
Small-scale Infiltration Basin	2.5 acres
Small-scale Sand Filter	2.5 acres

4.3. Performance and Role of BMPs in Meeting Standards

The New Jersey rules assign specific roles and performance capabilities to various BMPs, detailed in Tables 5-1, 5-2, and 5-3. The following table synthesizes this information for common practices.

Best Management Practice	Stormwater Runoff Quality TSS Removal Rate (%)	Addresses Stormwater Runoff Quantity?	Addresses Groundwater Recharge?	Minimum Separation from Seasonal High-Water Table (feet)
Blue Roof	0	Yes	No	N/A
Cistern	0	Yes	No	-
Dry Well(a)	0	No	Yes	2
Extended Detention Basin	40-60	Yes	No	1
Grass Swale	50 or less	No	No	2(e) or 1(f)
Green Roof	0	Yes	No	-
Manufactured Treatment Device(g)	50 or 80	No	No	Dependent upon device
Pervious Paving System(a)	80	Yes	Yes(b) / No(c)	2(b) or 1(c)
Small-Scale Bioretention Basin(a)	80 or 90	Yes	Yes(b) / No(c)	2(b) or 1(c)
Small-Scale Infiltration Basin(a)	80	Yes	Yes	2
Small-Scale Sand Filter(a), (b)	80	Yes	Yes	2
Standard Constructed Wetland	90	Yes	No	N/A
Vegetative Filter Strip	60-80	No	No	-
Wet Pond(d)	50-90	Yes	No	N/A

Notes:

- (a) Subject to the applicable contributory drainage area limitation specified at N.J.A.C. 7:8-5.3(b).
- (b) Designed to infiltrate into the subsoil.
- (c) Designed with underdrains.
- (d) Designed to maintain at least a 10-foot wide area of native vegetation along at least 50 percent of the shoreline and to include a stormwater runoff retention component for reuse.
- (e) Designed with a slope of less than two percent.
- (f) Designed with a slope of equal to or greater than two percent.
- (g) Manufactured treatment devices that meet the definition of green infrastructure at N.J.A.C. 7:8-1.2.