New Jersey Stormwater Best Management Practices Manual

February 2009

CHAPTER 9.1

Bioretention Systems

Definition

A bioretention system consists of a soil bed planted with suitable non-invasive (preferably native) vegetation. Stormwater runoff entering the bioretention system is filtered through the soil planting bed before being either conveyed downstream by an underdrain system or infiltrated into the existing subsoil below the soil bed. Vegetation in the soil planting bed provides uptake of pollutants and runoff and helps maintain the pores and associated infiltration rates of the soil in the bed.

A bioretention system can be configured as either a bioretention basin or a longer, narrower bioretention swale. In general, a bioretention basin has a flat bottom while a bioretention swale may have sloping bottom. Runoff storage depths above the soil bed surface are typically shallow. The TSS removal rate for bioretention systems is 80 or 90 percent, depending upon the thickness of the soil planting bed and the type of vegetation grown in the bed.

Purpose

Bioretention systems are used to remove a wide range of pollutants, such as suspended solids, nutrients, metals, hydrocarbons, and bacteria from stormwater runoff. They can also be used to reduce peak runoff rates and increase stormwater infiltration when designed as a multi-stage, multi-function facility.

Conditions Where Practice Applies

Bioretention systems can be used to filter the runoff from both residential and nonresidential developments. Concentrated inflow from a drainage pipe or swale must include adequate erosion protection and energy dissipation measures.

Bioretention systems are most effective when they receive runoff as close to its source as possible. They can vary in size and can receive and treat runoff from a variety of drainage areas within a land development site. They can be installed in lawns, median strips, parking lot islands, unused lot areas, and certain easements. They are intended to receive and filter storm runoff from both impervious areas and lawns.

A bioretention system must not be placed into operation until the contributing drainage area is completely stabilized. Therefore, system construction must either be delayed or upstream runoff diverted around the system until such stabilization is achieved. Such diversions must continue until stabilization is achieved. Additional information is provided in the section on Recommendations and Considerations.

The elevation of the Seasonal High Water Table (SHWT) relative to the bottom of a bioretention system is critical to ensure proper functioning of the system. As shown in Figure 9.1-2, the SHWT shall be at least 1 foot below the bottom of a bioretention system's underdrain system. For bioretention systems without underdrains, the SHWT shall be at least 2 foot below the bottom of the soil planting bed. In addition, it is important that the permeability of the existing subsoil below such bioretention systems is sufficient to convey the runoff passing through the soil planting bed. See *9.5 Standards for Infiltration Basins* for more information on the requirements and design of this type of bioretention system.

Finally, a bioretention system must have a maintenance plan and, if privately owned, shall be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

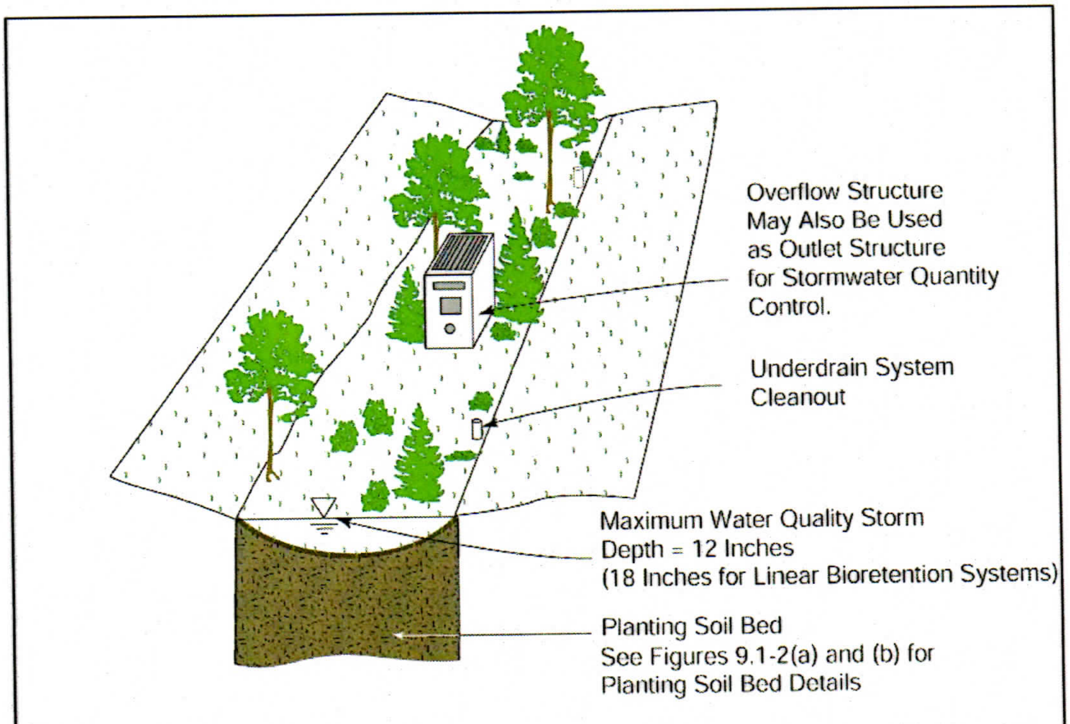
The basic design parameters for bioretention systems are its storage volume, the thickness, character, and permeability rate of its planting soil bed, and either the hydraulic capacity of its underdrain or the permeability of its subsoil (whichever is applicable). The system must have sufficient storage volume above the surface of the bed to contain the design storm runoff volume without overflow. The thickness and character of the bed itself must provide adequate pollutant removal, while the bed's permeability rate must be sufficient to drain the stored runoff within 72 hours. In addition, depending upon the type of bioretention system, either the capacity of the underdrain or the permeability of the existing subsoil must also be sufficient to allow the system to drain within 72 hours. Details of these and other design parameters are presented below. The components of typical bioretention systems are shown in Figure 9.1-1 and 9.1-2.

