CHAPTER 4

Stormwater Pollutant Removal Criteria

This chapter presents the criteria and methodologies necessary to determine the pollutant removal rates of stormwater management measures used individually and in series to meet the stormwater quality requirements of the Stormwater Management Rules at N.J.A.C. 7:8. According to these Rules, a "major development" project that creates at least 0.25 acres of new or additional impervious surface must include stormwater management measures that reduce the average annual total suspended solids (TSS) load in the development site's post-construction runoff by 80 percent. This 80 percent requirement has been based, in part, upon Section 6217(g) of the 1990 Coastal Zone Management Act Reauthorization Amendments as enforced by the U.S. Environmental Protection Agency. In addition, these stormwater management measures must reduce the average annual nutrient load in the post-construction runoff by the maximum extent feasible. This requirement has been included in the Stormwater Management Rules because nutrients, consisting primarily of various forms of nitrogen and phosphorous, are recognized as a major class of stormwater pollutants from land development.

The stormwater management measures used to reduce the average annual TSS and nutrient loads can be structural and/or nonstructural in nature. To achieve the reduction requirements, they must be designed to treat the runoff from the stormwater quality design storm, a 1.25-inch/2-hour variable rate rainfall event. Details of the stormwater quality design storm are presented in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Details of nonstructural and structural stormwater management measures, also known as Best Management Practices (BMPs), are presented respectively in *Chapter 2: Low Impact Development Techniques* and *Chapter 9: Structural Stormwater Management Measures*.

TSS Removal Rates for Individual BMPs

As noted above, the Stormwater Management Rules require an 80 percent TSS reduction in the post-construction runoff from a land development site that increases impervious surface by 0.25 acres or more. This reduction is to be achieved by conveying the site's runoff through one or more onsite BMPs that have the ability to remove a portion of the TSS load. To demonstrate compliance with this requirement, the NJDEP has adopted official TSS removal rates for each of the BMPs described in detail in Chapter 9. These BMPs and their adopted TSS removal rates are presented below in Table 4-1. Different removal rates and BMPs may be utilized if supporting information is provided and accepted by the applicable review agencies.

It is important to note that the TSS removal rates shown in Table 4-1 have been based upon several sources of BMP research and monitoring data as well as consultation with numerous stormwater management experts. As demonstrated by that research, actual TSS removals at specific BMPs during specific storm events will depend upon a number of site factors and can be highly variable. As such, the TSS removal rates presented in Table 4-1 are considered representative values that are based upon a recognition of this variability and the state's need to develop and implement a statewide stormwater management program. Furthermore, the TSS removal rates are also considered to accurately represent the relative TSS removal efficiencies of the various BMPs listed in the table.

Table 4-1: TSS Removal Rates for BMPs

Best Management Practice (BMP)	Adopted TSS Removal Rate (%)
Bioretention System	90
Constructed Stormwater Wetland	90
Dry Well	Volume Reduction Only[1]
Extended Detention Basin	40 to 60[2]
Infiltration Structure	80
Manufactured Treatment Device	See N.J.A.C. 7:8-5.7(d)[3]
Pervious Paving System	Volume Reduction Or 80[4]
Sand Filter	80
Vegetative Filter	60-80
Wet Pond	50-90[5]

[1] See text below.
[2] Final rate based upon detention time. See Chapter 9.
[3] To be determined through testing on a case-by-case basis. See text below.
[4] If system includes a runoff storage bed that functions as an infiltration basin. See Chapter 9.
[5] Final rate based upon pool volume and detention time. See Chapter 9.

As shown in Table 4-1, a dry well and certain types of pervious paving do not have an adopted TSS removal rate. This is due to the fact that, as described in Chapter 9, a dry well is intended to infiltrate runoff only from a roof and other impervious area with minimal TSS loading. A pervious paving system without a runoff storage bed can reduce the runoff volume from standard paving, but is not used to treat runoff from other impervious areas. As such, these systems are not considered to be effective in reducing the overall TSS load from a development site. However, in recognition of their infiltration ability, both BMPs can be used to reduce the volume of development site runoff and, consequently, the size and cost of other onsite BMPs. Use of these "volume reduction" BMPs are illustrated in Example 4-2 below and described in detail in Chapter 5.

In addition, Table 4-1 also indicates that the adopted TSS removal rates for manufactured treatment devices must be determined on a case-by-case basis. Manufactured treatment devices are proprietary water quality devices that use a variety of stormwater treatment techniques. They have and continue to be developed by a variety of companies. As such, the actual TSS removal rate for a specific device will depend on a number of factors, and a single representative TSS removal rate cannot be developed. Instead, the NJDEP's Division of Science, Research & Technology (DSRT) is responsible for certifying final pollutant removal rates for all manufactured treatment devices. This certification process is described in detail in Chapter 9.

