Appendix I. Design Standards for Structural Stormwater Management Measures

New Jersey Stormwater
Best Management Practices Manual

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CHAPTER 9.0

Structural Stormwater Management Measures

This chapter presents specific planning, design, construction, and maintenance information about a range of structural stormwater management measures that may be used to address the groundwater recharge and stormwater quality and quantity requirements of the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. The specific structural measures, also known as structural Best Management Practices (BMPs), included in this chapter are:

9.1 – Bioretention Systems
9.2 – Constructed Stormwater Wetlands
9.3 – Dry Wells
9.4 – Extended Detention Basins
9.5 – Infiltration Basins
9.6 – Manufactured Treatment Devices
9.7 – Pervious Paving Systems
9.8 – Rooftop Vegetated Cover (Reserved)
9.9 – Sand Filters
9.10 – Vegetative Filters
9.11 – Wet Ponds

Information regarding each BMP is presented in a separate subchapter, which consists of the following sections.

Definition – Most if not all BMPs are actually rather complex stormwater management systems that have multiple components and utilize several physical, chemical, and biological processes. In addition, many of these components and processes are shared by multiple BMPs. This can often cause confusion over where in the manual users can find information regarding a specific BMP. To prevent this confusion, the

Definition section provides a definitive description of the BMP, including its major components and processes. It also presents the BMP's adopted TSS removal rate.

Purpose – This section describes the uses for which the BMP is particularly suited. This includes groundwater recharge and runoff quality and quantity control as well as ancillary uses such as recreation, wildlife habitat, and open space preservation. This information is intended to help manual users decide whether a particular BMP is capable of meeting their project needs.

Conditions Where Practice Applies – In addition to sharing many components and processes, all BMPs also have unique features and requirements. These must be recognized and met during a BMP's planning, design, and review phases if the BMP is to provide effective, efficient, and enduring service. This section concisely presents these BMP features and requirements so that manual users can decide whether a particular BMP is appropriate for their project

Design Criteria – This section presents specific BMP design criteria that must be met for a particular BMP to achieve the TSS removal rates adopted in the Stormwater Management Rules at N.J.A.C. 7:8. The design criteria also provides the information necessary to address groundwater recharge and stormwater quantity performance standards. The criteria presented in this section vary with each BMP and can range from required runoff storage volumes to maximum drainage area size to minimum soil permeabilities.

Maintenance – Effective BMP performance requires regular and effective maintenance. In addition, the NJDEP Stormwater Management Rules require that all structural BMPs have a specific maintenance plan that must be followed by those responsible for its operation and maintenance. This section provides specific maintenance information which, in combination with *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures,* can be used to develop such a plan and to help ensure the effective, efficient, and enduring service envisioned by the BMP designer.

Considerations – This section presents valuable information that should be considered during a particular BMP's planning, design, review and/or construction phases. While not mandatory, this information is intended to promote BMPs that comprehensively meet the expectations of their designers, reviewers, owners, and maintenance personnel.

Recommendations – As noted above, all BMPs have unique features, requirements, ancillary functions, and maintenance needs. This section identifies various factors that, while not necessarily a mandatory design criteria, should nevertheless be included in the development of a BMP's design whenever possible.

References – This section identifies the major published sources of technical information that were used by the NJDEP in the development of each BMP's subchapter.

Regarding references, it is important to note that the information presented in each BMP subchapter was developed not only from published sources, but also through detailed technical discussions held at numerous BMP Manual Technical and Advisory Committee meetings hosted by the NJDEP. The information and conclusions developed at these meetings reflect the technical knowledge of the committee members, which was derived, in part, from numerous published and unpublished sources.

In recognition of the continued growth of our stormwater management knowledge, it should also be noted that compliance with the NJDEP Stormwater Management Rules is not limited to the BMPs presented in this chapter. Other BMPs that possess similar levels of effectiveness, efficiency, and endurance may also be utilized provided that such levels can be similarly demonstrated.

CHAPTER 9.1

Standard for Bioretention Systems

Definition

A bioretention system consists of a soil bed planted with native vegetation located above an underdrained sand layer. It can be configured as either a bioretention basin or a bioretention swale. Stormwater runoff entering the bioretention system is filtered first through the vegetation and then the sand/soil mixture before being conveyed downstream by the underdrain system. Runoff storage depths above the planting bed surface are typically shallow. The adopted TSS removal rate for bioretention systems is 90 percent.

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 runoff from both residential and nonresidential developments. Runoff inflow should preferably be overland flow to prevent disturbance to the vegetation and soil bed. Concentrated inflow from a drainage pipe or swale must include adequate erosion protection and energy dissipation measures.

Bioretention systems are most effective if 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, Construction Specifications.

The elevation of the Seasonal High Water Table (SHWT) is critical to ensure proper functioning of the bioretention basin, and must be evaluated to ensure that the SHWT is at least 1 foot below the bottom of the bioretention basin's underdrain system during non-drought conditions. Finally, both the SHWT and the permeability of the soil below the system are critical for bioretention systems that utilize infiltration rather than an underdrain system. See *9.5 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, should 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 a bioretention system are its storage volume, the thickness, character, and permeability rate of its planting soil bed, and the hydraulic capacity of its underdrain. The system must have sufficient storage volume above the surface of the bed to contain the design 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. The underdrain must also have sufficient hydraulic capacity. Details of these and other design parameters are presented below. The components of a typical bioretention system are shown in Figure 9.1-1.

A. Storage Volume, Depth, and Duration

Bioretention systems shall be designed to treat 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 treatment of the stormwater quality design storm shall be 12 inches in a bioretention basin and 18 inches in a bioretention swale. The minimum diameter of any outlet or overflow orifice is 2.5 inches.

The bottom of a bioretention system, including any underdrain piping or gravel layer, must be a minimum of 1 foot above the seasonal high groundwater table. The planting soil bed and underdrain system shall be designed to fully drain the stormwater quality design storm runoff volume within 72 hours.

B. Permeability Rates

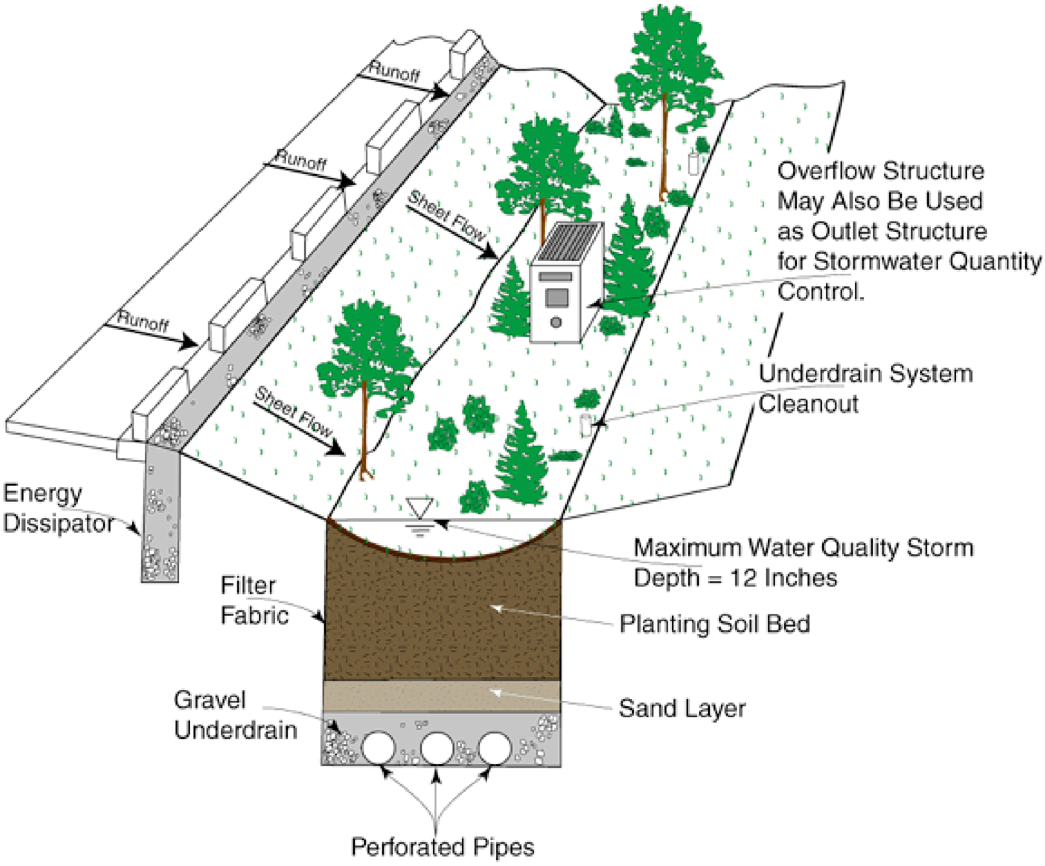
The design permeability rate through the planting soil bed must be sufficient to fully drain the stormwater quality design storm runoff volume within 72 hours. This permeability rate must be determined by field or laboratory testing. Since the actual permeability rate may vary from test results and may 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.

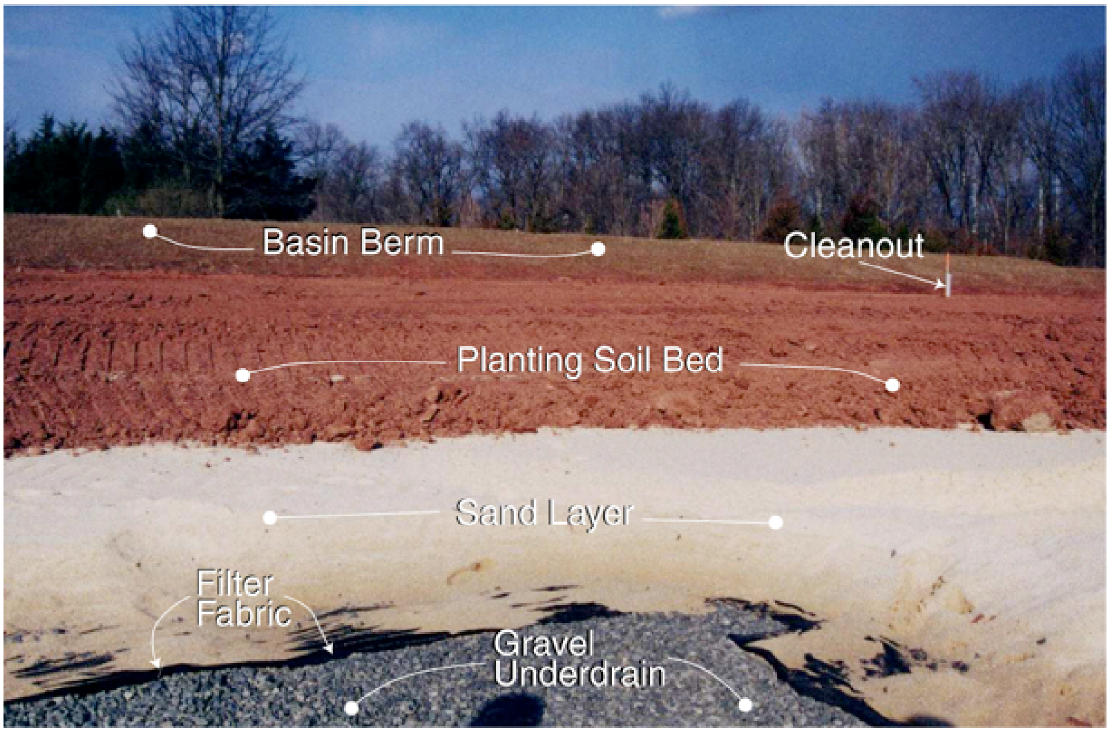
C. Planting Soil Bed

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 10 to 15 percent clays, a minimum 65 percent sands, with the balance as silts. The material's pH should range from 5.5 to 6.5. The material shall be placed in 12 to 18 inch lifts. The total depth or thickness of the planting soil bed should be a minimum of 3 feet.

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.

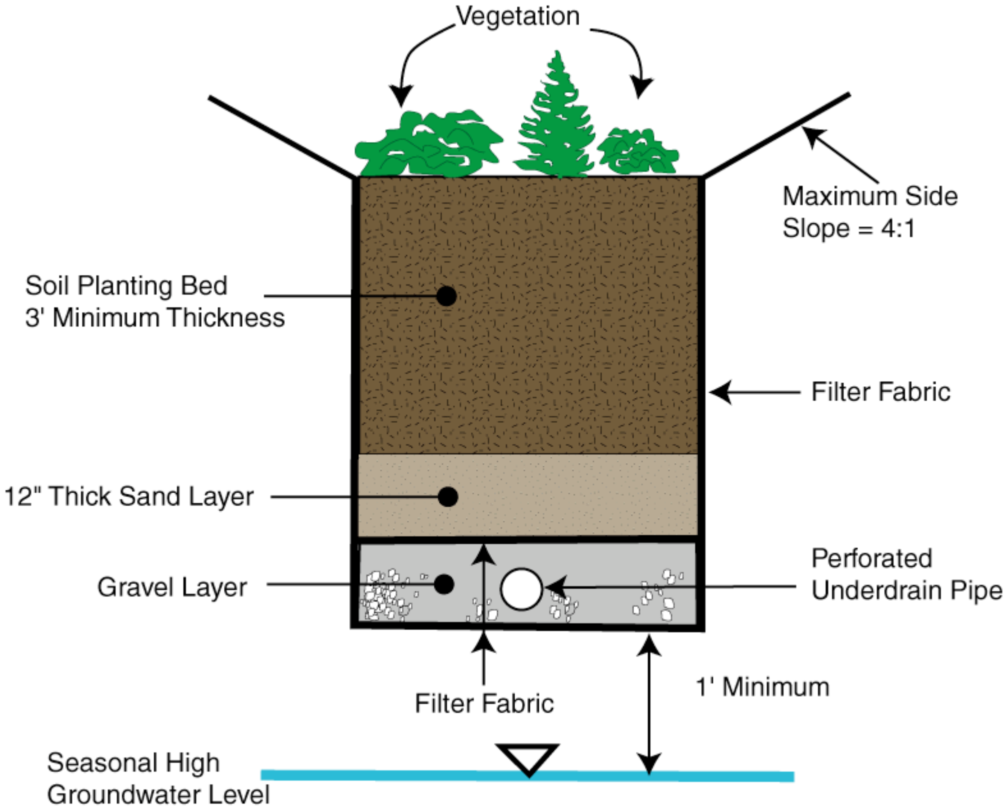
Figure 9.1-1: Bioretention System Components





Source: Adapted from Claytor and Schueler, 1996.

Figure 9.1-2 Bioretention Systems Details



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.

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 12 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).

The underdrain piping must be rigid Schedule 40 PVC pipe (AASHTO M-278) laid at a minimum slope of 0.50 percent. The portion of drain piping beneath the planting soil bed and sand layer must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. 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 to or 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.

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 reduce the potential for erosion, scour, and disturbance to vegetation, stormwater inflows to a bioretention system should occur as sheet flow where practical. Stone strips or aprons may be used at the downstream edge of upstream impervious surfaces to further dissipate sheet flow velocities and flow patterns. All points of concentrated 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 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 or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. 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.

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 should be mowed at least once a month during the growing season. 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. 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

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 basins are susceptible to clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Therefore, using a bioretention basin 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 basins designed for infiltration (instead of an underdrain system) 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 basin 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 basins 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 reduce incoming velocities and 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 should be sized to hold the sediment volume expected between clean-outs.

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CHAPTER 9.2

Standard for Constructed Stormwater Wetlands

Definition

Constructed stormwater wetlands are wetland systems designed to maximize the removal of pollutants from stormwater runoff through settling and both uptake and filtering by vegetation. Constructed stormwater wetlands temporarily store runoff in relatively shallow pools that support conditions suitable for the growth of wetland plants. The adopted removal rate for constructed stormwater wetlands is 90 percent.

Purpose

Constructed stormwater wetlands are used to remove a wide range of stormwater pollutants from land development sites as well as provide wildlife habitat and aesthetic features. Constructed stormwater wetlands can also be used to reduce peak runoff rates when designed as a multi-stage, multi-function facility.

Conditions Where Practice Applies

Constructed stormwater wetlands require sufficient drainage areas and dry weather base flows to function properly. The minimum drainage area to a constructed stormwater wetland is 10 acres to 25 acres, depending on the type of wetland. See text below for details.

Constructed stormwater wetlands should not be located within natural wetland areas, since they will typically not have the same full range of ecological functions. While providing some habitat and aesthetic values, constructed stormwater wetlands are designed primarily for pollutant removal and erosion and flood control.

It is important to note that a constructed stormwater wetland must be able to maintain its permanent pool level. If the soil at the wetland site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary.

