Briefing: Large-Scale Green and Non-Green Infrastructure for Stormwater Management

Executive Summary

This document provides a comprehensive analysis of large-scale Green Infrastructure (GI) and non-GI Best Management Practices (BMPs) for stormwater management, based on New Jersey's regulatory framework. The central theme is the strategic selection and design of BMPs to satisfy state standards for groundwater recharge, stormwater runoff quality, and stormwater runoff quantity. A clear distinction is made between GI solutions, which mimic natural hydrology, and non-GI or traditional engineered systems.

Key takeaways include:

- **Regulatory Hierarchy:** New Jersey Stormwater Management Rules (amended July 2023) mandate the use of GI BMPs (listed in Table 5-1) to meet groundwater recharge and runoff quality standards. Non-GI BMPs (Table 5-3) are only permissible if a variance or waiver is granted.
- **Dominant BMP Types:** The document provides detailed examinations of critical BMPs, including bioretention systems, constructed wetlands, extended detention basins, and various Manufactured Treatment Devices (MTDs).
- **Bioretention Systems:** These are a cornerstone of GI strategy, designed either with underdrains for filtration or without for infiltration. Their design is governed by specific parameters for soil media, ponding depth, and separation from the water table.
- **Manufactured Treatment Devices (MTDs):** MTDs are essential for space-constrained projects. New Jersey maintains a rigorous certification program categorizing MTDs as either GI or non-GI based on their treatment mechanism. As of July 2023, sizing calculations for MTDs must use NRCS methodology, replacing the Rational Method.
- **Performance-Based Design:** BMP selection is dictated by performance metrics, primarily Total Suspended Solids (TSS) removal rates. Certified GI MTDs uniformly achieve an 80% TSS removal rate, while non-GI systems vary between 50% and 80%.
- **Sizing and Engineering:** Stormwater BMP design is a technical process driven by hydrologic calculations based on a specific design storm—in New Jersey, the Water Quality Design Storm is 1.25 inches of rainfall over two hours.

Regulatory Framework for Stormwater BMPs in New Jersey

The New Jersey Stormwater Management Rules, amended in July 2023, establish a clear framework for how design engineers must address stormwater management for new developments. The rules prioritize the use of Green Infrastructure to manage groundwater recharge, stormwater runoff quality, and stormwater runoff quantity.

Core Requirements

- **Groundwater Recharge and Runoff Quality (N.J.A.C. 7:8-5.4 and 5.5):** To meet these standards, design engineers are required to utilize GI BMPs as identified in Table 5-1 or an approved alternative measure.
- **Stormwater Runoff Quantity (N.J.A.C. 7:8-5.6):** To satisfy runoff quantity standards, engineers may use BMPs from Table 5-1, Table 5-2, and/or an approved alternative.
- **Waivers and Variances:** If a project is granted a waiver or variance from the strict GI requirements, BMPs from Tables 5-1, 5-2, or 5-3 may be used to meet all three standards (recharge, quality, and quantity).

Maximum Contributory Drainage Area Limitations

Certain Green Infrastructure BMPs are subject to limitations on the maximum drainage area they can serve:

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

Classification and Performance of Stormwater BMPs

The New Jersey regulations classify BMPs into three tables based on their infrastructure type (primarily GI vs. non-GI) and their role in the compliance hierarchy. Performance is primarily measured by the percentage of Total Suspended Solids (TSS) removed and the ability to manage quantity and promote recharge.

Table 5-1: Green Infrastructure BMPs for Standard Compliance

These BMPs are the primary tools for meeting groundwater recharge and stormwater quality standards without a variance.

Best Management Practice	Stormwater Runoff Quality TSS removal rate (percent)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum separation from seasonal high-water table (feet)
Cistern	0	Yes	No	-
Dry Well[a]	0	No	Yes	2
Grass Swale	50 or less	No	No	2[e] or 1[f]
Green Roof	0	Yes	No	-
Manufactured Treatment Device[a] [g]	50 or 80	No	No	Dependent upon the device
Pervious Paving System[a]	80	Yes	Yes[b] or No[c]	2[b] or 1[c]
Small-Scale Bioretention Basin[a]	80 or 90	Yes	Yes[b] or No[c]	2[b] or 1[c]
Small-Scale Infiltration Basin[a]	80	Yes	Yes	2
Small-Scale Sand Filter	80	Yes	Yes	2
Vegetative Filter Strip	60-80	No	No	-

Table 5-2: Green Infrastructure BMPs for Stormwater Runoff Quantity

These GI BMPs are approved to meet stormwater quantity standards. They can also be used for recharge and quality if a waiver or variance is obtained.