Finally, as noted in Table 4-1, the adopted TSS removal rates for extended detention basins and wet ponds will vary depending on such specific features as detention time and permanent pool volume. Details for each BMP are also provided in Chapter 9.

TSS Removal Rates for BMPs in Series

The TSS removal rates specified in Table 4-1 for certain BMPs range as low as 40 percent, which indicates that these BMPs will not be able to meet the 80 percent TSS reduction requirement by themselves. As such, it will be necessary at times to use a series of BMPs in a treatment train to achieve the required 80 percent TSS removal rate. In such cases, the total removal rate of the BMP treatment train is based on the removal rate of the second BMP applied to the fraction of the TSS load remaining after the runoff has passed through the first BMP (Massachusetts DEP, 1997).

A simplified equation for the total TSS removal rate (R) for two BMPs in series is:

$$R = A + B - [(A \times B) / 100] \qquad \text{(Equation 4-1)}$$

Where:

R = Total TSS Removal Rate

A = TSS Removal Rate of the First or Upstream BMP

B = TSS Removal Rate of the Second or Downstream BMP

The use of this equation is demonstrated in Example 4-1 below.

Example 4-1: Total TSS Removal Rate for BMPs in Series

A stormwater management system consists of both a vegetative filter and an extended detention basin to collect and treat runoff from a small commercial parking lot. Runoff from the parking lot will sheet flow off the parking lot through the filter strip, which will have a turf grass surface cover, before being discharged to the extended detention basin. The extended detention basin will have a detention time of 18 hours.

From Table 4-1 and Chapter 9, the adopted TSS removal rates for these individual BMPs are:

Turf Grass Vegetative Filter = 60%

Extended Detention Basin with 18-Hour Detention Time = 50%

From Equation 4-1,

$$R = A + B - [(A \times B) / 100]$$

$$R = 60 + 50 - [(60 \times 50) / 100] = 110 - 30 = 80\% \text{ Total TSS Removal Rate}$$

It should be noted that the total TSS removal rate of the stormwater management system described in Example 4-1 above can also be computed by the following technique:

Initial TSS Load Upstream of Vegetated Filter Strip = 1.0

TSS Load Removed by Vegetated Filter Strip = 1.0 X 60% Removal Rate = 0.6

Remaining TSS Load Downstream of Vegetated Filter Strip = 1.0 – 0.6 = 0.4

TSS Load Removed by Extended Detention Basin = 0.4 X 50% Removal Rate = 0.2

Final TSS Load Downstream of Extended Detention Basin = 0.4 – 0.2 = 0.2

Total TSS Removal Rate = 1.0 – 0.2 = 0.8 or 80%

This technique can also be used in place of Equation 4-1 when there are more than two BMPs in series.

Guidelines for Arranging BMPs in Series

As described in Example 4-1, it may be necessary or desirable to use a series of BMPs in a treatment train to provide adequate TSS removal. In selecting the order or arrangement of the individual BMPs, the following general guidelines should be followed:

1. Arrange the BMPs from upstream to downstream in ascending order of TSS removal rate. In this arrangement, the BMP with the lowest TSS removal rate would be located at the upstream end of the treatment train. Downstream BMPs should have progressively higher TSS removal rates.
2. Arrange the BMPs from upstream to downstream in ascending order of nutrient removal rate. Similar to 1 above, the BMP with the lowest nutrient removal rate would be located at the upstream end of the treatment train in this arrangement. Downstream BMPs should have progressively higher nutrient removal rates.
3. Arrange the BMPs from upstream to downstream by their relative ease of sediment and debris removal. In this arrangement, the BMP from which it is easiest to remove collected sediment and debris would be located at the upstream end of the treatment train. In downstream BMPs, it should be progressively more difficult to remove sediment and debris.

In applying these guidelines, it is recommended that they generally be applied in the order presented above. As such, a series of BMPs would be preliminarily arranged in accordance with their relative TSS removal rates (Guideline 1). This preliminary arrangement would then be refined by the BMPs' relative nutrient removal rate (Guideline 2) and then their ease of sediment and debris removal (Guideline 3). Two or more iterations may be necessary to select the optimum arrangement, which should also include consideration for site conditions and the abilities and equipment of the party responsible for the BMPs' maintenance.

Finally, it should be noted that, unless otherwise approved by the applicable reviewing agencies or specifically indicated in the certification of a specific manufactured treatment device, all manufactured treatment devices that achieve TSS removal primarily through swirling and/or baffles should be placed at the upstream end of a treatment train.