Finally, a constructed stormwater wetland must have a maintenance plan and, if privately owned, should 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 a constructed stormwater wetland are the storage volumes within its various zones. In general, the total volume within these zones must be equal to the design runoff volume. An exception to this requirement is made for an extended detention wetland. In addition, the character, diversity, and hardiness of the wetland vegetation must be sufficient to provide adequate pollutant removal. Details of these and other design parameters are presented below.

Constructed stormwater wetlands typically consist of three zones: pool, marsh, and semi-wet. Depending upon their relative size and the normal or dry weather depth of standing water, the pool zone may be further characterized as either a pond, micropond, or forebay. Similarly, the marsh zone may be further characterized as either high or low marsh based again upon the normal standing water depth in each.

Depending on the presence and relative storage volume of the pool, marsh, and semi-wet zones, a constructed stormwater wetland may be considered to be one of three types: pond wetland, marsh wetland, or extended detention wetland. As described in detail below, a pond wetland consists primarily of a relatively deep pool with a smaller marsh zone outside it. Conversely, a marsh wetland has a greater area of marsh than pool zone. Finally, an extended detention wetland consists of both pool and marsh zones within an extended detention basin.

Table 9.2-1 below presents pertinent design criteria for each type of constructed stormwater wetland. As shown in the table, each type (i.e., pond, marsh, and extended detention wetland) allocates different percentages of the total stormwater quality design storm runoff volume to its pool, marsh, and semi-wet zones. In a pond wetland, this volume is distributed 70 percent to 30 percent between the pool and marsh zones. Conversely, in a marsh wetland, the total runoff volume is distributed 30 percent to 70 percent between the pool and marsh zones. Both of these zone volumes are based on their normal standing water level.

However, in an extended detention wetland, only 50 percent of the stormwater quality design storm runoff volume is allocated to the pool and wetland zones, with 40 percent of this amount (or 20 percent of the total stormwater quality design storm runoff volume) provided in the pool zone and 60 percent (or 30 percent of the total runoff volume) provided in the marsh zone. The remaining 50 percent of the stormwater quality design storm runoff volume is provided in the wetland's semi-wet zone above the normal standing water level, where it is temporarily stored and slowly released similar to an extended detention basin. As noted in Table 9.2-1, the detention time in the semi-wet zone of an extended detention wetland must meet the same detention time requirements as an extended detention basin. These requirements are presented in *Chapter 9.4: Standard for Extended Detention Basins*. The minimum diameter of any outlet orifice in all wetland types is 2.5 inches.

The components of a typical stormwater wetland are illustrated in Figure 9.2-1. Pertinent design criteria for each component are presented in Table 9.2-1. Additional details of each type of constructed stormwater wetland and the components of each are described below.

A. Pool Zone

Pools generally have standing water depths of 2 to 6 feet and primarily support submerged and floating vegetation. Due to their depths, support for emergent vegetation is normally limited. As noted above, the pool zone may consist of a pond, micropond, and/or forebay, depending on their relative sizes and depths. Descriptions of these pool types are presented below.

1. Pond

Ponds generally have standing water depths of 4 to 6 feet and, depending on the type, may comprise the largest portion of a constructed stormwater wetland. Ponds provide for the majority of particulate settling in a constructed stormwater wetland.

2. Micropond

In general, a micropond also has a standing water depth of 4 to 6 feet, but is smaller in surface area than a standard pond. A micropond is normally located immediately upstream of the outlet from a constructed stormwater wetland. At that location, it both protects the outlet from clogging by debris and provides some degree of particulate settling. Since a micropond does not provide the same degree of settling as a standard pond, it is normally combined with a larger area of marsh than a standard pond.

3. Forebay

Forebays are located at points of concentrated inflow to constructed stormwater wetlands. As such, they serve as pretreatment measures by removing coarser sediments, trash, and debris. They typically have normal standing water depths of 2 to 4 feet.

B. Marsh Zone

Marshes have shallower standing water depths than ponds, generally ranging from 6 to 18 inches. At such depths, they primarily support emergent wetland vegetation. As noted above, a marsh is classified as either a high or low marsh, depending on the exact depth of standing water.

1. Low Marsh

A low marsh has a standing water depth of 6 to 18 inches. It is suitable for the growth of several emergent wetland plant species.

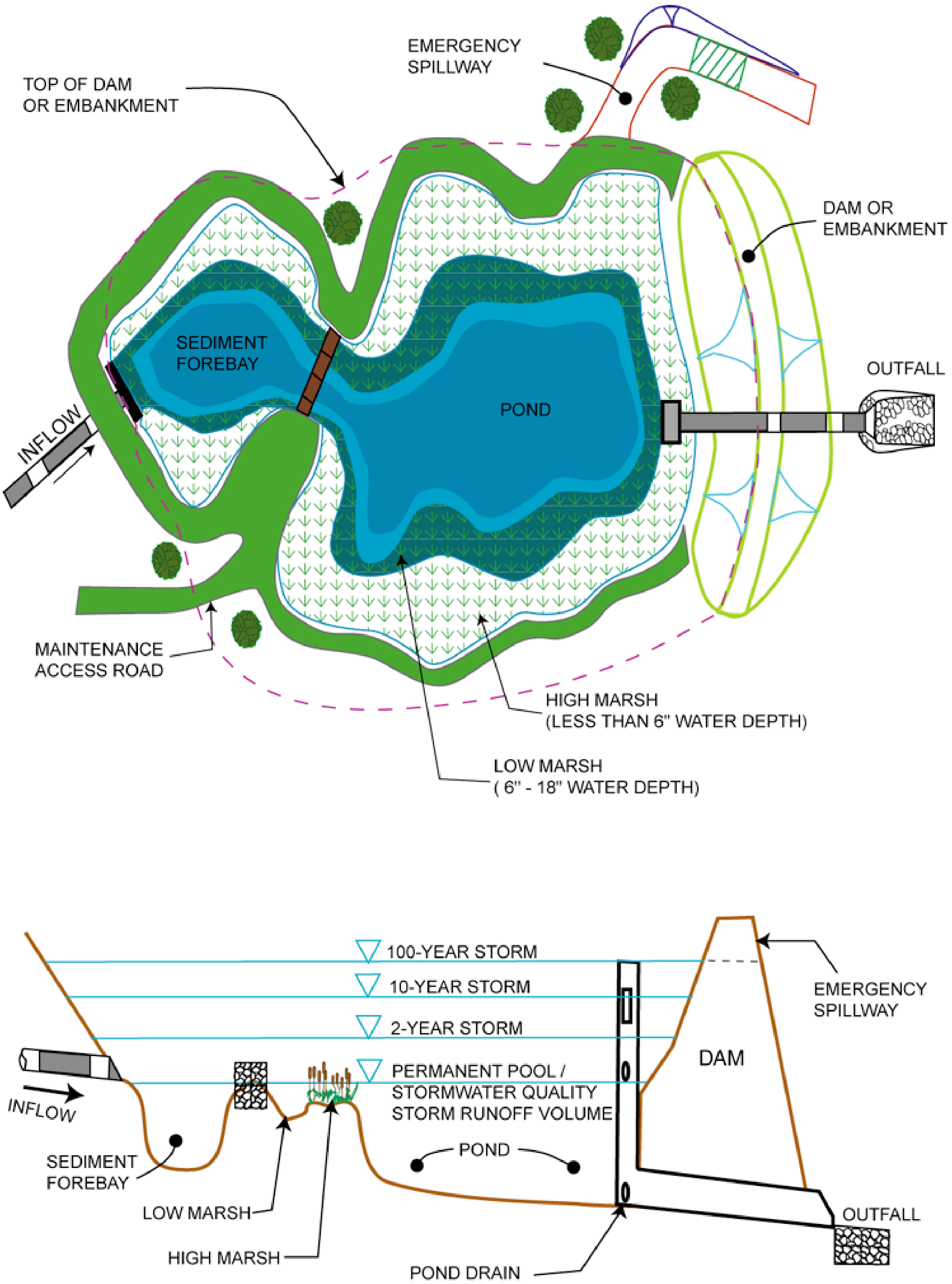
2. High Marsh

A high marsh has a maximum standing water depth of 6 inches. Due to its shallower depth, it will have a higher standing water surface area to volume ratio than a low marsh. It will normally support a greater density and diversity of emergent wetland species than a low marsh.

C. Semi-Wet Zone

The semi-wet zone in a constructed stormwater wetland is located above the pool and marsh zones and is inundated only during storm events. As a result, it can support both wetland and upland plants.

Figure 9.2-1: Constructed Stormwater Wetland Components



Source: Adapted from Schueler and Claytor 2000.

Table 9.2–1: Design Criteria for Constructed Stormwater Wetlands

Wetland Design Feature	Type of Constructed Stormwater Wetland		
	Pond	Marsh	Extended Detention
Minimum Drainage Area (Acres)	25	25	10
Minimum Length to Width Ratio	1:1	1:1	1:1
Allocation of Stormwater Quality Design Storm Runoff Volume (Pool / Marsh / Semi-Wet*)	70 / 30 / 0	30 / 70 / 0	20 / 30 / 50*
Pool Volume (Forebay / Micropond / Pond)	10 / 0 / 60	10 / 20 / 0	10 / 10 / 0
Marsh Volume (Low / High)	20 / 10	45 / 25	20 / 10
Sediment Removal Frequency (Years)	10	2 to 5	2 to 5
Outlet Configuration	Reverse-Slope Pipe or Broad Crested Weir	Reverse-Slope Pipe or Broad Crested Weir	Reverse-Slope Pipe or Broad Crested Weir

* In an Extended Detention Wetland, 50 percent of the stormwater quality design storm runoff volume is temporarily stored in the semi-wet zone. Release of this volume must meet the detention time requirements for extended detention basins (see text above and Chapter 9.4).

D. Types of Constructed Stormwater Wetlands

1. Pond Wetlands

Pond wetlands consist primarily of ponds with standing water depths ranging from 4 to 6 feet in normal or dry weather conditions. Pond wetlands utilize at least one pond component in conjunction with high and low marshes. The pond is typically the component that provides for the majority of particulate pollutant removal. This removal is augmented by a forebay, which also reduces the velocity of the runoff entering the wetland. The marsh zones provide additional treatment of the runoff, particularly for soluble pollutants.

Pond wetlands require less site area than marsh wetlands and generally achieve a higher pollutant removal rate than the other types of constructed stormwater wetland. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component.

2. Marsh Wetlands

Marsh wetlands consist primarily of marsh zones with standing water depths ranging up to 18 inches during normal or dry weather conditions. These zones are further configured as low and high marsh components as described above. The remainder of the stormwater quality design storm runoff volume storage is provided by a micropond. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component.

Marsh wetlands should be designed with sinuous pathways to increase retention time and contact area. Marsh wetlands require greater site area than other types of constructed stormwater wetlands. In order to have the base and/or groundwater flow rate necessary to support emergent plants and minimize mosquito breeding, marsh wetlands may also require greater drainage areas than the other types. This is due to the relatively larger area of a marsh wetland as compared with either a pond or extended detention wetland. This larger area requires greater rates of normal inflow to generate the necessary flow velocities and volume changeover rates.

3. Extended Detention Wetlands

Unlike pond and marsh wetlands, an extended detention wetland temporarily stores a portion of the stormwater quality design storm runoff volume in the semi-wet zone above its normal standing water level. This temporary runoff storage, which must be slowly released in a manner similar to an extended detention basin, allows the use of relatively smaller pool and marsh zones. As a result, extended detention wetlands require less site area than pond or marsh wetlands. See Table 9.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component. See *Chapter 9.4: Standard for Extended Detention Basins* for the required detention times for the temporary semi-wet zone storage.

Due to the use of the semi-wet zone, water levels in an extended detention wetland will also increase more during storm events than pond or marsh wetlands. Therefore, the area of wetland vegetation in an extended detention wetland can expand beyond the normal standing water limits occupied by the pool and marsh zones. Wetland plants that tolerate intermittent flooding and dry periods should be selected for these areas.

E. Drainage Area

The minimum drainage area to a constructed stormwater wetland generally varies from 10 to 25 acres, depending on the type of constructed stormwater wetland. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater inflow is available. See Table 9.2-1 for details. See also *D. Types of Constructed Stormwater Wetlands* above and *B. Water Budget* in the *Recommendations* section below for discussions of base and groundwater flow needs.

F. Overflows

All constructed stormwater wetlands must be able to convey overflows to downstream drainage systems in a safe and stable manner. Constructed stormwater wetlands 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.

G. Tailwater

The design of all hydraulic outlets must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-Line and Off-Line Systems

Constructed stormwater wetlands 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 outlet or 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 normal permanent pool level. In off-line constructed stormwater wetlands, most or all of the runoff from storms larger than the stormwater quality design storm bypass the basin through an upstream diversion. This not only reduces the size of the required basin storage volume, but reduces the basin's long-term pollutant loading and associated maintenance. In selecting an off-line design, the potential effects on wetland vegetation and ecology of diverting higher volume runoff events should be considered.

I. Safety Ledges

Safety ledges must be constructed on the slopes of all constructed stormwater wetlands with a permanent pool of water deeper than 3 feet. Two ledges must be constructed, each 4 to 6 feet in width. The first or upper ledge must be located between 1 and 1.5 feet above the normal standing water level. The second or lower ledge must be located approximately 2.5 feet below the normal standing water level.

Maintenance

Effective constructed stormwater wetland 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 constructed stormwater wetlands. Specific maintenance requirements for constructed stormwater wetlands are presented below. These requirements must be included in the wetland's maintenance plan.

A. General Maintenance

All constructed stormwater wetland 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 forebays, bottoms, trash racks, outlet structures, and riprap or gabion aprons.

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 should be mowed at least once a month during the growing season. 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 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.

The types and distribution of the dominant plants must also be assessed during the semi-annual wetland inspections described above. This assessment should be based on the health and relative extent of both the original species remaining and all volunteer species that have subsequently grown in the wetland. Appropriate steps must be taken to achieve and maintain an acceptable balance of original and volunteer species in accordance with the intent of the wetland's original design.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the constructed stormwater wetland. 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 and return the various wetland pools to their normal standing water levels. This drain or drawdown time should then be used to evaluate the wetland's actual performance. If significant increases or decreases in the normal drain time are observed, the wetland's outlet structure, forebay, and 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 wetland.

Considerations

Constructed stormwater wetlands are limited by a number of site constraints, including soil types, depth to groundwater, contributing drainage area, and available land area at the site.

A. Construction

The following minimum setback requirements should apply to stormwater wetland installations:

Distance from a septic system leach field = 50 feet.

Distance from a septic system tank = 25 feet.

Distance from a property line = 10 feet.

Distance from a private well = 50 feet.

A seven-step process is recommended for the preparation of the wetland bed prior to planting (Schueler 1992).

1. Prepare final pondscaping and grading plans for the stormwater wetland. At this time order wetland plant stock from aquatic nurseries.
2. Once the stormwater wetland volume has been excavated, the wetland should be graded to create the major internal features (pool, safety ledge, marshes, etc.).
3. After the mulch or topsoil has been added, the stormwater wetland needs to be graded to its final elevations. All wetland features above the normal pool should be stabilized temporarily.
4. After grading to final elevations, the pond drain should be closed and the pool allowed to fill. Usually nothing should be done to the stormwater wetland for six to nine months or until the next planting season. A good design recommendation is to evaluate the wetland elevations during a standing period of approximately six months. During this time the stormwater wetland can experience storm flows and inundation, so that it can be determined where the pondscaping zones are located and whether the final grade and microtopography will persist overtime.
5. Before planting, the stormwater wetland depths should be measured to the nearest inch to confirm planting depth. The pondscape plan may be modified at this time to reflect altered depths or availability of plant stock.

6. Erosion controls should be strictly applied during the standing and planting periods. All vegetated areas above the normal pool elevation should be stabilized during the standing period, usually with hydroseeding.
7. The stormwater wetland should be de-watered at least three days before planting since a dry wetland is easier to plant than a wet one.

Topsoil and/or wetland mulch is added to the stormwater wetland excavation. Since deep subsoils often lack the nutrients and organic matter to support vigorous plant growth, the addition of mulch or topsoil is important. If it is available, wetland mulch is preferable to topsoil.

B. Site Constraints

Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an impermeable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners is recommended. At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible.

C. Design Approach

A pondscaping plan should be developed for each constructed stormwater wetland. This plan should include hydrological calculations (or water budget), a wetland design and configuration, elevations and grades, a site/soil analysis, and estimated depth zones. The plan should also contain the location, quantity, and propagation methods for the wetland plants. Site preparation requirements, maintenance requirements, and a maintenance schedule are also necessary components of the plan.