A. Storage Volume, Depth, and Duration

Bioretention systems shall be designed to treat, and discharge the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes.* The maximum water depth during the treatment of the stormwater quality design storm runoff volume shall be 12 inches in a flat-bottomed bioretention system and 18 inches at the deepest end of a sloped-bottom bioretention system. The minimum diameter of any overflow orifice is 2.5 inches.

As shown in Figure 9.1-2, the bottom of a bioretention system with an underdrain must be a minimum of 1 foot above the seasonal high groundwater table (SHWT). This includes the underdrain piping and gravel underdrain layer. For a bioretention system without an underdrain, the SHWT must be at least 2 foot below the bottom of the system's soil planting bed. As noted above, the planting soil bed and either the underdrain system or

Figure 9.1-1: Bioretention Basin Schematic



Source: Adapted from Claytor and Schueler, 1996.

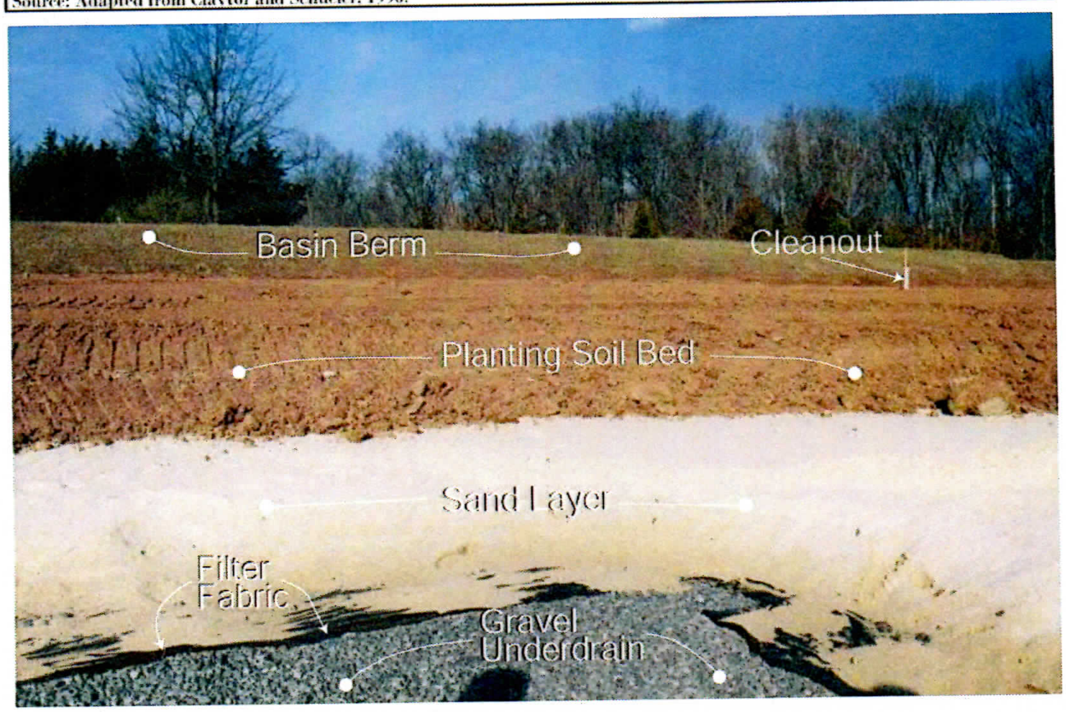
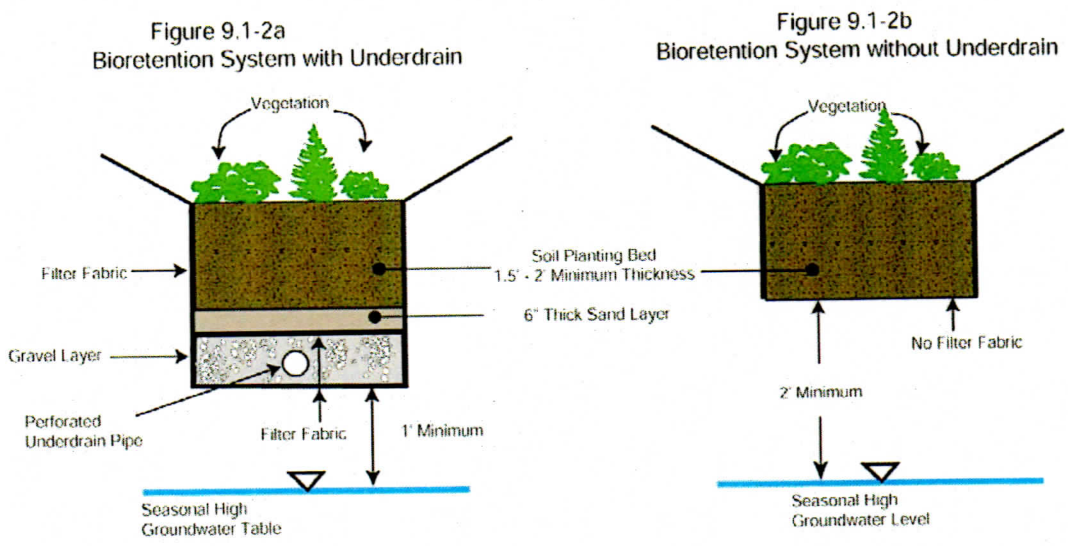