Best Management Practice	Stormwater Runoff Quality TSS removal rate (percent)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum separation from seasonal high-water table (feet)
Bioretention System	80 or 90	Yes	Yes[b] or No[c]	2[b] or 1[c]
Infiltration Basin	80	Yes	Yes	2
Sand Filter[b]	80	Yes	Yes	2
Standard Constructed Wetland	90	Yes	No	N/A
Wet Pond[d]	50-90	Yes	No	N/A

Table 5-3: BMPs Permissible Only with a Waiver or Variance

These BMPs, largely non-GI, may only be used to satisfy recharge, quality, and quantity standards if a waiver or variance from the GI requirements is granted.

Best Management Practice	Stormwater Runoff Quality TSS removal rate (percent)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum separation from seasonal high-water table (feet)
Blue Roof	0	Yes	No	N/A
Extended Detention Basin	40-60	Yes	No	1
Manufactured Treatment Device(h)	50 or 80	No	No	Dependent upon the device
Sand Filter(c)	80	No	No	1
Subsurface Gravel Wetland	90	No	No	1
Wet Pond	50-90	Yes	No	N/A

Key Design Notes and Definitions

- **(a)** Subject to the applicable contributory drainage area limitations.
- **(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% of the shoreline and to include a retention component for beneficial reuse (e.g., irrigation).
- **(e)** Designed with a slope of less than 2%.
- **(f)** Designed with a slope of equal to or greater than 2%.
- **(g)** MTDs that meet the definition of green infrastructure at N.J.A.C. 7:8-1.2.
- **(h)** MTDs that do not meet the definition of green infrastructure.

In-Depth Analysis of Key BMP Categories

Bioretention Systems

Bioretention systems are shallow, landscaped depressions that manage stormwater runoff through filtration and infiltration. They are highly effective at managing recharge, water quality, and quantity. Real-world examples are shown in place at Rutgers University's Busch Campus.

Primary Types:

- **Bioretention System with Infiltration:** Designed without an underdrain to maximize groundwater recharge. It requires a minimum separation of 2 feet from the seasonal high water table (SHWT). Filter fabric is used on the sides only to allow infiltration into the undisturbed subsoil.

- **Bioretention System with Underdrain:** Uses a perforated pipe system within a gravel layer to collect and discharge filtered water. This design is used when infiltration is not feasible and requires only a 1-foot separation from the SHWT. Filter fabric encloses the gravel layer at the sides and bottom.

Key Design Components:

- **Soil Planting Bed:** Minimum depth of 18-24 inches. Composed of 85-95% sands, ≤15% silt and clay, and amended with 3-7% organics.
- **Runoff Depth:** Designed to handle a maximum runoff depth of 12 inches (18 inches for linear systems).
- **Layers:** Typically includes an optional mulch layer, the main soil bed, a 6-inch thick sand layer, and a gravel layer housing the underdrain network.
- **Outlet Structure:** An outlet control structure with a trash rack manages the discharge of treated water.

Sizing Methodology for Bioretention Systems: A Case Study

The technical approach to sizing BMPs involves hydrologic calculations to determine runoff volume, which then informs the design.

- **Sizing Principle:** The bottom area of a bioretention basin is sized based on the volume of stormwater runoff that needs to be treated.
- **Design Storm:** The New Jersey Water Quality Design Storm (NJWQDS) is defined as **1.25 inches** of rainfall non-uniformly distributed over 2 hours.