The water budget should demonstrate that there will be a continuous supply of water to sustain the constructed stormwater wetland. The water budget should be developed during site selection and checked after preliminary site design. Drying periods of longer than two months have been shown to adversely effect plant community richness, so the water balance should confirm that drying will not exceed two months.

D. Effectiveness

A review of the existing performance data indicates that the removal efficiencies of constructed stormwater wetlands are slightly higher than those of conventional pond systems, e.g. as wet ponds or dry extended detention ponds. Of the three designs described above, the pond/wetland system has shown the most reliable terms of overall performance.

Studies have also indicated that removal efficiencies of constructed stormwater wetlands decline if they are covered by ice or receive snow melt. Performance also declines during the non-growing season and during the fall when the vegetation dies back. Until vegetation is well established, pollutant removal efficiencies may be lower than expected.

E. Regulatory Issues

A constructed stormwater wetlands, once constructed, may be regulated by the Freshwater Wetlands Protection Act, and require additional permits for subsequent maintenance or amendment of the constructed stormwater wetland.

Recommendations

A. Vegetation

Establishment and maintenance of the wetland vegetation is an important consideration when planning a stormwater wetland. The following is a series of recommendations (Horner et al. 1994) for creating constructed stormwater wetlands.

> In selecting plants, consider the prospects for success more than selection of native species. Since diversification will occur naturally, use a minimum of adaptable species. Give priority to perennial species that establish rapidly. Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod). Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available. Match site conditions to the environmental requirements of plant selections. Avoid using only species that are foraged by the wildlife expected on site.
>
> Establishment of woody species should follow herbaceous species. Add vegetation that will achieve other objectives, in addition to pollution control. Monoculture planting should be avoided due to increased risk of loss from pests and disease. When possible field collected plants should be used in lieu of nursery plants. Plants collected from the field have already adapted and are acclimated to the region. These plants generally require less care than greenhouse plants. If nursery plants are used they should be obtained locally, or from an area with similar climatic conditions as the eco-region of the constructed wetland. Alternating plant species with varying root depths have a greater opportunity of pollutant removal.
>
> Stormwater wetland vegetation development can also be enhanced through the natural recruitment of species from nearby wetland sites. However, transplanting wetland vegetation is still the most reliable method of propagating stormwater wetland vegetation, and it provides cover quickly. Plants are commercially available through wetland plant nurseries.
>
> The plant community will develop best when the soils are enriched with plant roots, rhizomes, and seed banks. Use of wetlands mulch enhances the diversity of the plant community and speeds establishment. Wetlands mulch is hydric soil that contains vegetative plant material. The upper 6 inches of donor soil should be obtained at the end of the growing season, and kept moist until installation. Drawbacks to using constructed stormwater wetlands mulch are its unpredictable content.
>
> During the initial planting precautions should be undertaken to prevent and prohibit animals from grazing until plant communities are well established. Such precautions could be deer fencing, muskrat trapping, planting after seasonal bird migrations, or attracting birds of prey and bats to control nutria populations

B. Water Budget

The water budget should demonstrate that there will be a continuous supply of water to sustain the stormwater wetland. The water budget should demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate. As discussed above, drying periods of longer than two months have been shown to adversely affect plan community richness, so the water balance should confirm that drying will not exceed two months (Schueler 1992).

C. Wetlands Area

The constructed wetlands should have a minimum surface area in relation to the contributing watershed area. The reliability of pollutant removal tends to increase as the stormwater wetland to watershed ratio increases, although this relationship is not always consistent. Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland.

D. Outlet Configuration

A hooded outlet is recommended with an invert or crest elevation at least 1 foot below the normal pool surface.

A bottom drain pipe with an inverted elbow to prevent sediment clogging should be installed for complete draining of the constructed stormwater wetland for emergency purposes or routine maintenance. Both the outlet pipe and the bottom drain pipe should be fitted with adjustable valves at the outlet ends to regulate flows. Spillways should be designed in conformance with state regulations and criteria for dam safety.

E. Pretreatment

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

As shown in Figure 9.2-1, forebays at the inflow points to a constructed stormwater wetland can capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized in accordance with Table 9.2-1 to hold the sediment volume expected between clean-outs.

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CHAPTER 9.3

Standard for Dry Wells

Definition

A dry well is a subsurface storage facility that receives and temporarily stores stormwater runoff from roofs of structures. Discharge of this stored runoff from a dry well occurs through infiltration into the surrounding soils. A dry well may be either a structural chamber and/or an excavated pit filled with aggregate. Due to the relatively low level of expected pollutants in roof runoff, a dry well cannot be used to directly comply with the suspended solids and nutrient removal requirements contained in the NJDEP Stormwater Management Rules at N.J.A.C. 7:8. However, due to its storage capacity, a dry well may be used to reduce the total stormwater quality design storm runoff volume that a roof would ordinarily discharge to downstream stormwater management facilities.

Purpose

Dry wells can be used to reduce the increased volume of stormwater runoff caused by roofs of buildings. While generally not a significant source of runoff pollution, roofs are one of the most important sources of new or increased runoff volume from land development sites. Dry wells can also be used to indirectly enhance water quality by reducing the amount of stormwater quality design storm runoff volume to be treated by the other, downstream stormwater management facilities.

Dry wells can also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of dry wells and other groundwater recharge facilities to meet them.

Conditions Where Practice Applies

The use of dry wells is applicable only where their subgrade soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, dry wells are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination. Specifically, dry wells must not be used in the following locations:

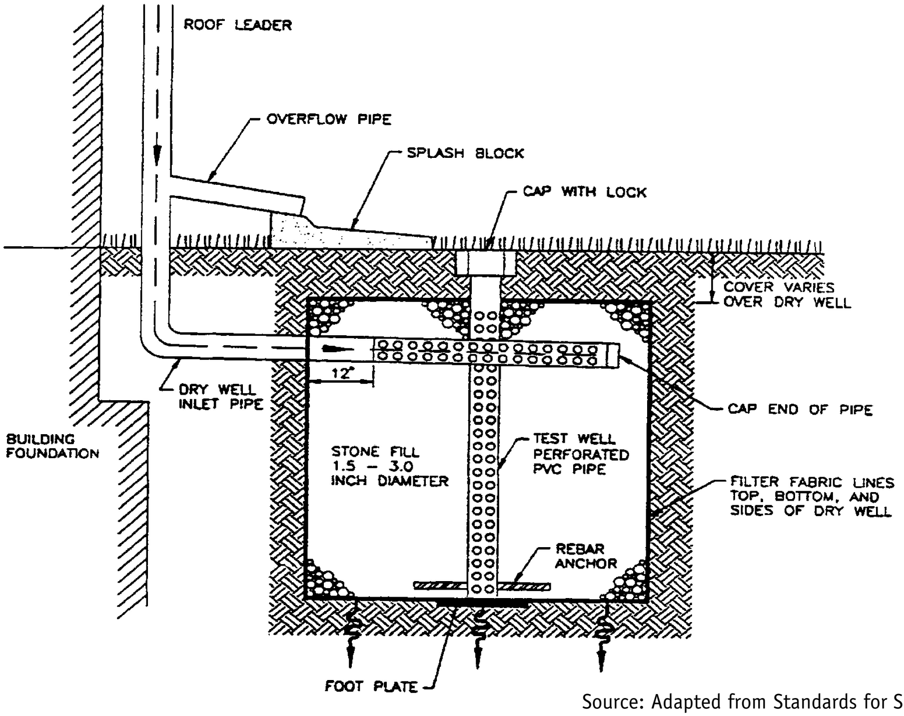
- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied; or pesticides are loaded, unloaded, or stored.

- Areas where hazardous materials are expected to be present in greater than “reportable quantities” as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where dry well use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is exposed to “source material.” “Source material” means any material(s) or machinery, located at an industrial facility, that is directly or indirectly related to process, manufacturing or other industrial activities, that could be a source of pollutants in any industrial stormwater discharge to groundwater. Source materials include, but are not limited to raw materials, intermediate products, final products, waste materials, by-products, industrial machinery and fuels, and lubricants, solvents, and detergents that are related to process, manufacturing, or other industrial activities that are exposed to stormwater.

In addition, as required by the NJDEP Stormwater Management Rules, dry wells must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Dry wells must be located and configured where their construction will not compact the soils below the dry well. Finally, a dry well must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Figure 9.3-1: Dry Well Components



Source: Adapted from Standards for Soil Erosion and Sediment Control in New Jersey

Design Criteria

The basic design parameters for a dry well are its storage volume and the permeability rate of the subgrade soils. A dry well must have sufficient storage volume to contain the design runoff volume without overflow, while the subgrade soils' permeability rate must be sufficient to drain the stored runoff within 72 hours. Details of these and other design parameters are presented below. The components of a typical dry well are shown above in Figure 9.3-1.

A. Storage Volume, Depth, and Duration

A dry well must be designed to treat the total runoff volume generated by the dry well's maximum design storm. This may either be the groundwater recharge or stormwater quality design storm, depending upon the dry well's proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. A dry well must also fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the dry well ineffective and may result in anaerobic conditions, odor, and both water quality and mosquito breeding problems. The bottom of the dry well must be at least 2 feet above seasonal high water table or bedrock and be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

As discussed in *Considerations* below, construction of a dry well must be done without compacting the dry well's subgrade soils. As such, all excavation must be performed by equipment placed outside the dry well whenever possible. This requirement should be considered when designing the dimensions and total storage volume of a dry well.

It is important to note that the use of dry wells is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of dry wells for larger storm events and the requirements by which such dry wells are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

B. Permeability Rates

The minimum design permeability rate of the subgrade soils below a dry well will depend upon the dry well's location and maximum design storm. The use of dry wells for stormwater quality or quantity control is feasible only where the soils are sufficiently permeable to allow a reasonable rate of infiltration. Therefore, dry wells designed for storms greater than the groundwater recharge storm can be constructed only in areas with Hydrologic Soil Group A and B soils. Additional permeability requirements are presented below in Table 9.3-1.

Table 9.3-1: Minimum Design Permeability Rates for Dry Wells

Maximum Design Storm	Minimum Design Permeability Rate (Inches/Hour)
Groundwater Recharge*	0.2
Stormwater Quality	0.5
*See text for required diversion of runoff from greater storms.	

It is important to note that, for dry wells that are used only for groundwater recharge (see Table 9.3-1 above), all runoff from storms greater than the dry well's groundwater recharge storm must be directed around the dry well by a diversion structure or device located upstream of the dry well. If the dry well does receive runoff and associated pollutants from greater storm events, a minimum permeability rate of 0.5 inches/hour must be used. Minor basin inflows from greater storms during normal operation of the diversion are permissible provided they represent a small percentage of the total storm runoff volume. For example, the dry well overflow pipe shown in Figure 9.3-1 can serve as such a diversion if it is located vertically as close to the ground surface as practical. Details of a dry well's groundwater recharge storm are presented in Chapter 6.

In addition to the above, the design permeability rate of the subgrade soils must be sufficient to fully drain the dry well's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See *A. Soil Characteristics* in *Considerations* below for more information. 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 must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the subgrade soils 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 dry well's maximum design storm drain time.

C. Drainage Area

The maximum drainage area to a dry well is 1 acre.

D. Overflows

All dry wells must be able to safely convey system overflows to 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. The downstream drainage system must have sufficient capacity to convey the overflow from the dry well.

Maintenance

Effective dry well 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 dry wells. Specific maintenance requirements for dry wells are presented below. These requirements must be included in the dry well's maintenance plan.

A. General Maintenance

A dry well should be inspected at least four times annually as well as after every storm exceeding 1 inch of rainfall. The water level in the test well should be the primary means of measuring infiltration rates and drain times. Pumping stored runoff from an impaired or failed dry well can also be accomplished through the test well. Therefore, adequate inspection and maintenance access to the test well must be provided.

Disposal of debris, trash, sediment, and other waste material removed from a dry well should be done at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

B. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to drain the maximum design storm runoff volume from the dry well. This normal drain time should then be used to evaluate the dry well's actual performance. If significant increases in the normal drain time are observed or if it exceeds the 72 hour maximum, appropriate measures must be taken to comply with the drain time requirements and maintain the proper functioning of the dry well.

Considerations

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for the planning and preliminary design of dry wells. However, for final design and construction, soil tests are required at the exact location of a proposed dry well in order to confirm its ability to function properly without failure or interference.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed dry well. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the drywell or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further soil requirements.

In addition, the results of a dry well's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed dry well, to ensure reasonable data consistency. If significant differences exist between the dry well's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

For dry wells, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the dry well should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During dry well construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the dry well.

To help prevent subgrade soil contamination and clogging by sediment, dry well construction should be delayed until all other construction areas that may temporarily or permanently drain to the dry well are stabilized. This delayed construction emphasizes the need, as described above, to cordon off the dry well area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of the dry well as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the dry well bottom. Accumulated sediment can then be removed without disturbing the subgrade soils at the dry well bottom, which should be established only after all construction within the dry well's drainage area is completed and the drainage area stabilized.

If dry well construction cannot be delayed until its drainage area is stabilized, diversion piping or other suitable measures should be installed during all phases of construction to divert all runoff and sediment away from the dry well. These diversion measures should not be removed until all construction within the dry well's drainage area is completed and the drainage area stabilized.

Stone fill aggregate should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of dry wells with the contractor.

Recommendations

A. Pretreatment

As with all other best management practices, pretreatment can extend the functional life of a dry well. While generally not a significant source of runoff pollution, roofs can nevertheless be the source of particulates and organic matter and, during site construction, sediment and debris. Therefore, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to a dry well should be included wherever practical to minimize the amount of sediment and other particulates that can enter the dry well.

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CHAPTER 9.4

Standard for Extended Detention Basins

Definition

An extended detention basin is a facility constructed through filling and/or excavation that provides temporary storage of stormwater runoff. It has an outlet structure that detains and attenuates runoff inflows and promotes the settlement of pollutants. An extended detention basin is normally designed as a multi-stage facility that provides runoff storage and attenuation for both stormwater quality and quantity management. The adopted TSS removal rate for extended detention basins is 40 to 60 percent, depending on the duration of detention time provided in the basin.

Purpose

Extended detention basins are used to address both the stormwater runoff quantity and quality impacts of land development. The lower stages of an extended detention basin can detain runoff from the stormwater quality design storm for extended periods of time, thereby promoting pollutant removal through sedimentation. Higher stages in the basin can also attenuate the peak rates of runoff from larger storms for flood and erosion control. Extended detention basins are designed for complete evacuation of runoff and normally remain dry between storm events. However, to enhance soluble pollutant removal, the lower stages of an extended detention basin may also be designed with a permanent pool and partially function as either a wetland or retention basin (see *Chapter 9.2: Standard for Constructed Stormwater Wetlands* and *Chapter 9.11: Standard for Wet Ponds*).

Conditions Where Practice Applies

Extended detention basins may be used at sites where significant increases in runoff are expected from site development. In addition, standard detention basins may be retrofitted or converted to extended detention by increasing the time over which the basin releases the stormwater quality design storm runoff volume, provided that erosion and flood control volumes and outflow rates are not adversely altered.