Figure 9.1-2: Bioretention System Details



existing subsoil below the soil planting bed shall be designed to fully drain the stormwater quality design storm runoff volume within 72 hours.

B. Permeability Rates

The design permeability rate through the planting soil bed must be sufficient to fully drain the stormwater quality design storm runoff volume within 72 hours. This permeability rate must be determined by field and/or laboratory testing. Since the actual permeability rate may vary from test results and may also decrease over time due to soil bed consolidation or the accumulation of sediments removed from the treated stormwater, a factor of safety of two shall be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soil bed material is 4 inches/hour, the design rate would be 2 inches/hour (i.e., 4 inches per hour/2). This design rate would then be used to compute the system's stormwater quality design storm drain time. The maximum allowable design permeability shall be 10 inches/hour for any permeability at 20 inches/hour or greater.

C. Planting Soil Bed

The planting soil bed provides the environment for water and nutrients to be made available to the vegetation. The soil particles can adsorb some additional pollutants through cation exchange, and voids within the soil particles can store a portion of the stormwater quality design storm runoff volume. The planting soil bed material should consist of the following mix, by weight: 85 to 95 percent sands, with no more than 25% of the sands as fine or very fine sands; no more than 15% silt and clay with 2% to 5% clay content. The entire mix shall then be amended with 3 to 7% organics. The mix must be certified by either the vendor who premixes the soil or by a professional engineer licensed by the State of New Jersey present during any onsite soil material mixing. The material's pH should range from 5.5 to 6.5. The material shall be placed in 12 to 18 inch lifts. Additional material may be necessary to account for the subsequent settling of the material over time.

The TSS removal rate of a bioretention system will depend upon the thickness of the soil planting bed and the type of vegetation grown in the bed. The various bed thicknesses, vegetation types, and associated TSS removal rates are shown in Table 9.1-1.

Table 9.1-1: Bioretention System Removal Rates		
TSS Removal Rate	**Thickness of Soil Planting Bed**	**Bioretention Vegetation**
80%	1.5 Feet	Terrestrial Forested Community
80%	2.0 Feet	Site-Tolerant Grasses
90%	2.0 Feet	Terrestrial Forested Community

As noted above, the design permeability rate of the soil bed material must be sufficient to drain the stormwater quality design storm runoff volume within 72 hours. Filter fabric should be placed along the sides of the planting soil bed to prevent the migration of soil particles from the adjacent soil into the planting soil bed. Filter fabric should not be placed at the bottom of the soil planting bed in a bioretention system that does not have an underdrain since the filter fabric may cause a layer of fines to collect on the fabric and result in a loss of permeability.