Sites with Multiple Discharge Points and Subareas

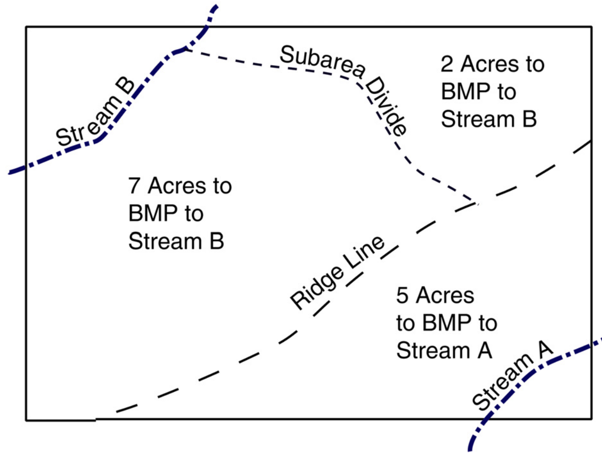
In general, if runoff is discharged from a site at multiple points, the 80 percent TSS removal requirement will have to be applied at each discharge point. However, the application of this requirement will depend upon the exact amount of physical and hydraulic separation between the various discharge points. If the runoff from two or more discharge points combine into a single waterway or conveyance system before leaving the site, these separate discharge points can be considered as a single one for purposes of computing TSS removal.

In addition, where there are multiple onsite subareas to a single discharge point, the removal rates for the subareas can be combined through a weighted averaging technique. It should be noted that the averaging of TSS removal rates is applicable only where the anticipated pollutant loadings from each of the subareas are similar. As such, the TSS removal rate for an onsite BMP receiving runoff from a commercial parking lot cannot be averaged with a second onsite BMP serving a lawn or landscaped area.

Example 4-2 below provides further explanations of the procedures described above for computing TSS removal rates at sites with both multiple discharge points and subareas.

Example 4-2: TSS Removal Rates at Sites with Multiple Discharge Points and Subareas

A 15-acre site has a ridge running through it from northeast to southwest. Five acres of the site drain in a southeasterly direction to Stream A, while the remaining 10 acres drain in a northwesterly direction to Stream B. Since Stream A and B do not join on the site, each portion of the site will have to be evaluated separately for compliance with the 80 percent TSS removal requirement.



Southeast Drainage to Stream A

The site runoff to Stream A will first be routed through a bioretention system.

The bioretention system TSS removal rate is 90 percent. This exceeds the 80 percent removal requirements and meets the TSS removal requirement for the southeast drainage area.

Northwest Drainage to Stream B

One acre of rooftop runoff from the stormwater quality design storm will be directed to dry wells, thereby reducing the drainage area to be served by other BMPs by 1 acre. The remaining 9 acres to Stream B are divided into two subareas of 2 and 7 acres, respectively. A vegetative filter will treat the runoff from one of the subareas, while a constructed stormwater wetland will treat the runoff from other. The anticipated pollutant loadings from each subarea are similar.

The TSS removal rate for a vegetative filter with meadow is 70 percent, which is not sufficient by itself to meet the 80 percent TSS removal requirement. However, the constructed stormwater wetland TSS removal rate is 90 percent, which exceeds the 80 percent TSS removal requirement. By averaging of removal rates, the use of these two BMPs may be sufficient to meet the 80 percent removal requirement for this portion of the site.

Two alternatives to address the TSS load in the runoff from the northwest portion of the site to Stream B are presented below.

OPTION A: The meadow vegetative filter will be used to treat the runoff from the 7 acre subarea, while the constructed stormwater wetland will be used in the 2 acre subarea.

Apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

7 Acres X 70% TSS Removal for Vegetative Filter= 4.9

2 Acres X 90% TSS Removal for Wetland = 1.8

Total Acreage-Removal Rate = 4.9 + 1.8 = 6.7

6.7 Total Acreage-Removal Rate / 9 Acres = 0.74 or 74% Average TSS Removal Rate

Therefore, for Option A, the northwest portion of the site does not meet the 80 percent TSS removal requirement.

OPTION B: The vegetative filter will be used to treat the runoff from the 2 acre subarea, while the constructed stormwater wetland will be used in the 7 acre subarea.

Once again, apply the various TSS removal rates to the areas to be treated by each BMP and determine the average TSS removal rate for the entire northwest portion of the site.

2 Acres X 70% TSS Removal for Vegetative Filter = 1.4

7 Acres X 90% TSS Removal for Wetland = 6.3

Total Acreage-Removal Rate = 1.4 + 6.3 = 7.7

7.7 Total Acreage-Removal Rate / 9 Acres = 0.86 or 86% Average TSS Removal Rate

Therefore, for Option B, the northwest portion of the site does meet the 80 percent TSS removal requirement.