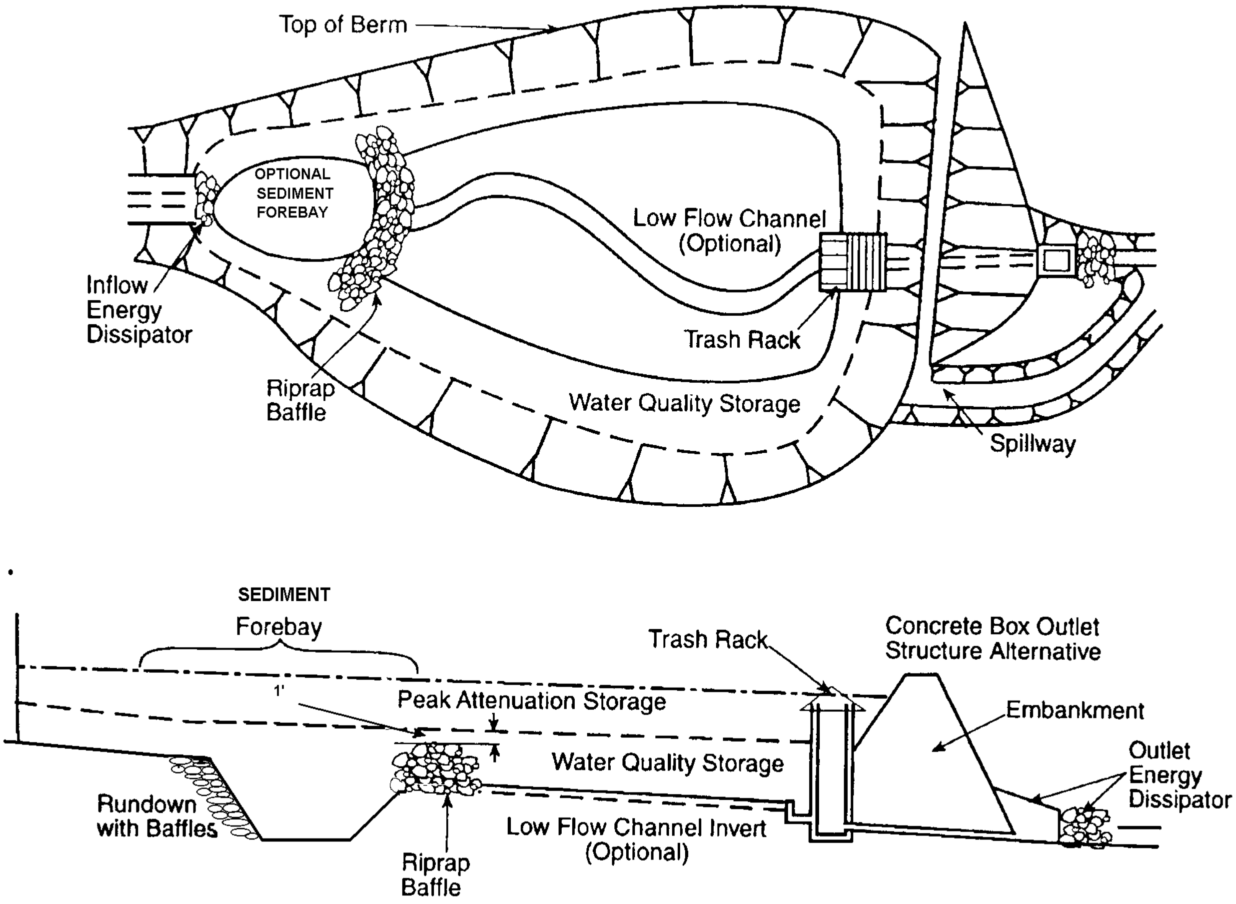
Extended detention basins can be used at residential, commercial, and industrial development sites. However, their limited effectiveness in removing both particulate and soluble pollutants may limit their use for water quality treatment.

Finally, an extended detention basin must have a maintenance plan and, if privately owned, should 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 an extended detention basin are its storage volume and detention time. An extended detention basin must have the correct combination of storage volume and outflow capacity to contain and slowly discharge the design runoff volume over a prescribed period of time. Details of these and other design parameters are presented below. The components of a typical extended detention basin are shown in Figure 9.4-1.

Figure 9.4-1: Extended Detention Basin Components



Source: Adopted from Pennsylvania Handbook of Best Management Practices for Developing Areas, which adapted the figure from Dam Design and Construction Standards, Fairfax County, Virginia.

A. Storage Volume, Depth, and Duration

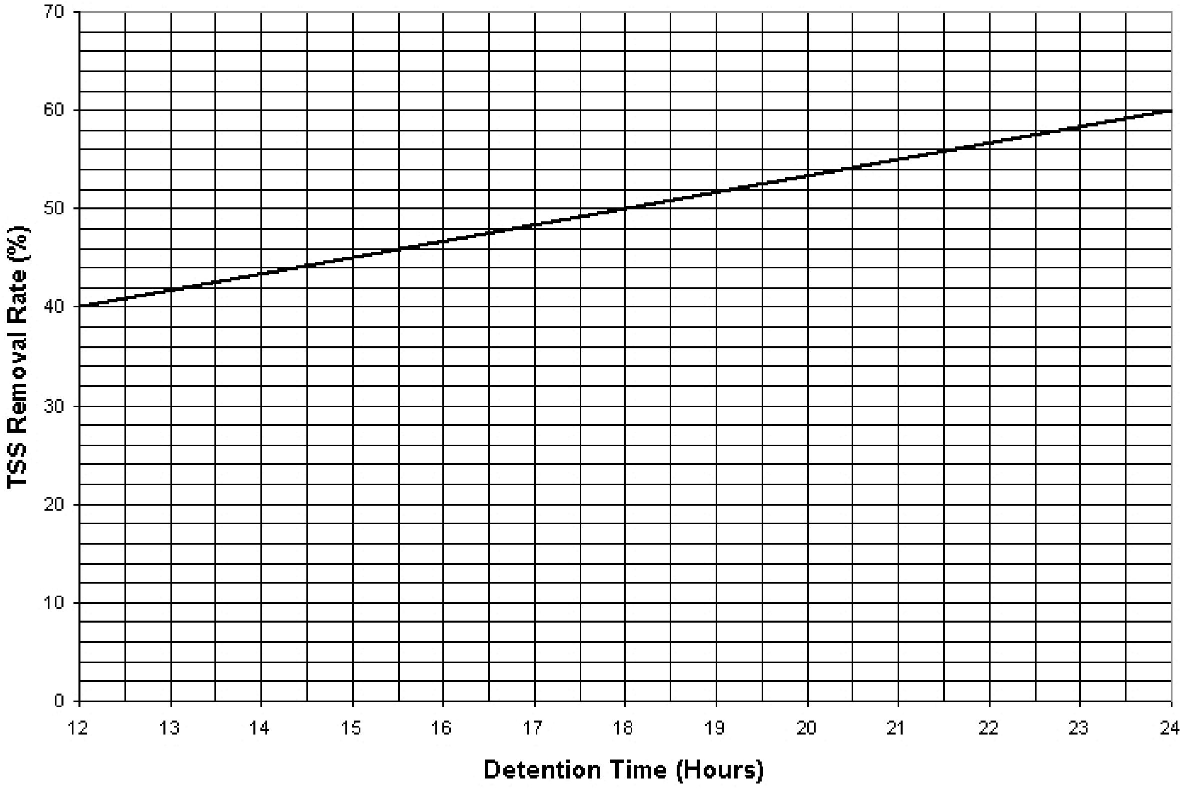
Extended detention basins should be designed to treat the runoff volume generated by the stormwater quality design storm. Techniques to compute this volume are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. To achieve a 60 percent TSS removal rate, a minimum of 10 percent of this runoff volume must remain in the basin 24 hours after the peak basin water surface and maximum runoff storage volume is achieved. This applies to all types of land developments.

It should be noted that the time from when the maximum storage volume is achieved until only 10 percent of that volume remains in an extended detention basin is defined as the basin's detention time. As noted above, a 24-hour detention time is required in an extended detention basin in order to achieve a 60 percent TSS removal rate. Figure 9.4-2 below can be used to determine the TSS removal rates at extended detention basins with detention times of 12 to 24 hours. The minimum diameter of any outlet orifice must be 2.5 inches.

The lowest elevation in an extended detention basin, excluding low flow channels, must be at least 1 foot above the seasonal high groundwater table. The lowest elevation in any low flow channel, including any underdrain pipes and bedding material, must be at or above the seasonal high groundwater table.

To enhance safety by minimizing standing water depths, the vertical distance between the basin bottom and the elevation of the first stormwater quantity control outlet (normally set equal to the maximum stormwater quality design storm water surface) should be no greater than 3 feet wherever practical.

Figure 9.4-2: TSS Removal Rate vs. Detention Time



B. Overflows

All extended detention basins must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Extended detention basins that are 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.

C. Tailwater

The hydraulic design of the outlet structure, outlet pipe, emergency spillway, and underdrain systems in an extended detention basin must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

D. Other Components

Information regarding outlet structures, bottom and side slopes, trash racks, low flow channels, conduit outlet protection, and vegetative cover can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

E. Subsurface Extended Detention Basins

A subsurface detention basin is located entirely below the ground surface. Runoff may be stored in a vault, perforated pipe, and/or stone bed. If a stone bed is utilized for any part of the storage volume, all runoff to the subsurface basin must either be pretreated or the basin's storage volume increased to account for the loss of volume in the stone bed due to sediment accumulation. This loss should be based upon the expected life of the basin. This increase is due to the impracticality of removing this sediment from the stone storage bed. This pretreatment must remove at least 50 percent of the TSS in the runoff from the basin's maximum design storm.

Following pretreatment, additional TSS removal can then be provided by the subsurface extended detention basin as the secondary BMP in a treatment train. Computation of the total TSS removal rate is described in *Chapter 4: Stormwater Pollution Removal Criteria*. See *Recommendations* below for additional information on runoff pretreatment.

Maintenance

Effective extended detention basin 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 extended detention basins. Specific maintenance requirements for extended detention basins are presented below. These requirements must be included in the basin's maintenance plan.

A. General Maintenance

All extended detention basin 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 inlets.

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 should be mowed at least once a month during the growing season. 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 bottom surface 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 must not compromise the intended purpose of the extended detention basin. 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 completely drain the maximum design storm runoff volume from the basin. This normal drain time should then be used to evaluate the basin's actual performance. If significant increases or decreases in the normal drain time are observed, the basin's outlet structure, 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 basin.

Considerations

For effective stormwater quality control, the basin must collect as much site runoff as possible, especially from the site's roadways, parking lots, and other impervious areas. The majority of the key pollutants that are removed by extended detention basins originate on these surfaces.

A typical extended detention basin will range from 3 to 12 feet in depth. Depth is often limited by groundwater conditions or the need for positive drainage from excavated basins. At the location of the proposed extended detention basin, the depth to seasonal high groundwater table must be determined. If the basin intercepts the groundwater, it may result in a loss of runoff storage volume, mosquito breeding, and difficulty maintaining the basin bottom.

When designing an extended detention basin, bottom soils should be examined. If soils are relatively impermeable (USDA Hydrologic Soil Group "D"), a dry extended detention basin may exhibit problems with standing water. Conversely, if soils are very permeable (Group "A") the effects on groundwater should be considered. If bedrock lies close to the surface of the soil, excavation for necessary storage volume may be too costly and difficult. In Karst landscapes, other alternatives to detention basins should be examined.

Recommendations

A. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of an extended detention system. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life of the system. This is usually accomplished through such means as a vegetative filters, 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 also be included at the inflow points to an extended detention basin to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

It should be remembered that the runoff to all subsurface extended detention basins that utilize stone beds to store runoff must be pretreated. This pretreatment must provide 50 percent removal of TSS for the maximum design storm runoff to the basin. See *E. Subsurface Extended Detention Basins* in *Design Criteria* above for more information.

B. Sediment Accumulation

A properly designed extended detention basin will accumulate considerable amounts of sediment over time, leading to the loss of the detention volume and, thus, both runoff quality and quantity control effectiveness. Therefore, depending on the clean-out intervals, an increase in an extended detention basin's maximum design storm storage volume should be considered to compensate for this expected loss of storage volume. See *E. Subsurface Extended Detention Basins* in *Design Criteria* above for more information on required volume increases in subsurface basins.

C. Flow Paths

An extended detention basin relies on the process of sedimentation for removal of runoff pollutants. Therefore, the basin should be designed to maximize the degree of sedimentation. Flow path lengths should be maximized and long, narrow basin configurations with length to width ratios from 2:1 to 3:1 should be utilized. Basins that are shallow and have larger surface area to depth ratios will provide better pollutant removal efficiencies than smaller, deeper basins.

D. Wetland Creation

It may be possible to establish a wetland area in the bottom stage of an extended detention basin to increase the pollutant removal rate. See *Chapter 9.2: Standard for Constructed Stormwater Wetlands* for more information.

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New Jersey Stormwater Best Management Practices Manual

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http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm

CHAPTER 9.5

Standard for Infiltration Basins

Definition

An infiltration basin is a facility constructed within highly permeable soils that provides temporary storage of stormwater runoff. An infiltration basin does not normally have a structural outlet to discharge runoff from the stormwater quality design storm. Instead, outflow from an infiltration basin is through the surrounding soil. An infiltration basin may also be combined with an extended detention basin to provide additional runoff storage for both stormwater quality and quantity management. The adopted TSS removal rate for infiltration basins is 80 percent.

It should be noted that a dry well is a specialized infiltration facility intended only for roof runoff. See *Chapter 9.3: Standard for Dry Wells* for further details.

Purpose

Infiltration basins are used to remove pollutants and to infiltrate stormwater back into the ground. Such infiltration also helps to reduce increases in both the peak rate and total volume of runoff caused by land development. Pollutant removal is achieved through filtration of the runoff through the soil as well as biological and chemical activity within the soil.

Infiltration basins may also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of infiltration basins and other groundwater recharge facilities to meet them.

Conditions Where Practice Applies

The use of infiltration basins is applicable only where the soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, infiltration basins are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination.

Specifically, infiltration basins must not be used in the following locations:

- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied or pesticides are loaded, unloaded, or stored.
- Areas where hazardous materials are expected to be present in greater than "reportable quantities" as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where infiltration basin use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is exposed to "source material." "Source material" means any material(s) or machinery, located at an industrial facility, that is directly or indirectly related to process, manufacturing, or other industrial activities, that could be a source of pollutants in any industrial stormwater discharge to groundwater. Source materials include, but are not limited to raw materials, intermediate products, final products, waste materials, by-products, industrial machinery and fuels, and lubricants, solvents, and detergents that are related to process, manufacturing, or other industrial activities that are exposed to stormwater.

In addition, as required by the Stormwater Management Rules, infiltration basins must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Infiltration basins must be configured and located where their construction will not compact the soils below the basin. In addition, an infiltration basin must not be placed into operation until the contributing drainage area is completely stabilized. Basin construction must either be delayed until such stabilization is achieved, or upstream runoff must be diverted around the basin. Such diversions must continue until stabilization is achieved.

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

Design Criteria

The components of a typical infiltration basin are shown in Figure 9.5-1. Additional details of each component are described below.

A. Storage Volume, Depth, and Duration

An infiltration basin must be designed to treat the total runoff volume generated by the basin's maximum design storm. This may either be the groundwater recharge or stormwater quality design storm, depending upon the basin's proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. An infiltration basin must also fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the basin ineffective and may result in anaerobic conditions, odor, and both water quality and mosquito breeding problems. The bottom of the infiltration basin must be at least 2 feet above seasonal high water table or bedrock. For surface basins, this distance must be measured from the bottom of the sand layer as shown in Figure 9.5-1. The basin bottom must be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

To enhance safety by minimizing standing water depths, the vertical distance between the basin bottom and the maximum design storm water surface in surface infiltration basins should be no greater than 2 feet.

As discussed in *Considerations* below, construction of an infiltration basin must be done without compacting the basin's subgrade soils. As such, all excavation must be performed by equipment placed outside the basin whenever possible. This requirement should be considered when designing the dimensions and total storage volume of an infiltration basin.

It is important to note that the use of infiltration basins is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of infiltration basins for larger storm events and the requirements by which such basins are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

B. Permeability Rates

The minimum design permeability rate of the soils below an infiltration basin will depend upon the basin's location and maximum design storm. The use of infiltration basins for stormwater quality control is feasible only where soil is sufficiently permeable to allow a reasonable rate of infiltration. Therefore, infiltration basins designed for storms greater than the groundwater recharge storm can be constructed only in areas with Hydrologic Soil Group A and B soils. Additional permeability requirements are presented below in Table 9.5-1.

Table 9.5-1: Minimum Design Permeability Rates for Infiltration Basins

Maximum Design Storm	Basin Location	Minimum Design Permeability Rate (Inches/Hour)
Groundwater Recharge*	Subsurface	0.2
Groundwater Recharge	Surface	0.5
Stormwater Quality	Surface and Subsurface	0.5
*See text for required diversion of runoff from greater storms.		

It is important to note that, for subsurface infiltration basins that are used only for groundwater recharge (see Table 9.5-1 above), all runoff from storms greater than the basin's groundwater recharge storm must be directed around the basin by a diversion structure or device located upstream of the basin. If the basin does receive runoff and associated pollutants from greater storm events, a minimum permeability rate of 0.5 inches/hour must be used. Minor basin inflows from greater storms during normal operation of the diversion are permissible provided they represent a small percentage of the total storm runoff volume. Details of an infiltration basin's groundwater recharge storm are presented in *Chapter 6*. See *E. Online and Offline Systems* below for additional information.

In addition to the above, the design permeability rate of the soil must be sufficient to fully drain the infiltration basin's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See *A. Soil Characteristics* in *Considerations* below for more information. 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 must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soils 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 basin's maximum design storm drain time.