D. Vegetation

The vegetation in a bioretention system removes some of the nutrients and other pollutants in the stormwater inflow. The environment around the root systems breaks down some pollutants and converts others to less harmful compounds. The use of native plant material is recommended for bioretention systems wherever possible. The goal of the planting plan should be to simulate a forest-shrub community of primarily upland type. As there will be various wetness zones within a well-designed and constructed bioretention system, plants must be selected and placed appropriately. In general, trees should dominate the perimeter zone that is subject to less frequent inundation. Shrubs and herbaceous species that are adapted to moister conditions and expected pollutant loads should be selected for the wetter zones. The number of stems per acre should average 1,000 with tree spacing of 12 feet and shrub spacing of 8 feet.

Site-tolerant grasses may also be utilized in a bioretention system. Such grasses may facilitate system construction and maintenance but will receive a lower TSS removal rate. Care must be taken to ensure that mowing and other maintenance of these grasses are performed by lightweight equipment to prevent the compaction of the soil planting bed material.

Please refer to *Part 4 – Bioretention* of *Chapter 7 – Landscaping* for additional details and guidance on vegetation for bioretention systems.

E. Sand Layer

The sand layer serves as a transition between the planting soil bed and the gravel layer and underdrain pipes. It must have a minimum thickness of 6 inches and consist of clean medium aggregate concrete sand (AASSHTO M-6/ASTM C-33). To ensure proper system operation, the sand layer must have a permeability rate at least twice as fast as the design permeability rate of the planting soil bed.

F. Gravel Layer and Underdrain

The gravel layer serves as bedding material and conveyance medium for the underdrain pipes. It must have sufficient thickness to provide a minimum of 3 inches of gravel above and below the pipes. It should consist of 0.5 to 1.5 inch clean broken stone or pea gravel (AASHTO M-43).

Underdrain piping beneath the soil planting bed and sand layer must be perforated. All remaining underdrain piping, including cleanouts, must be non-perforated. All joints must be secure and watertight. Cleanouts must be located at the upstream and downstream ends of the perforated section of the underdrain and extend above the surface of the planting soil bed. Additional cleanouts should be installed as needed, particularly at underdrain pipe bends and connections. Cleanouts can also serve to drain standing water stored above clogged or malfunctioning planting soil beds. If the cleanout serves to drain standing water, care should be taken to prevent debris from entering the cleanout.

The underdrain piping must connect to a downstream storm sewer manhole, catch basin, channel, swale, or ground surface at a location that is not subject to blockage by debris or sediment and is readily accessible for inspection and maintenance. Blind connections to downstream storm sewers are prohibited. To ensure proper system operation, the gravel layer and perforated underdrain piping must have a conveyance rate at least twice as fast as the design permeability rate of the sand layer.

G. Inflows

To provide pretreatment, the stormwater inflow to a bioretention system should occur as a sheet flow across vegetation where it can be demonstrated that such flow is stable in accordance with Vegetative Filters criteria described in Chapter 9.10 and the Standards for Soil Erosion and Sediment Control in New Jersey. Stone strips or aprons may be used at the downstream edge of upstream impervious surfaces to further dissipate sheet flow velocities and flow patterns. Where the inflow cannot be designed as stable sheet flow, the use of structural conveyance measures such as concrete chute, pipe, mats or other similar method should be used. All points of inflow to a bioretention system must have adequate erosion protection measures designed in accordance with the Standards for Soil Erosion and Sediment Control in New Jersey.

H. Overflows

All bioretention systems must be able to safely convey system overflows to the downstream drainage systems. The capacity of the overflow must be consistent with the remainder of the site's drainage system and sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Bioretention systems classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards. Overflow capacity can be provided by a hydraulic structure such as a drain inlet, weir, or catch basin, or a surface feature such as a swale or open channel as site conditions allow. See Chapter 9.4: Standard for Extended Detention Basins for details of outflow and overflow structures in multi-purpose bioretention systems that also provide stormwater quantity control.

I. Tailwater

The hydraulic design of the underdrain and overflow systems, as well as any stormwater quantity control outlets, must consider any significant tailwater effects of downstream waterways, conveyance systems, or other stormwater management facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood or tide elevation in a downstream waterway or storm sewer system.