Nutrients

In addition to TSS removal, the Stormwater Management Rules also require the reduction of post-construction nutrients to the maximum extent feasible. In general, to demonstrate compliance with this requirement, a two step approach should be used. First, the input of nutrients to the drainage area should be limited as much as feasible. Second, when selecting a stormwater management measure to address the TSS removal requirement, the measure with the best nutrient removal rate that also best meets the site's constraints should be chosen. Details of each step in this approach are provided below.

Reducing Nutrient Input

A significant amount of nutrients are in stormwater runoff due to fertilization of lawns. As described in Chapter 2, lawns should be minimized in favor of other vegetated cover. Existing site areas with desirable vegetation communities should be left in a natural state and forested areas and meadows should be considered as alternatives to the standard lawn. Ground covers provide aesthetically pleasing, innovative landscapes that are adaptable to the local environment. These types of land cover reduce lawn area and the consequent need for fertilization. A landscape design that minimizes the use of lawn can be beneficial in preventing pesticides, as well as nutrients from fertilizers, from stormwater runoff.

Soil testing determines the soil nutrient level as well as pH. Using the test results to determine the appropriate application of lime and fertilizer required for lawn areas will increase efficient uptake and decrease associated costs of lawn maintenance as well as minimize nutrient input. Low or no phosphorous fertilizers may be adequate to maintain the health of the landscape after the vegetation has fully established. Soil test kits are available at most lawn and garden care centers as well as through the Rutgers Cooperative Extension county offices. Fertilization specifications must be included in the maintenance manual.

Pet waste is another source of nutrients in stormwater runoff. To prevent or minimize pet waste problems, residents must be required to pick up after their animal and dispose of the material in the toilet or garbage. Homeowner associations must include this condition in homeowner's agreements. Signage should be located strategically throughout the development to reinforce this criterion. Education is critical to successful pet waste management.

Nutrient Removal Rates

Site conditions and the need to reduce post-construction TSS by 80 percent are primary factors in the selection of appropriate BMPs for a development site. However, removal of nutrients such as phosphorous and the various forms of nitrogen must also be considered in this selection process. The chosen BMP must meet the TSS criteria, but must also maximize nutrient removal for the site. To assist with the selection of BMPs for nutrients, information regarding estimated nutrient removal rates is provided in Table 4-2.

Table 4.2 – Typical Phosphorous and Nitrogen Removal Rates for BMPs

Best Management Practice (BMP)	Total Phosphorous Removal Rate (%)	Total Nitrogen Removal Rate (%)
Bioretention Basin	60	30
Constructed Stormwater Wetland	50	30
Extended Detention Basin	20	20
Infiltration Basin	60	50
Manufactured Treatment Devices	See N.J.A.C. 7:8-5.7(d)	See N.J.A.C. 7:8-5.7(d)
Pervious Paving[2]	60	50
Sand Filter	50	35
Vegetative Filter	30	30
Wet Pond	50	30

The nutrient removal rates presented in Table 4-2 should be considered typical values based upon data from a range of research studies. Due to the multiple forms and complex behavior of nutrients in stormwater runoff and the similarly complex processes by which nutrient loading is altered by BMPs, actual removal rates for specific BMPs and development sites may vary.

The nutrient removal data in Table 4-2 is intended to assist designers in the selection of appropriate BMPs to meet both the 80 percent TSS and maximum feasible nutrient removal requirements in the NJDEP Stormwater Management Rules. During this selection process, primary consideration should be given to achieving the Rules' 80 percent TSS removal requirement with one or more BMPs that are compatible with and responsive to site conditions and constraints, maintenance needs, and safety concerns. The selection process should then be further refined to achieve the Rules' maximum feasible nutrient requirement utilizing the structural BMP data in Figure 4.2 and, as necessary, other appropriate resources. In doing so, it should be remembered that many nonstructural BMPs can also help achieve the nutrient removal requirement, and must be considered prior to the use of structural BMPs.

The nutrient removal data in Table 4-2 can also be used to optimize existing BMP retrofits.

Additional Considerations

From the information presented in this chapter, it should be evident that BMPs are intended to reduce the pollutants in stormwater runoff. However, sometimes an unintended consequence of stormwater management facilities is their attractiveness to waterfowl, such as Canada geese. Canada geese are attracted to lawn areas adjacent to water bodies. As such, wet ponds and other stormwater management structures can appeal to these waterfowl, whose resulting fecal input can result in an increase in nutrient loading to systems that are intended to reduce such pollutants. As a result, adjustments to a BMP's design and/or maintenance plan may be necessary to discourage waterfowl from contributing pollutants to the stormwater measure. Additional guidance on Canada geese is available in Management of Canada Geese in Suburban Areas: A Guide to the Basics, available at http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/Goosedraft.pdf.

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