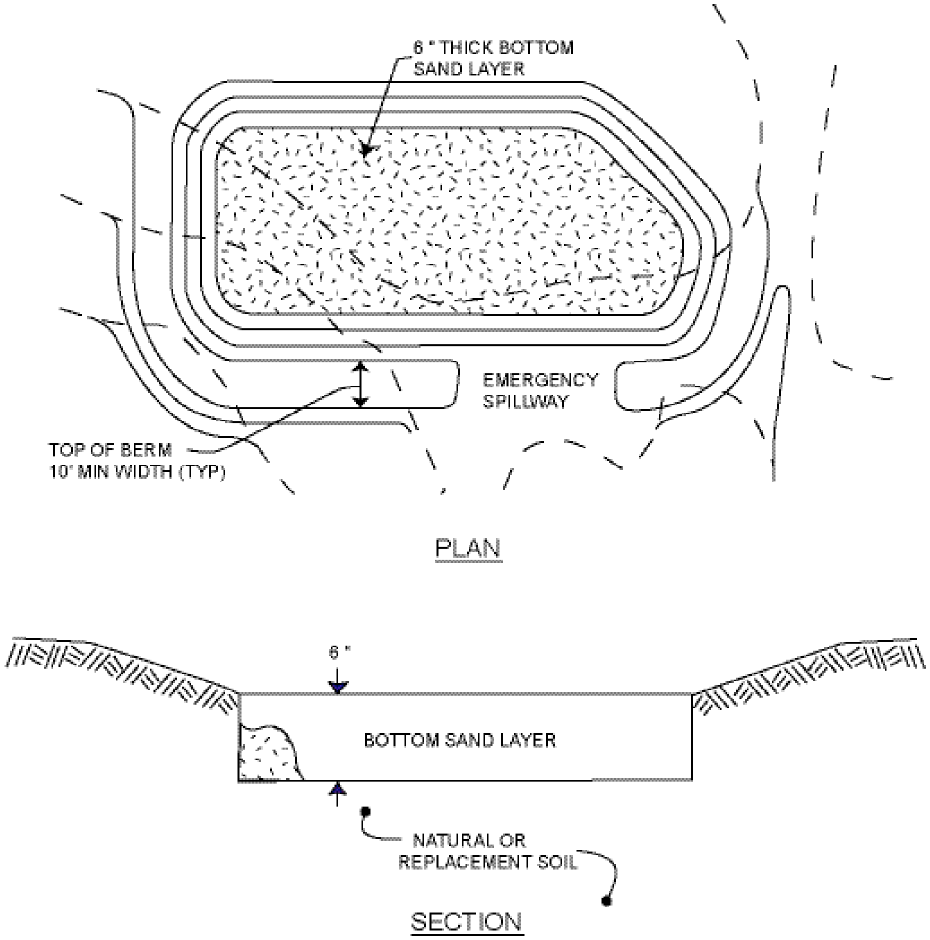
C. Bottom Sand Layer

To help ensure maintenance of the design permeability rate over time, a 6 inch layer of sand must be placed on the bottom of an infiltration basin (see Figure 9.5-1). This sand layer can intercept silt, sediment, and debris that could otherwise clog the top layer of the soil below the basin. The sand layer will also facilitate silt, sediment, and debris removal from the basin and can be readily restored following removal operations. The sand layer must meet the specifications of a K5 soil. This must be certified by a professional engineer licensed in the State of New Jersey.

D. Overflows

All infiltration basins must be able to convey overflows to downstream drainage systems in a safe and stable manner. Infiltration basins that are 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.

Figure 9.5-1: Infiltration Basin Components



NOTES

1. BOTTOM SAND LAYER MUST CONSIST OF K5 SAND WITH A MAXIMUM OF 15% FINES AND A MINIMUM PERMEABILITY RATE OF 20 INCHES PER HOUR.

2. BASIN CONSTRUCTION MUST NOT COMPACT SOILS BELOW BASIN BOTTOM.

3. SEE TEXT FOR ADDITIONAL REQUIREMENTS.

Source: Adapted from T&M Associates.

E. On-Line and Off-Line Systems

Infiltration basins may be constructed either on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the maximum design storm and conveying the runoff from larger storms through an overflow. With the proper soil and drainage area conditions, an infiltration basin may also be combined with a detention basin to provide runoff quantity control in the detention portion of the basin. 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 infiltration basins, most or all of the runoff from storms larger than the maximum design storm bypass the basin through an upstream diversion. This not only reduces the size of the required basin storage volume, but also reduces the basin's long-term pollutant loading and associated maintenance. See *B. Permeability Rates* above for additional information on diversion requirements, particularly for subsurface infiltration basins used only for groundwater recharge.

F. Subsurface Infiltration Basins

A subsurface infiltration basin is located entirely below the ground surface. It may consist of a vault, perforated pipe, and/or stone bed. However, due to the greater difficulty in removing silt, sediment, and debris, all runoff to a subsurface infiltration basin must be pretreated. This pretreatment must remove 80 percent of the TSS in the runoff from the basin's maximum design storm.

Following pretreatment, additional TSS removal can then be provided by the subsurface infiltration basin as the secondary BMP in a treatment train. Computation of the total TSS removal rate is described in *Chapter 4: Stormwater Pollution Removal Criteria*. See *A. Pretreatment* in *Recommendations* below for information on runoff pretreatment.

G. Basis of Design

The design of an infiltration basin is based upon Darcy's Law:

$$Q = KIA$$

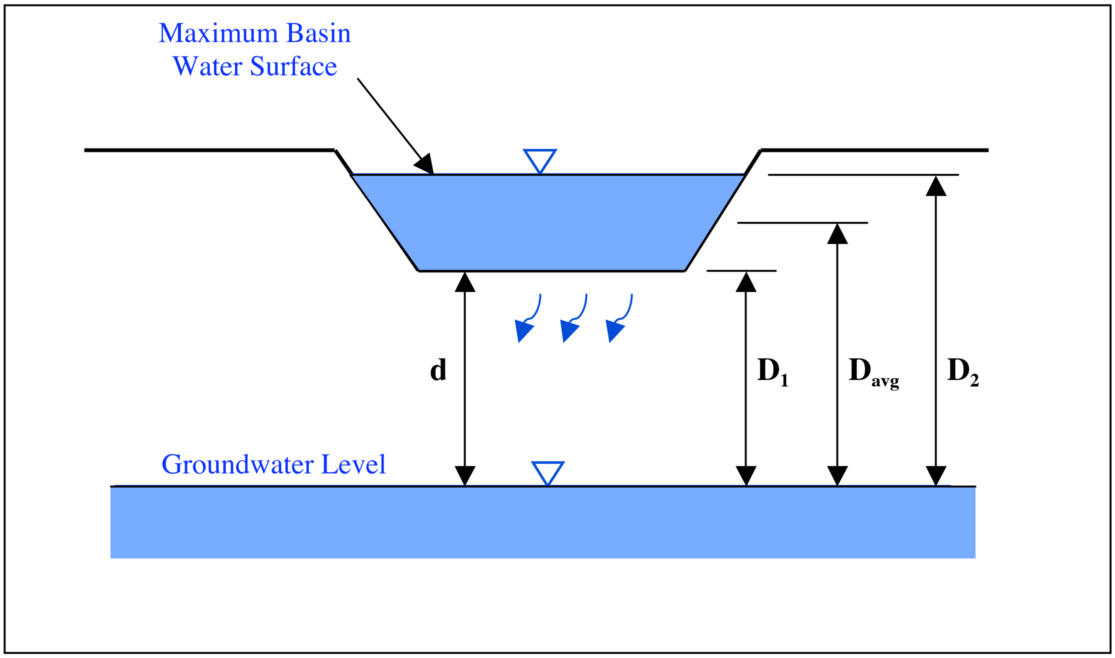
where:

Q = the rate of infiltration in cubic feet per second (cfs)
K = the hydraulic conductivity of the soil in feet per second (fps)
I = the hydraulic gradient
A = the area of infiltration in square feet (sf)

From the variables shown in Figure 9.5-2 below:

Average Hydraulic Gradient = D_{avg}/d
Minimum Hydraulic Gradient = D_1/d
Maximum Hydraulic Gradient = D_2/d

Figure 9.5-2: Schematic of Darcy's Law



The hydraulic conductivity is either field measured or laboratory measured for the soil on site. A number of percolation tests should be done to obtain a reliable measurement of permeability of the underlying soil.

Maintenance

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

A. General Maintenance

All infiltration basin 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, riprap or gabion aprons, and inflow points. This applies to both surface and subsurface infiltration basins.

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.

Studies have shown that readily visible stormwater management facilities like infiltration basins receive more frequent and thorough maintenance than those in less visible, more remote locations. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. The structure must be inspected for unwanted tree growth at least once a year.

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 season. 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 must not compromise the intended purpose of the infiltration basin. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

All vegetated areas should be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the remaining vegetation and basin subsoil.

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 bottom of the basin. This normal drain or drawdown time should then be used to evaluate the basin's actual performance. If significant increases or decreases in the normal drain time are observed, the basin's bottom surface, subsoil, 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 basin. This applies to both surface and subsurface infiltration basins.

The bottom sand layer in a surface infiltration basin should be inspected at least monthly as well as after every storm exceeding 1 inch of rainfall. The permeability rate of the soil below the basin may also be retested periodically. If the water fails to infiltrate 72 hours after the end of the storm, corrective measures must be taken. Annual tilling by light equipment can assist in maintaining infiltration capacity and break up clogged surfaces.

Considerations

Infiltration basins can present some practical design problems. When planning for an infiltration basin that provides stormwater quality treatment, consideration should be given to soil characteristics, depth to the groundwater table, sensitivity of the region, and runoff water quality. Particular care must be taken when constructing infiltration basins in areas underlain by carbonate rocks known as Karst landscapes. See Appendix A10 of the Standards for Soil Erosion and Sediment Control in New Jersey for further guidance in Karst landscape areas.

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for the planning and preliminary design of infiltration basins. However, for final design and construction, soil tests are required at the exact location of a proposed basin in order to confirm its ability to function properly without failure.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed infiltration basin. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the basin or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further subgrade soil requirements.

In addition, the results of a basin's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed infiltration basin, to ensure reasonable data consistency. If significant differences exist between the basin's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

For infiltration basins, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the infiltration basin should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During basin construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the basin.

To help prevent subgrade soil contamination and clogging by sediment, basin construction should be delayed until all other construction within in its drainage area is completed and the drainage area stabilized. This delayed construction emphasizes the need, as described above, to cordon off the basin area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of an infiltration basin as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the basin bottom. Accumulated sediment can then be removed without disturbing the subgrade soils at the basin bottom, which should be established only after all construction within the basin's drainage area is completed and the drainage area stabilized.

Once the final grading phase of a surface infiltration basin is reached, the bottom of the basin should be deeply tilled with a rotary tiller or disc harrow and then smoothed out with a leveling drag or equivalent grading equipment. These procedures should preferably be performed with equipment located outside the basin bottom. If this is not possible, it should be performed with light-weight, rubber-tired equipment.

If basin construction cannot be delayed until its drainage area is stabilized, diversion berms or other suitable measures should be placed around the basin's perimeter during all phases of construction to divert all runoff and sediment away from the basin. These diversion measures should not be removed until all construction within the basin's drainage area is completed and the drainage area stabilized.

Broken stone fill used in subsurface infiltration basins should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of infiltration basins with the contractor.

C. Runoff Quality

The quality of runoff entering an infiltration basin is a primary consideration in determining whether infiltration is advisable and, if so, in designing the basin itself. The planning of an infiltration basin must consider which pollutants will be present in the runoff and whether these pollutants will degrade groundwater quality. Certain soils can have a limited capacity for the treatment of bacteria and the soluble forms of nitrogen, phosphorus, and other pollutants like road salts and pesticides. Such pollutants are either attenuated in the soil column or go directly to the water table. Unfortunately, the soils that normally have the highest and, therefore, most suitable permeability rates also have the least ability to treat such pollutants. As a result, pretreatment of soluble pollutants prior to entry into the infiltration basin may be necessary in these soils. Pretreatment measures may include vegetative filters, bioretention systems (where the infiltration basin takes the place of the standard underdrain), and certain sand filters. Alternatively, the existing soil below the infiltration basin bottom may be augmented or replaced by soils with greater soluble pollutant removal rates.

Recommendations

A. Pretreatment

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

Forebays can be included at the inflow points to an infiltration basin to capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of system maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

As described above, it should be remembered that the runoff to all subsurface infiltration basins must be pretreated. This pretreatment must provide 80 percent removal of TSS for the maximum design storm runoff. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for additional pretreatment information for subsurface infiltration basins used for groundwater recharge.

This pretreatment requirement does not apply to roofs and other above-grade surfaces. However, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to a subsurface infiltration basin should be included wherever practical to minimize the amount of sediment and other particulates that can enter the basin.

B. Sensitivity of the Area

The planning of an infiltration basin site should consider the geologic and ecological sensitivity of the proposed site. Sensitive areas include FW1 streams, areas near drinking water supply wells, and areas of high aquifer recharge. Infiltration basins should be sited at least 100 feet from a drinking water supply well. They should also be sited away from foundations to avoid seepage problems. Measures should be taken in areas of aquifer recharge to ensure good quality water is being infiltrated to protect ground water supplies. Infiltration basins should be located away from septic systems to help prevent septic system failure and other adverse system interference.

C. Slopes

Topography of the location is an important consideration for basin operation. Ideally, basin construction should not occur where surrounding slopes are greater than 10 percent. The grading of the basin floor should be as level as possible (with the slope approaching zero) to achieve uniform spreading across the breadth and the length of the basin.

Grading and landscaping throughout the infiltration basin and its components must be designed to facilitate mowing, trimming, sediment and debris removal, and other maintenance activities.

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CHAPTER 9.6

Standard for Manufactured Treatment Devices

Definition

A manufactured treatment device is a pre-fabricated stormwater treatment structure utilizing settling, filtration, absorptive/adsorptive materials, vortex separation, vegetative components, and/or other appropriate technology to remove pollutants from stormwater runoff.

The TSS removal rate for manufactured treatment devices is based on the NJDEP certification of the pollutant removal rates on a case-by-case basis. Details are provided below. Other pollutants, such as nutrients, metals, hydrocarbons, and bacteria can be included in the verification/certification process if the data supports their removal efficiencies.

Purpose

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality treatment measure, or waterbody.

Conditions Where Practice Applies

A manufactured treatment device is adequate for small drainage areas that contain a predominance of impervious cover that is likely to contribute high hydrocarbon and sediment loadings, such as small parking lots and gas stations. For larger sites, multiple devices may be necessary. Devices are normally used for pre-treatment of runoff before discharging to other, more effective stormwater quality treatment facilities.

In addition, a manufactured treatment device must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

In addition to its certified pollutant removal rate, the basic design parameters for a manufactured treatment device will depend on the techniques it employs to remove particulate and dissolved pollutants from runoff. In general, the design of devices that treat runoff with no significant storage and flow rate attenuation must be based upon the peak design flow rate. However, devices that do provide storage and flow rate attenuation must be based, at a minimum, on the design runoff volume and, in some instances, on a routing of the design runoff hydrograph. Details of these and other design parameters are presented below.

A. Pollutant Removal Rates

The NJDEP Division of Science, Research & Technology (DSRT) is responsible for certifying final pollutant removal rates for all manufactured treatment devices. This final certification process must be based upon one of the following:

1. Verification of the device's pollutant removal rates by the N.J. Corporation for Advanced Technology (NJCAT) in accordance with the New Jersey Energy and Environmental Technology Verification Program at N.J.S.A. 13:D-134 et seq. This verification must be conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity" as developed under the Environmental Council of States (ECOS) and Technology Acceptance and Reciprocity Partnership (TARP). This stormwater protocol ensures that technologies are evaluated in a uniform manner assuring minimum standards for quality assurance and quality control (QA/QC). In addition, the protocol establishes an interstate reciprocity pathway for technology and regulatory acceptance.
2. Verification of the device's pollutant removal rates by another TARP state, or another state or government agency that is recognized by New Jersey through a formal reciprocity agreement, provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity."
3. Verification of the device's pollutant removal rates by other third party testing organizations (i.e., NSF), provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity." Other testing protocols may be considered if it is determined by the NJDEP to be equivalent to the Tier II Protocol.

It should be noted that the pollutant removal rates for a manufactured treatment device may be granted interim conditional certification by the NJDEP provided that the manufacturer submits an interim verification report through NJCAT and further agrees to apply for and complete the final certification process described above. All interim certifications are effective for a limited time period, as determined on a case-by-case basis by the NJDEP.

B. Flow Rates and Storage Volumes

To achieve its assigned TSS removal rate, a manufactured treatment device must be designed to treat the runoff generated by the stormwater quality design storm. Techniques to compute the runoff rates and volume from this storm event are discussed in *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Depending on the device's pollutant removal technique(s), the primary design parameter for a manufactured treatment device will normally be either the peak rate and/or total runoff volume from the stormwater quality design storm. Devices that convey inflow with little or no storage and provide pollutant removal only through such techniques as vortex flow, filtration, and/or absorption must be based on the peak rate of stormwater quality design storm runoff. Devices that store and convey runoff more slowly and provide pollutant removal through such techniques as sedimentation and/or filtration must also be based on the total volume of runoff. Hydraulic losses through a device must be considered in the design of all related upstream and downstream drainage system components.