J. On-line and Off-line Systems

Bioretention systems may be constructed on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an overflow. Multi-purpose on-line systems also store and attenuate these larger storms to provide runoff quantity control. In such systems, the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface. In off-line bioretention systems, most or all of the runoff from storms larger than the stormwater quality design storm bypasses the system through an upstream diversion. This not only reduces the size of the required system storage volume, but also reduces the system's long-term pollutant loading and associated maintenance. Please note that the volume below the lowest outlet in a bioretention system may not be used for runoff storage for the purpose of complying with the Standards for Soil Erosion and Sediment Control in New Jersey. The system designer should contact the local Soil Conservation District for additional guidance.

Maintenance

Effective bioretention system performance requires regular and effective maintenance. Chapter 8: Maintenance and Retrofit of Stormwater Management Measures provides information and requirements for preparing a maintenance plan for stormwater management facilities, including bioretention systems. Specific maintenance requirements for bioretention systems are presented below. These requirements must be included in the system's maintenance plan.

A. General Maintenance

All bioretention system components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually as well as after every storm exceeding 1 inch of rainfall. Such components may include bottoms, trash racks, low flow channels, outlet structures, riprap or gabion aprons, and cleanouts.

Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass outside of the bioretention system should be mowed at least once a month during the growing season. Grasses within the bioretention system must be carefully maintained so as not to compact the soil, and through hand-held equipment, such as a hand held line trimmer. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover should be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the bioretention system. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

C. Structural Components

All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume below the ground surface in the bioretention system. This normal drain time should then be used to evaluate the system's actual performance. If significant increases or decreases in the normal drain time are observed or if the 72 hour maximum is exceeded, the system's planting soil bed, underdrain system, and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the system.

The planting soil bed at the bottom of the system should be inspected at least twice annually. The permeability rate of the soil bed material may also be retested. If the water fails to infiltrate 72 hours after the end of the storm, corrective measures must be taken.

Considerations

A. Optional Surface Mulch Layer

The mulch layer on the surface of the planting soil bed provides an environment for plant growth by maintaining moisture, providing microorganisms, and decomposing incoming organic matter. The mulch layer may also act as a filter for finer particles still in suspension and maintain an environment for the microbial community to help break down urban runoff pollutants. Care must be taken to ensure that the mulch layer does reduce the design permeability rate of the surface. The mulch layer should consist of standard 1 to 2 inch shredded hardwood or chips. It should be applied to a depth of 2 to 4 inches and replenished as necessary. However, prior to utilizing a mulch layer, consideration should be given to problems caused by scour and floatation during storm events and the potential for mosquito breeding.

Recommendations and Considerations

A. Site Considerations

The planning of a bioretention system should consider the topography and geologic and ecological characteristics of both the proposed system site and contiguous areas. Bioretention systems should not be planned in areas where mature trees would have to be removed or where Karst topography is present.

B. Construction

During basin construction, precautions must be taken to prevent planting soil bed compaction by construction equipment and sediment contamination by runoff. Basin excavation and planting soil placement should be performed with equipment placed outside the basin bottom whenever possible. Light earth moving equipment with oversized tires or tracks should be utilized when the basin must be entered.

Bioretention systems are susceptible to clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Therefore, using a bioretention system site for construction sediment control is discouraged. When unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the basin bottom. Sediment can then accumulate and be removed during site construction without disturbing the final basin bottom, which should be established only after all other construction within its drainage area is completed and the drainage area stabilized. If basin construction cannot be delayed until then and the basin will not be used for sediment control, diversion berms should be placed around the basin's perimeter during all phases of construction to divert all sediment and runoff completely away from the basin. These berms should not be removed until all construction within the basin's drainage area is completed and the area stabilized.

To prevent compaction of the soil below the basin that will reduce its infiltration capacity, bioretention-infiltration basins should be excavated with light earth moving equipment, preferably with tracks or over-sized tires located outside the basin bottom. Once the basin's final construction phase is reached, the floor of the basin must be deeply tilled with a rotary tiller or disc harrow and smoothed over with a leveling drag or equivalent grading equipment.

Upon stabilization of the bioretention systems and its drainage area, the infiltration rate of the planting soil bed must be retested to ensure that the rate assumed in the computations is provided at the basin. The permeability rate of the subsoil below the basin must also be retested after construction at bioretention systems that utilize infiltration rather than an underdrain system.

C. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a bioretention system. Pretreatment can capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filter, a forebay, or a manufactured treatment device. Information on vegetative filters and manufactured treatment devices is presented in Chapters 9.10 and 9.6, respectively.

Forebays can be included at the inflow points to a bioretention system to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay is typically 10% of the Water Quality Design Storm runoff volume and should be sized to hold the sediment volume expected between clean-outs.

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