Calculation Example:

1. **Given Parameters:**
    - Regulated motor vehicle surface area: **1.2 acres**
    - Runoff coefficient (conservative): **1.0**
    - Maximum ponding depth (distance from basin bottom to lowest outlet orifice): **6 inches**
    - Measured filter media permeability: **4.0 inches/hour**
    - Required safety factor: **2**
2. **Calculate Runoff Volume (V):**
    - V = Rainfall Depth x Runoff Coefficient x Surface Area
    - V = 1.25 inches x 1.0 x 1.2 acres = 1.5 inch-acres
    - V = (1.25 in / 12 in/ft) x (1.2 acres x 43,560 sq ft/acre) = **5,450 cubic feet**
3. **Calculate Required Bottom Area (A):**
    - A = Runoff Volume / Maximum Ponding Depth
    - A = 5,450 cubic ft / (6 inches / 12 in/ft) = **10,900 sq ft** (or 0.25 acres)
4. **Calculate Water Ponding Time (T):**
    - T = Max Ponding Depth / (Measured Permeability / Safety Factor)

- T = 6 inches / (4 inches/hr / 2) = **3 hours**

5. **Conclusion:** The calculated ponding time of 3 hours is well below the maximum allowable time of 72 hours, making the 0.25-acre bottom area acceptable.

Constructed Wetlands

Constructed wetlands are engineered systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to treat stormwater.

Wetland Type	Minimum Required Drainage Area	Key Water Depth Criteria
Pond / Marsh	25 Acres	High Marsh: Max 6 inches; Low Marsh: 6-18 inches; Pool: 4-6 feet
Extended Detention	10 Acres	High Marsh: Max 6 inches; Low Marsh: 6-18 inches; Pool: 4-6 feet; Semi-Wet Zone: Inundated only during storm events

All types share common features like a forebay for initial sediment settling, an outlet riser, an emergency spillway, and a minimum length-to-width ratio of 1:1.

Extended Detention Basins

These basins are primarily designed for stormwater quantity control. They temporarily detain runoff and release it slowly through a multi-stage outlet structure. They provide a moderate water quality benefit, with TSS removal rates increasing with detention time, ranging from approximately **40% for a 12-hour detention to 60% for a 24-hour detention**.

Subsurface Gravel Wetlands

This specialized wetland design is engineered to enhance nitrogen removal. It features a lower anaerobic gravel layer that promotes denitrification by microbes. The system often includes multiple gravel cells and a pre-treatment zone to optimize this process.

Manufactured Treatment Devices (MTDs)

MTDs are proprietary, engineered systems used to treat stormwater runoff, often installed underground. They are critical for redevelopment projects and in densely populated areas like New Jersey where space is limited. The state has certified approximately 20 MTDs through a suite of laboratory and field testing protocols.

Main Categories:

1. **Hydrodynamic Separators:** Use vortex motion and gravity to separate solids.

2. **Media Filters:** Pass stormwater through a filter media (e.g., sand, specialized sorbents) to remove pollutants.
3. **Retention/Detention/Recharge Chambers:** Underground systems for storage or infiltration.

Regulatory Guidance for MTDs

- **Green Infrastructure (GI) MTDs:** To be classified as GI, an MTD must: (1) infiltrate stormwater into the subsoil, and/or (2) treat stormwater through filtration by vegetation or soil. GI MTDs can be configured as tree boxes, planter boxes, or vaults that infiltrate into the subsoil below.
- **Sizing Calculation (Effective July 17, 2023):** The Rational Method can no longer be used for sizing MTDs. The Natural Resources Conservation Service (NRCS) methodology must now be used.
- **Certified TSS Removal:** Certified GI MTDs achieve an **80% TSS removal rate**. MTDs not considered GI have certified rates of either **50% or 80%**.

Principles of Hydrodynamic Separation

Many hydrodynamic separators leverage the principle of secondary currents found in meandering channels. In a curved channel, a transverse flow develops near the bed that moves from the outer bank toward the inner bank. This causes sediment to be transported and deposited at the inner bank. This fluid dynamics principle was famously applied in the **DuJiangYan Water Diversion Project in China, built in 256 BC**, which effectively separates sediment from water and is still functioning today.

MTD Maintenance

Regular maintenance is crucial for the effective operation of MTDs. Accumulated solids, trash, and debris must be removed periodically. This is typically done using vacuum trucks to clean out the internal chambers of the underground devices.

Advanced Stormwater Treatment Techniques

Enhancing Nitrogen Removal

Research is underway to improve the nitrogen removal capabilities of stormwater treatment facilities. One promising technique involves amending bioretention cells with biochar and "training" microbes, such as ***Geobacter metallireducens***, to remove nitrate from runoff. Experimental results show that under biotic, bio-reduced conditions, nitrate concentrations in test samples dropped from over 4.0 mM to near-zero in approximately 48-72 hours, a significantly faster and more complete removal than in other test conditions.