C. Overflows

All manufactured treatment devices must be able to safely overflow or bypass flows in excess of the stormwater quality design storm to downstream drainage systems. The capacity of the overflow or bypass must be consistent with the remainder of the site's drainage system. All such flows must be conveyed in such a manner that trapped material, including floatables, is not resuspended and released. The designer must also check the capacity of the downstream conveyance system to ensure the adequacy of the overflow or bypass. All manufactured treatment devices must also have similar provisions to safely overflow and/or bypass runoff in the event of internal component clogging, blockage, and/or failure.

D. Tailwater

The hydraulic design of all manufactured treatment devices must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

E. Subsurface Devices

All subsurface or underground devices must be designed for HS-20 traffic loading at the surface. All joints and connections must be watertight. The manhole cover or other approved permanent marker for the treatment device must clearly indicate that it is a pollutant-trapping device. Sufficient and suitable access must be provided for each chamber in the device for inspection and maintenance activities. This must include adequate clearance from adjacent structures to allow for placement and operation of maintenance equipment. All subsurface devices must also be installed a minimum of 20 feet from a septic tank/drainage field. Any subsurface device within 20 feet of a slope greater than 2:1 requires a geotechnical review.

F. On-line and Off-line Devices

Manufactured treatment devices 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. In off-line devices, most or all of the runoff from storms larger than the stormwater quality design storm bypass the device through an upstream diversion. This not only reduces the size of the required device overflow, but also reduces the device's long-term pollutant loading and associated maintenance, and the threat of resuspension and release of trapped material by larger storm inflows.

Maintenance

Effective performance of a manufactured treatment device 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 manufactured treatment devices. Specific maintenance requirements for these devices are presented below. These requirements must be included in the device's maintenance plan.

A. General Maintenance

All manufactured treatment devices should be inspected and maintained in accordance with the manufacturer's instructions and/or recommendations and any maintenance requirements associated with the device's certification by the NJDEP Office of Innovative Technology. In addition, all device 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. 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. Vegetation

In those devices utilizing vegetation, trimming of vegetation must be performed on a regular schedule based on specific site conditions. Vegetated areas must be inspected at least annually for erosion and scour as well as unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. All use of fertilizers, mechanical treatments, pesticides, and other means to ensure optimum vegetation health in devices utilizing vegetation should not compromise the intended purpose of the device. 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 maximum level of oil, sediment, and debris accumulation allowed before removal is required. These levels should then be monitored during device inspections to help determine the need for removal and other device maintenance.

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CHAPTER 9.7

Standard for Pervious Paving Systems

Definition

Pervious paving systems are paved areas that produce less stormwater runoff than areas paved with conventional paving. This reduction is achieved primarily through the infiltration of a greater portion of the rain falling on the area than would occur with conventional paving. This increased infiltration occurs either through the paving material itself or through void spaces between individual paving blocks known as pavers.

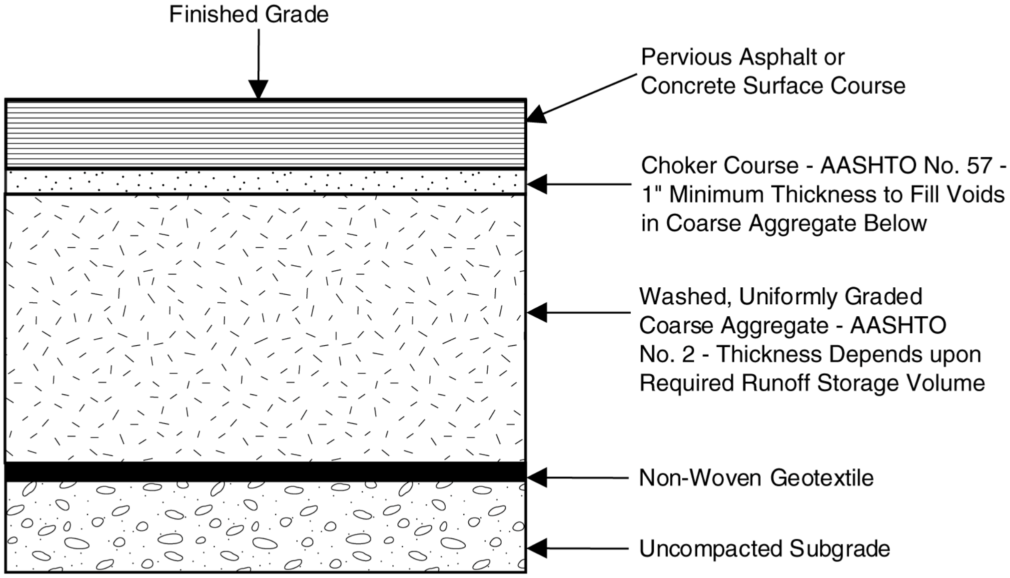
Pervious paving systems are divided into three general types. Each type depends primarily upon the nature of the pervious paving surface course and the presence or absence of a runoff storage bed beneath the surface course. These three types are summarized in Table 9.7-1 and discussed below. Porous paving and permeable paver with storage bed systems treat the stormwater quality design storm runoff through storage and infiltration. Therefore, these systems have adopted TSS removal rates similar to infiltration structures. The adopted TSS removal rate for each type of pervious paving system is presented in Table 9.7-1.

Table 9.7-1: Types of Pervious Paving Systems

Type of Paving System	General Description of Paving System	Adopted TSS Removal Rate
Porous paving	Porous asphalt or concrete paving constructed over runoff storage bed of uniformly graded broken stone	80%
Permeable pavers with storage bed	Impervious concrete pavers with surface voids constructed over runoff storage bed of uniformly graded broken stone	80%
Permeable pavers without storage bed	Impervious concrete pavers with surface voids constructed over structural bed of sand and crushed stone	Volume reduction only

Porous paving systems consist of a porous asphalt or concrete surface course placed over a bed of uniformly graded broken stone. The broken stone bed is placed on an uncompacted earthen subgrade and is used to temporarily store the runoff that moves vertically through the porous asphalt or concrete into the bed. The high rate of infiltration through the porous paving is achieved through the elimination of the finer aggregates that are typically used in conventional paving. The remaining aggregates are bound together with an asphalt or Portland cement binder. The lack of the finer aggregate sizes creates voids in the normally dense paving that allow runoff occurring on the paving to move vertically through the paving and into the void spaces of the broken stone storage bed below. From there, the stored runoff then infiltrates over time into the uncompacted subgrade soils similar to an Infiltration Basin. The depth of the bed, which also provides structural support to the porous surface course, depends upon the volume and rate of rainfall that the porous paving system has been designed to store and infiltrate and the void ratio of the broken stone. A typical detail of a porous paving system is shown in Figure 9.7-1.

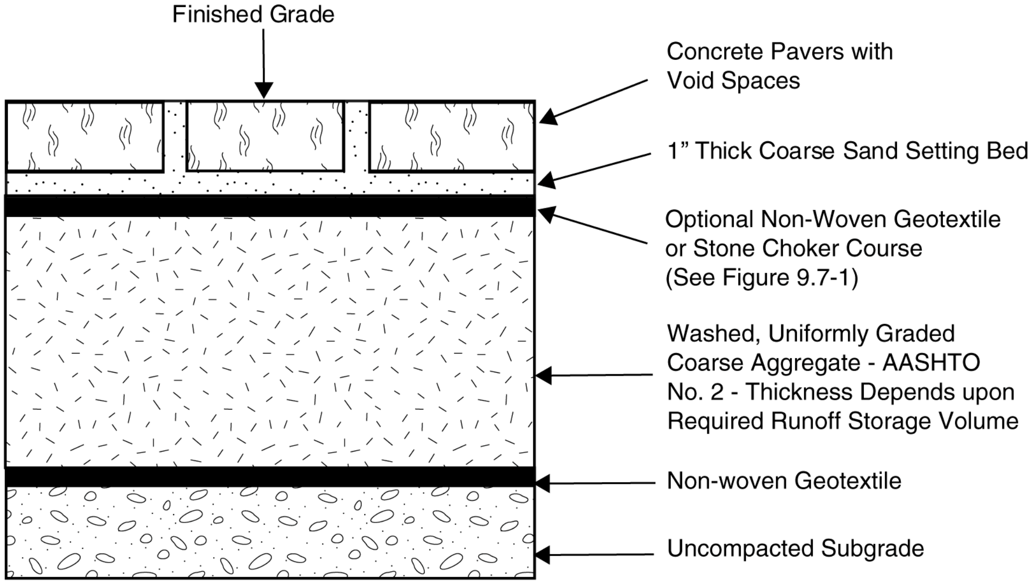
Figure 9.7-1: Porous Paving Details



Source: Cahill Associates.

A permeable paver with storage bed system also has a subsurface storage bed and functions in a similar manner to a porous paving system. However, instead of a continuous porous asphalt or concrete surface course, the system's surface consists of impervious concrete blocks known as pavers that either have void spaces cast into their surfaces or interlock in such a way as to create such void spaces. These void spaces allow runoff from the impervious paver surface to collect and move vertically past the individual pavers into the broken stone storage bed below. Similar to a porous paving system, the runoff stored in the broken stone storage bed, which also provides structural support to the pavers, then infiltrates over time into the uncompacted subgrade soils. A typical detail of a permeable paver with storage bed system is shown in Figure 9.7-2.

Figure 9.7-2: Permeable Pavers with Storage Base

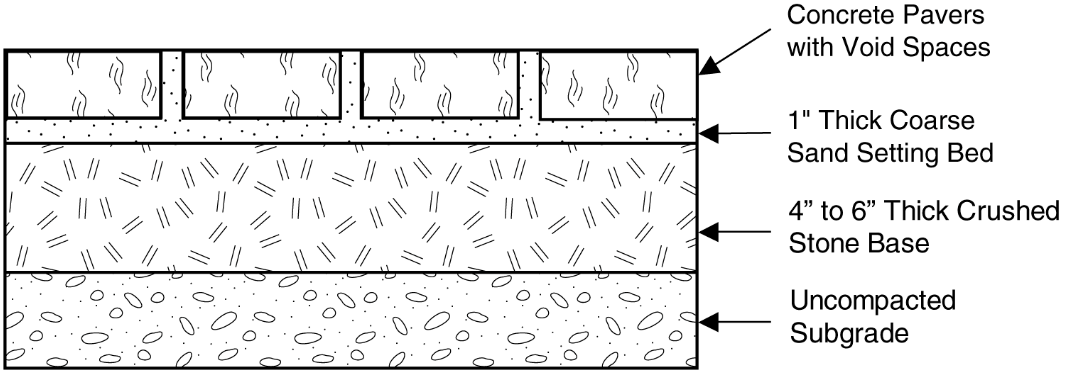


It is important to note that both a porous paving system and a permeable paver with storage bed system function in the same manner as any other infiltration-based BMP such as an infiltration basin or dry well. That is, the fundamental means of runoff quantity control is into and through the subgrade soils below the BMP. Therefore, in terms of runoff quantity control, the porous paving or permeable paver surface course acts solely as a conveyance measure that delivers the surface course runoff to the subgrade soils. In addition, the broken stone storage bed serves only to temporarily store the runoff transmitted through the surface course. For these reasons, the design and use of porous paving and permeable paver with storage bed systems are generally subject to the same design, operation, and maintenance requirements of all other infiltration-based BMPs. Details of these requirements are presented in *Design Criteria* below.

In addition to runoff volume control, porous paving and permeable paver with storage bed systems also provide stormwater quality control through the infiltration process when designed to store and infiltrate the stormwater quality design storm runoff volume. This is again similar to other infiltration-based BMPs such as infiltration basins. In addition, the porous or permeable paver surface course in such systems can be considered to provide pretreatment of the runoff to their respective subsurface storage beds.

Permeable pavers without a storage bed is the third type of pervious paving system. As described by its name, this type of system does not have a broken stone runoff storage bed beneath it. Instead, the permeable pavers are placed on a generally thinner bed of sand and crushed stone that provides only structural support to the paver surface course and has no significant runoff storage volume. This lack of storage volume prevents the system from storing and infiltrating the relatively larger volumes of runoff typically achieved by a porous paving or permeable paver with storage bed system. However, because of the void spaces in the paver surface, a portion of the runoff from the pavers, albeit smaller than the storage bed systems, can still collect in the surface voids spaces and infiltrate through the sand and crushed stone bed and into the subgrade soils. A typical detail of a permeable paver without storage bed system is shown in Figure 9.7-3.

Figure 9.7-3: Permeable Paver without Storage Base



Purpose

In general, pervious paving systems are used to reduce runoff rates and volumes from paved, on-grade surfaces such as patios, walkways, driveways, fire lanes, and parking spaces. Pervious paving systems with runoff storage beds below them achieve these reductions through the delivery and storage of runoff and eventual infiltration into the subgrade soils. Through this infiltration process, these types of pervious paving systems also achieve stormwater quality treatment.

Porous paving and permeable paver with storage bed systems may also be used to meet the groundwater recharge requirements of the NJDEP Stormwater Management Rules. See *Recharge BMP Design Guidelines* in *Chapter 6: Groundwater Recharge* for a complete discussion of these requirements and the use of pervious paving and other groundwater recharge facilities to meet them.

Permeable pavers without storage bed systems also achieve reductions in runoff rates and volumes, primarily by generating less surface runoff than conventional paving. However, due to the lack of a runoff storage bed and significant runoff infiltration, these types of pervious paving systems achieve less runoff reductions than systems with storage beds. For similar reasons, they also do not provide any significant stormwater quality treatment. However, the reduction in runoff rates and volumes they do achieve may reduce the volume of stormwater quality design storm runoff to be treated by other, downstream stormwater management facilities.

Conditions Where Practice Applies

As noted above, porous paving and permeable pavers with storage bed systems function as infiltration facilities. As such, the use of such pervious paving systems is applicable only where their subgrade soils have the required permeability rates. Specific soil permeability requirements are presented below in *Design Criteria*.

Like other BMPs that rely on infiltration, porous paving and permeable pavers with storage bed systems are not appropriate for areas where high pollutant or sediment loading is anticipated due to the potential for groundwater contamination. Specifically, such systems must not be used in the following locations:

- Industrial and commercial areas where solvents and/or petroleum products are loaded, unloaded, stored, or applied or pesticides are loaded, unloaded, or stored.

- Areas where hazardous materials are expected to be present in greater than “reportable quantities” as defined by the U.S. Environmental Protection Agency in the Code of Federal Regulations at 40 CFR 302.4.
- Areas where system use would be inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.
- Areas with high risks for spills of toxic materials such as gas stations and vehicle maintenance facilities.
- Areas where industrial stormwater runoff is exposed to “source material.” “Source material” means any material(s) or machinery, located at an industrial facility, that is directly or indirectly related to process, manufacturing, or other industrial activities, that could be a source of pollutants in any industrial stormwater discharge to groundwater. Source materials include, but are not limited to raw materials, intermediate products, final products, waste materials, by-products, industrial machinery and fuels, and lubricants, solvents, and detergents that are related to process, manufacturing, or other industrial activities that are exposed to stormwater.

In addition, as required by the Stormwater Management Rules, porous paving and permeable pavers with storage bed systems must not be used where their installation would create a significant risk for basement seepage or flooding, cause surficial flooding of groundwater, or interfere with the operation of subsurface sewage disposal systems and other subsurface structures. Such adverse impacts must be assessed and avoided by the design engineer.

Porous paving and permeable pavers with storage bed systems must be configured and located where their construction will not compact the soils below the system. In addition, such systems must not be placed into operation until the contributing drainage area is completely stabilized. System construction must either be delayed until such stabilization is achieved, or upstream runoff must be diverted around the system. Such diversions must continue until stabilization is achieved.

Due to the reduced shear strength of the surface course, all pervious paving systems are limited to areas of relatively infrequent use by light vehicles. This includes parking lot spaces and secondary aisles, single family residential driveways, sidewalks and walkways, golf cart paths, fire and emergency access lanes, and overflow parking areas. In general, they should not be used in high traffic areas such as roadways, multiple family and nonresidential driveways, and primary parking lot aisles or in any area subject to use by heavy vehicles and other equipment.

One pervious paving use strategy is to alternate areas with impervious and pervious paving. In these instances, conventional paving would be reserved for the heavily trafficked corridors. A wide variety of concrete and brick permeable paving systems are available. These can be combined with conventional and porous paving systems to achieve functional and aesthetically pleasing designs.

Finally, all three types of pervious paving systems must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

The design criteria for pervious paving systems will depend upon the type of system to be used. Details of each system type are presented in Figures 9.7-1, 9.7-2, and 9.7-3 above. Design criteria for each type are presented below.

A. Storage Volume, Depth, and Duration

Porous paving and permeable paver with storage bed systems must be designed to treat the total runoff volume generated by the system's maximum design storm. This may be either the groundwater recharge or stormwater quality design storm depending upon the system's proposed use. Techniques to compute these volumes are discussed in *Chapter 6: Groundwater Recharge* and *Chapter 5: Computing Stormwater Runoff Rates and Volumes*. Such systems must also all fully drain this runoff volume within 72 hours. Runoff storage for greater times can render the systems ineffective and may result in anaerobic conditions and water quality problems. The bottom of these types of pervious paving systems must be at least 2 feet above seasonal high water table or bedrock. This distance must be measured from the bottom of the storage bed as shown in Figures 9.7-1 and 9.7-2. The system bottom must be as level as possible to uniformly distribute runoff infiltration over the subgrade soils.

As discussed in *Considerations* below, construction of all pervious paving systems must be done without compacting the system's subgrade soils. As such, all excavation must be performed by equipment placed outside the system's limits whenever possible. This requirement should be considered when designing the dimensions and total volume of a system's broken stone storage bed or crushed stone base.

It is important to note that the use of both porous paving and permeable pavers with storage bed systems is recommended in this manual only for the stormwater quality design storm and smaller storm events. Use of such systems for larger storm events and the requirements by which such systems are to be designed, constructed, and maintained should be reviewed and approved by all applicable reviewing agencies.

Since permeable paver without storage bed systems do not rely on significant runoff infiltration, they may be used for all frequency storm events.

B. Permeability Rates

The minimum design permeability rate of the soils below porous and permeable paving systems with storage beds will depend upon the pervious paving system's location and maximum design storm. The use of storage beds for stormwater quality control is feasible only where the soil is sufficiently permeable to allow a reasonable rate of infiltration. Therefore, porous paving and permeable paver with storage bed systems can be constructed only in areas with Hydrologic Soil Group A and B soils.

For porous paving and permeable paver with storage bed systems, the minimum design permeability rate of the subgrade soils below a system's runoff storage bed is 0.5 inches per hour. In addition, the design permeability rate of the soils must be sufficient to fully drain the system's maximum design storm runoff volume within 72 hours. This design permeability rate must be determined by field or laboratory testing. See *A. Soil Characteristics* in *Considerations* below for more information. 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 must be applied to the tested permeability rate to determine the design permeability rate. Therefore, if the tested permeability rate of the soils 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 maximum design storm drain time.

Due to its role as a runoff conveyance measure to the storage bed below, the porous surface course of a porous paving system must have a minimum permeability rate at least twice the maximum intensity of the system's design storm. In the case of systems designed for the stormwater quality design storm, this permeability rate would be 6.4 inches per hour (i.e., 2 X 3.2 inches per hour, which is the stormwater quality design storm's maximum intensity). Similarly, the minimum permeability of the material used to fill the void spaces of a permeable paver with storage bed system must also meet this requirement. However, since the void spaces in a permeable paver system comprise only a portion of the entire system surface, this minimum rate must be multiplied by the ratio of the entire system surface area to the area of the void spaces. Therefore, the void space material in a permeable paver with storage bed system comprised of 20 percent void space must have a minimum permeability of 2 X (1.0/0.2) or 10 times the maximum design storm intensity. For such systems designed for the stormwater quality design storm, this rate would be 3.2 X 10 or 32 inches per hour.

Since a permeable paver without storage bed system does not rely on significant runoff infiltration, its use does not require a minimum subgrade soil or void space material permeability rate. However, as described below, its ability to reduce runoff rates and volumes below those produced by conventional paving will depend upon both of these system characteristics.

To allow pervious paving surface courses to achieve their design permeability rates, the maximum surface course slope of all pervious paving systems is 5 percent.

C. Pretreatment

As with all other best management practices, pretreatment can extend the functional life and increase the pollutant removal capability of a pervious paving system that receives runoff from areas other than its own surface course. Pretreatment can reduce incoming velocities and capture coarser sediments, which will extend the life and reduce the required maintenance of the system. This is usually accomplished through the use of a vegetative filter immediately upstream of the pervious paving system. Steps can also be taken during the system's design to limit the amount of runoff from upstream areas that will flow to the system.

Runoff collected from parking lots, driveway, roads, and other on-grade surfaces that is conveyed directly to a porous paving or permeable paver storage bed without passing through the system's surface course must be pretreated in order to prevent the loss of storage volume and/or recharge capacity due to sedimentation and clogging. Such pretreatment must provide 80 percent removal of TSS for the system's maximum design storm runoff. This treatment can also be used to meet the site's overall TSS removal requirements.

This pretreatment requirement does not apply to roofs and other above-grade surfaces. However, roof gutter guards and/or sumps or traps (equipped with clean-outs) in the conduits to the system's storage bed should be included wherever practical to minimize the amount of sediment and other particulates that can enter the storage bed.

D. Computing Runoff Rates

In general, runoff to downstream areas from porous paving and permeable paver with storage bed systems will need to be computed under two circumstances. The first occurs when the capacity of the runoff storage bed is exceeded and the water level in the bed rises to the system's surface course. The second circumstance occurs when the intensity of precipitation exceeds the minimum permeability of the system's surface course. See *B. Permeability Rates* above for a discussion of these rates for each type of storage bed system. Once either or both of these circumstances occurs, the resultant system runoff rate to downstream areas for the remainder of the storm can be determined by subtracting the minimum system permeability rate from the rainfall rate. In the case of variable rate storm events such as the stormwater quality design storm or the NRCS Type III Storm, this must be done in a series of appropriate-length time increments over the remaining storm duration.

Runoff from permeable paver without storage bed systems must be computed for all storm events and can be performed by two methods. The first method is based upon a weighted average runoff coefficient (C) for the Rational or Modified Rational Methods or a weighted average Curve Number (CN) for the NRCS methodology. These values should be based upon the relative areas of the impervious pavers and pervious void spaces in the system's surface. The C or CN value for the paver area should be based upon an impervious surface, while the C or CN value for the void space should be based upon the type of material or surface cover in the void space and the Hydrologic Soil Group of the subgrade soil. In selecting this void space coefficient, all void spaces with vegetated covers should be assumed to be in poor hydrologic condition and all void spaces with bare soil or gravel fill should be based upon soil or gravel roadways.

The second method of computing runoff from permeable paver without storage bed systems considers the pavers to be unconnected impervious areas that drain onto the pervious void spaces. The resultant runoff from the system can then be based upon the unconnected impervious surface methods described in *Chapter 5*. In doing so, the criteria for selecting the appropriate CN for the void space must be based upon the criteria described in the preceding paragraph. In addition, it should be noted that the TR-55 method for unconnected impervious areas as described in *Chapter 5* cannot be used if the void space area is less than 70 percent of the total system area (i.e., the impervious portion of the entire system area exceeds 30 percent).

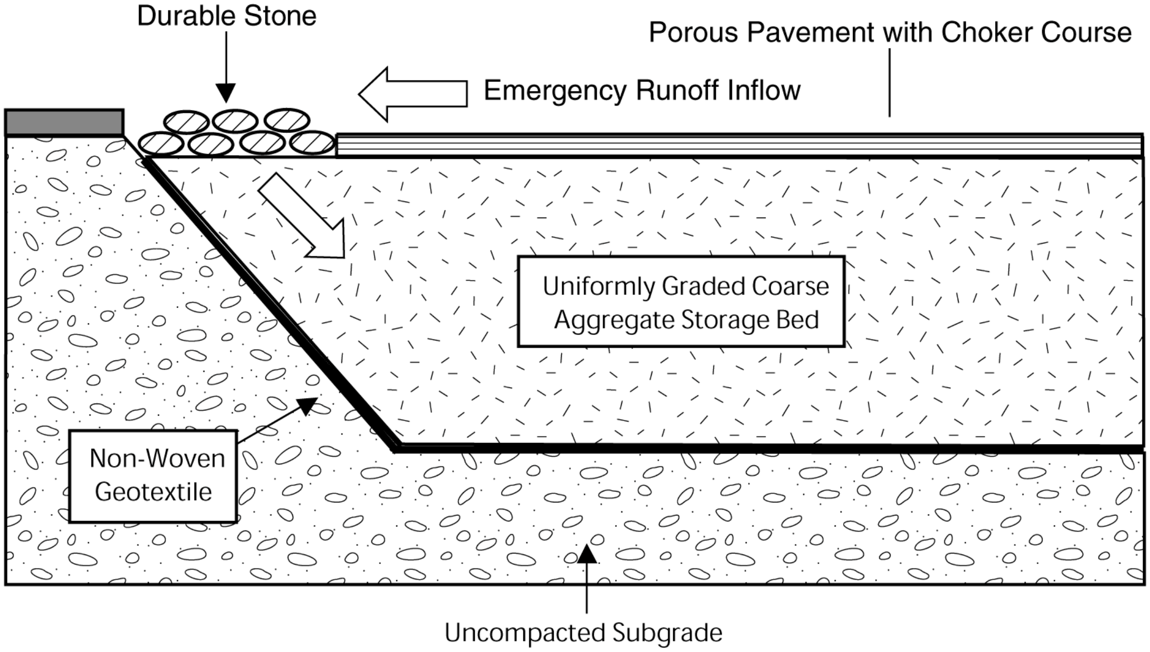
E. Overflows

All porous paving and permeable paver with storage bed systems must be able to safely convey system overflows to 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. The downstream drainage system must have sufficient capacity to convey the overflow from the pervious paving system.

F. Emergency Inflows

All porous paving and permeable paver with storage bed systems must have measures that will allow runoff from the maximum design storm to enter the runoff storage bed in the event that the porous or permeable paver surface course becomes clogged or otherwise incapable of conveying the maximum design storm runoff to the bed. This may be accomplished in different ways, including surface drain inlets connected to a series of perforated pipes laid throughout the storage bed or by extending the storage bed beyond the edge of the surface course and connecting it to the surface as shown in Figure 9.7-4.

Figure 9.7-4: Example of Porous Paving Emergency Inflow



Note: Emergency inflow may also be provided by surface drain inlets and perforated pipes in the storage bed. See text for details.

Source: Cahill Associates.

G. System Components

The typical components of each type of pervious paving system are shown in Figures 9.7-1, 9.7-2 and 9.7-3. While variations are permissible based upon specific site conditions, the typical system components shown in these figures should be included in all system designs. This includes the sand and crushed stone base below a permeable paver without storage bed system shown in Figure 9.7-3. All such systems constructed without these components must be treated as conventional paved surfaces for the purpose of all runoff and pollutant load computations.

The recommended aggregate for porous asphalt and concrete paving systems are shown in Table 9.7-2. For porous asphalt systems, the recommended amount of asphalt binder is 5.75 to 6.00 percent by weight. Lower amounts of binder have resulted in inadequate surface course shear strength and durability. As shown in Figures 9.7-1 and 9.7-2, the runoff storage beds in both porous paving and permeable paver with storage bed systems should be clean washed, uniformly graded AASHTO No. 2 broken stone. It is particularly important that this stone be washed to keep stone dust and other fine particles that can clog the surface of the subgrade soils from entering the storage bed. The interface between the porous or permeable paver surface course and the storage bed stone should be leveled with a choker course of AASHTO No. 57 broken stone with a minimum thickness of 1 inch. Finally, as shown in Figures 9.7-1 and 9.7-2, the interface between the storage bed stone and the subgrade soil should be lined with a non-woven geotextile. Additional system details are shown in the figures.

Table 9.7-2 – Porous Asphalt Paving Mix

U.S. Standard Sieve Size	Percent Passing
1/2 inch	100%
3/8 inch	95%
#4	35%
#8	15%
#16	10%
#30	2%

Source: Cahill Associates

Maintenance

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

General Maintenance

The surface course of all pervious paving systems must be inspected for cracking, subsidence, spalling, deterioration, erosion, and the growth of unwanted vegetation at least once a year. Remedial measures must be taken as soon as practical.

Care must be taken when removing snow from the pervious paving surface courses. Pervious paving surface courses can be damaged by snow plows or loader buckets that are set too low to the ground. This is particularly true at permeable paver systems where differential settlement of pavers has occurred. Sand, grit, or cinders should not be used on pervious paving surface courses for snow or ice control.

If mud or sediment is tracked onto the surface course of a pervious paving system, it must be removed as soon as possible. Removal should take place when the surface course is thoroughly dry. Disposal of debris, trash, sediment, and other waste matter removed from pervious paving surface courses should be done at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

B. Porous Paving Systems

The surface course of a porous paving system must be vacuum swept at least four times a year. This should be following by a high pressure hosing. All dislodged sediment and other particulate matter must be removed and properly disposed.

C. Permeable Paver Systems

Maintenance of permeable pavers should be consistent with the manufacturer's recommendations.

D. Vegetation

Mowing and/or trimming of turf grass used with permeable pavers must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. All 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 paver 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, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of a pervious paving system. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

E. 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 pervious paving system's surface course. 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 various system components and groundwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the system.

Considerations

Pervious paving systems can present some practical design problems, particularly those with subsurface runoff storage beds that rely on infiltration to discharge the stored runoff. When planning such systems, consideration should be given to soil characteristics, depth to the seasonal high groundwater table, sensitivity of the region, and runoff quality. Particular care must be taken when constructing all pervious paving systems in areas underlain by carbonate rocks known as Karst landscapes. See Appendix A10 of the Standards for Soil Erosion and Sediment Control in New Jersey for further guidance in Karst areas. Further considerations are presented below.

A. Soil Characteristics

Soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys can be used to obtain necessary soil data for system planning purposes, the preliminary design of all pervious paving systems, and the final design of permeable paver without storage bed systems. However, for the final design and construction of porous paving and permeable paver with storage bed systems, soil tests are required at the exact location of a proposed system in order to confirm its ability to function properly without failure.

Such tests should include a determination of the textural classification and permeability of the subgrade soil at and below the bottom of the proposed system's storage bed. The recommended minimum depth for subgrade soil analysis is 5 feet below the bottom of the storage bed or to the groundwater table. Soil permeability testing can be conducted in accordance with the Standards for Individual Subsurface Sewage Disposal Systems at N.J.A.C. 7:9A. See *Design Criteria* above for further subgrade soil requirements.

In addition, the results of a system's soil testing should be compared with the County Soil Survey data used in the computation of development site runoff and the design of specific site BMPs, including the proposed pervious paving system, to ensure reasonable data consistency. If significant differences exist between the system's soil test results and the County Soil Survey data, additional development site soil tests are recommended to determine and evaluate the extent of the data inconsistency and the need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such redesign to help ensure that the final site soil data is accurate.

B. Construction

Similar to other infiltration facilities, the construction of all pervious paver systems must follow certain procedures and sequences. Additional construction requirements are also required for specific systems due to their particular nature and components. Details are provided below.

1. All Pervious Paving Systems

For all pervious paving systems, protection of the subgrade soils from compaction by construction equipment and contamination and clogging by sediment are vital. Prior to its construction, the area to be used for the pervious paving system should be cordoned off to prevent construction equipment and stockpiled materials from compacting the subgrade soils. During system construction, precautions should be taken to prevent both subgrade soil compaction and sediment contamination. All excavation should be performed with the lightest practical excavation equipment. All excavation equipment should be placed outside the limits of the system's storage bed or base.

To help prevent subgrade soil contamination and clogging by sediment, system construction should be delayed until all other construction within in its drainage area is completed and the drainage area stabilized. This delayed construction emphasizes the need, as described above, to cordon off the system area to prevent compaction by construction equipment and material storage during other site construction activities. Similarly, use of a pervious paving system area as a sediment basin is strongly discouraged. Where unavoidable, excavation for the sediment basin should be a minimum of 2 feet above the final design elevation of the system's storage bed or base. Accumulated sediment can then be removed without disturbing the subgrade soils at the system's bottom, which should be established only after all construction within the system's drainage area is completed and the drainage area stabilized.

If system construction cannot be delayed until its drainage area is stabilized, diversion berms or other suitable measures should be placed around the system's perimeter during all phases of construction to divert all runoff and sediment away from the system. These diversion measures should not be removed until all construction within the system's drainage area is completed and the drainage area stabilized.

A preconstruction meeting should be held to review the specific construction requirements and restrictions of all pervious paving systems with the contractor.

2. Porous Paving Systems

Broken stone in runoff storage beds should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. In addition, the following construction requirements for porous asphalt paving systems are recommended by the USEPA:

- Paving temperature = 240° to 260° F.
- Minimum air temperature for paving = 50° F.
- Compact paving with one to two passes with 10-ton roller.
- No vehicular use for a minimum of two days after paving completed.

3. Permeable Paver Systems

Broken stone in runoff storage beds should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. In order to provide the runoff quantity and quality benefits described above in *Definition*, the subgrade soils below all permeable paver systems cannot be stabilized through compaction or with cement or other stabilizing agents that reduce the soils' permeability. All permeable paver systems constructed with such stabilization must be treated as conventional paved surfaces for the purpose of all runoff and pollutant load computations.

C. Runoff Quality

The quality of the runoff entering a porous paving or permeable paver with storage bed system is a primary consideration in determining whether such systems are advisable and, if so, in designing the systems themselves. The planning of such systems must consider which pollutants will be present in the runoff and whether these pollutants will degrade groundwater quality. Certain soils can have a limited capacity for the treatment of bacteria and the soluble forms of nitrogen, phosphorus, and other pollutants like road salts and pesticides. Such pollutants are either attenuated in the soil column or go directly to the water table. Unfortunately, the soils that normally have the highest and, therefore, most suitable permeability rates also have the least ability to treat such pollutants. As a result, pretreatment of soluble pollutants prior to entry into a pervious paving system's storage bed may be necessary in these soils. Pretreatment measures may include vegetated filter strips, bioretention systems (where the infiltration basin takes the place of the standard underdrain), and certain sand filters. Alternatively, the existing soil below the infiltration basin bottom may be augmented or replaced by soils with greater soluble pollutant removal rates.

Recommendations

A. Sensitivity of the Area

Since they rely on runoff infiltration, the planning of porous paving or permeable paver with storage bed systems should consider the geologic and ecological sensitivity of the proposed site. Sensitive areas include FW1 streams, areas near drinking water supply wells, and areas of high aquifer recharge. Such pervious paving systems should be sited at least 100 feet from a drinking water supply well. They should also be sited away from foundations to avoid seepage problems. Measures should be taken in areas of aquifer recharge to ensure good quality water is being infiltrated to protect groundwater supplies. Porous paving and permeable paver with storage bed systems should also be located away from septic systems to help prevent septic system failure and other adverse system interference.

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http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm

CHAPTER 9.9

Standard for Sand Filters

Definition

A sand filter consists of a forebay and underdrained sand bed. It can be configured as either a surface or subsurface facility. Runoff entering the sand filter is conveyed first through the forebay, which removes trash, debris, and coarse sediment, and then through the sand bed to an outlet pipe. Sand filters use solids settling, filtering, and adsorption processes to reduce pollutant concentrations in stormwater. The adopted TSS removal rate for sand filters is 80 percent.

Purpose

Sand filters are normally used to remove relatively large amounts of sediments, metals, hydrocarbons, and floatables from stormwater runoff.

Conditions Where Practice Applies

Sand filters are normally used in highly impervious areas with relatively high TSS, heavy metal, and hydrocarbon loadings such as roads, driveways, drive-up lanes, parking lots, and urban areas. However, due to their relatively high sediment removal capabilities, sand filters are not generally recommended in pervious drainage areas where high coarse sediment loads and organic material such as leaves can quickly clog the sand bed. Where such loadings cannot be avoided, pretreatment is recommended. Since sand filters can be located underground, they can also be used in areas with limited surface space.

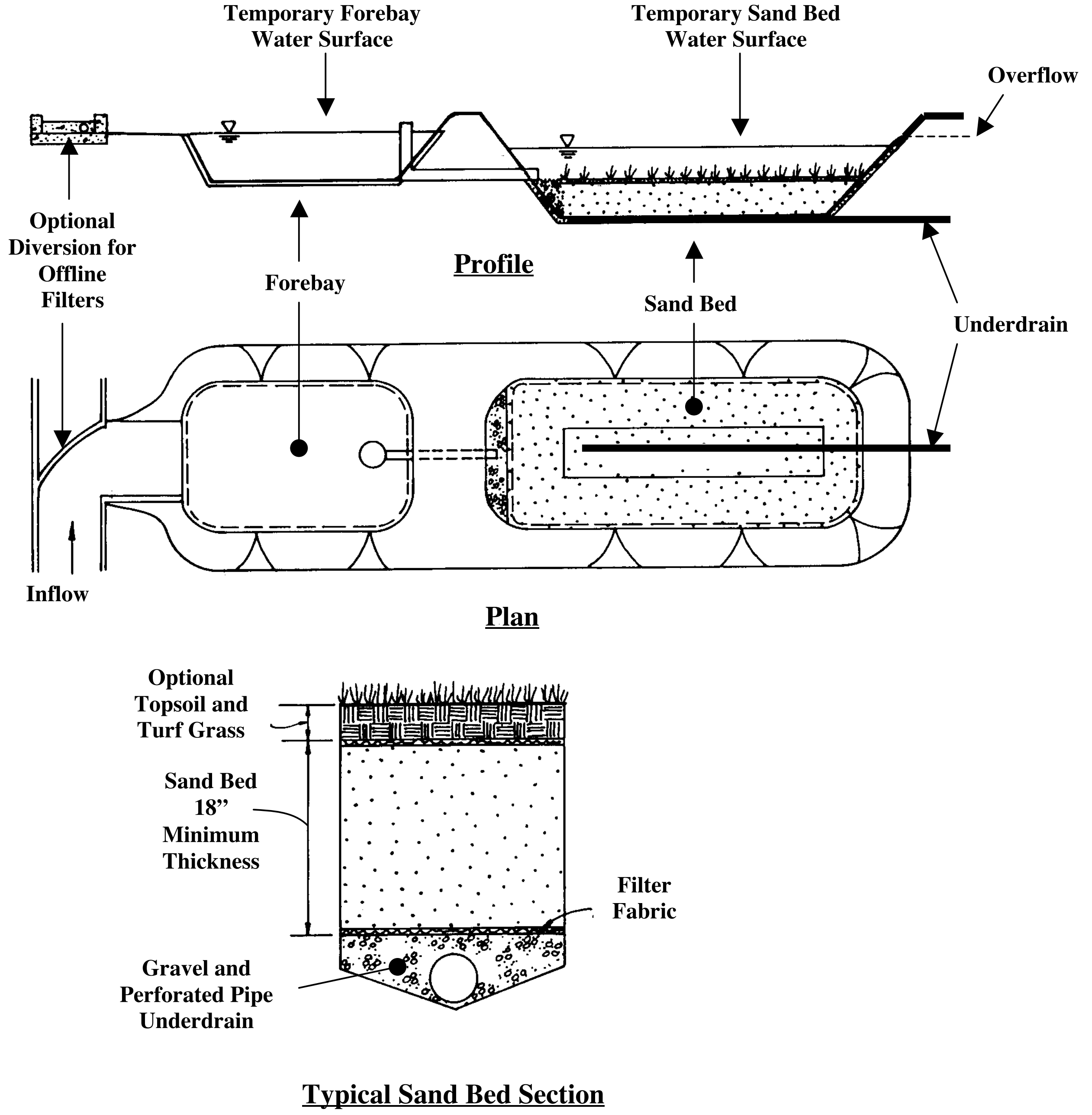
A sand filter must have a maintenance plan and, if privately owned, should be protected by easement, deed restriction, ordinance, or other legal measures that prevent its neglect, adverse alteration, and removal.

Design Criteria

In general, all sand filters consist of four basic components or zones: 1) Forebay Zone, 2) Sand Bed Zone, 3) Sand Bed Underdrain, and 4) Overflow. These and other typical sand filter components are shown in Figures 9.9-1, 2, and 3. These figures depict, respectively, a surface, subsurface, and perimeter sand filter, which are the three sand filter types discussed in this manual.

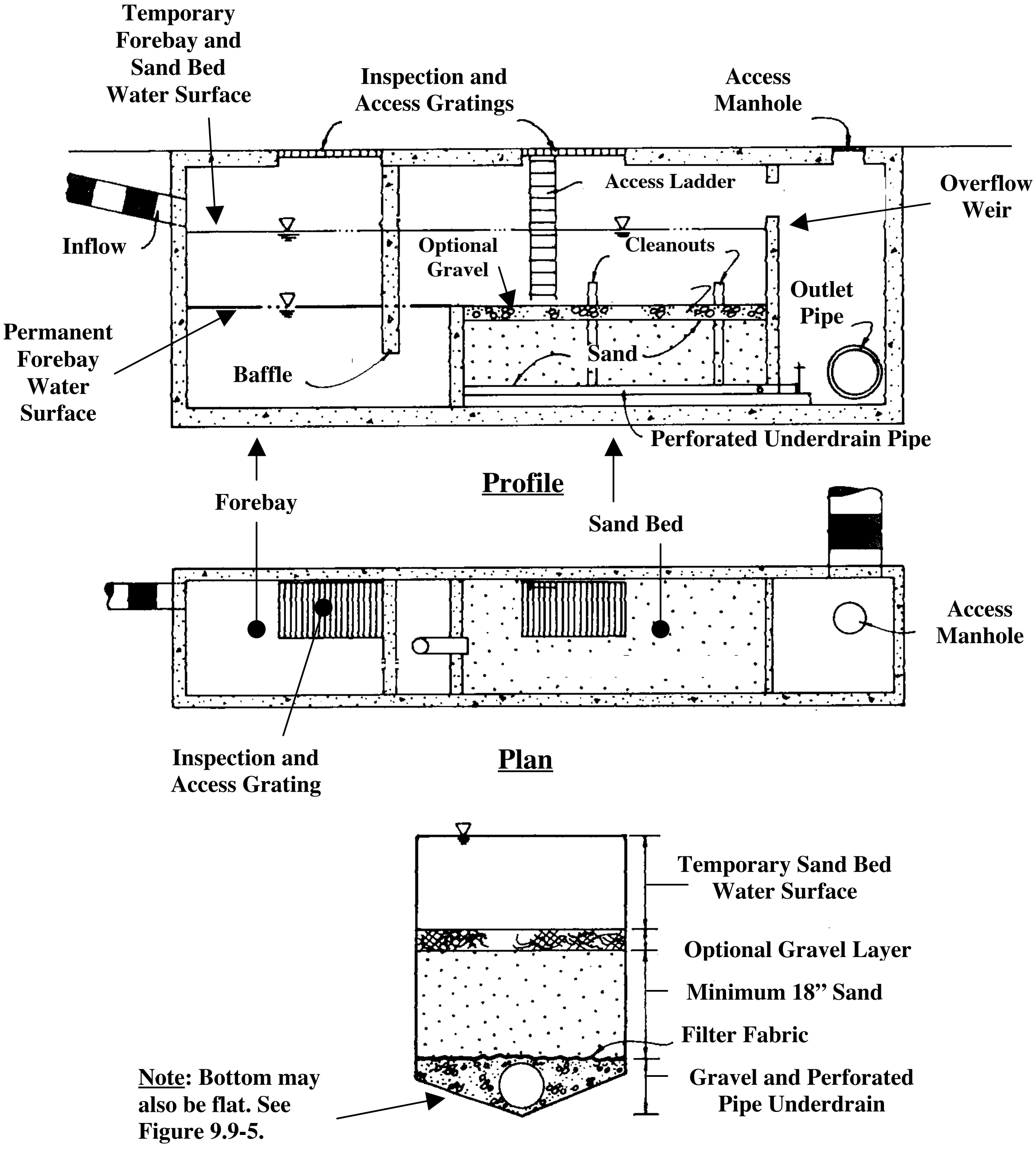
The basic design parameters for all three of these sand filter types are the surface areas and the temporary storage volumes in their forebay and sand bed zones and the thickness and infiltration rate of their sand beds. There must be sufficient total temporary storage volume within the forebay and sand bed zones (including the sand bed itself) to contain the design runoff volume and direct it thought the sand bed without overflow. The thickness of the sand bed must provide adequate pollutant removal, while the bed's permeability or infiltration rate must be sufficient to drain the stored runoff within 72 hours. In addition, the capacity of the sand bed underdrain must allow the sand bed to drain freely, while the overflow must safely convey the runoff from storms greater than the design storm. Details of these and other design parameters are presented below.

Figure 9.9-1: Typical Surface Sand Filter Components



Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-2: Typical Subsurface Sand Filter Components



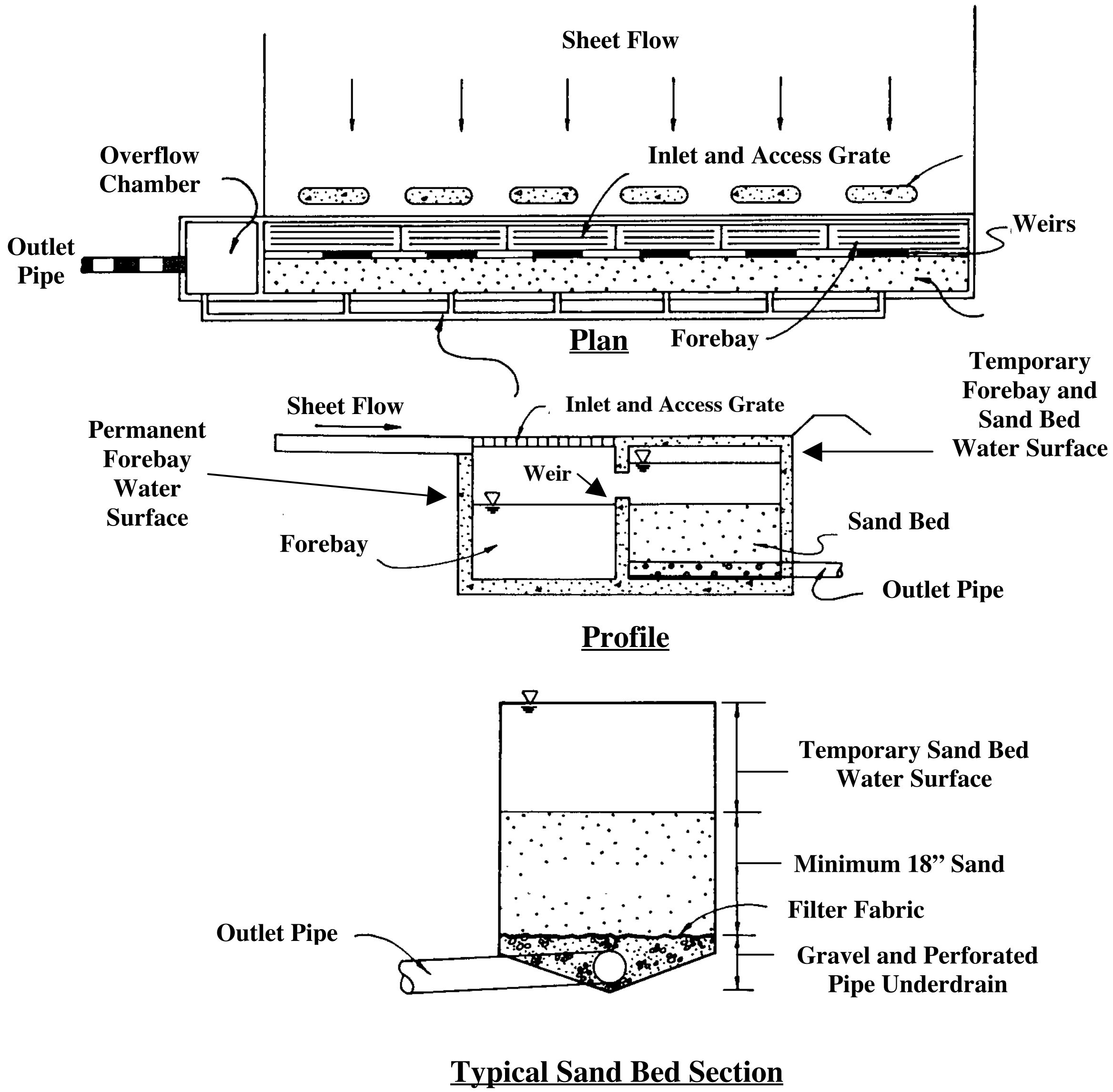
Profile

Plan

Typical Sand Bed Section

Source: Adapted from Claytor and Schueler, 1996.

Figure 9.9-3: Typical Perimeter Sand Filter Components



Note: Bottom may also be flat.
See Figure 9.9-5.

Source: Adapted from Claytor and Schueler, 1996.

A. Storage Volume and Duration

Sand filters must be designed to treat 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 time required to fully drain the stormwater quality design storm runoff volume is 72 hours. As shown in Table 9.9-1, a design drain time of 36 hours must be used when designing the sand bed.

B. Component Dimensions, Areas, and Volumes

The required volumes, areas, and dimensions of the various sand filter components are shown in Table 9.9-1. Several of these parameters are depicted in Figure 9.9-4.

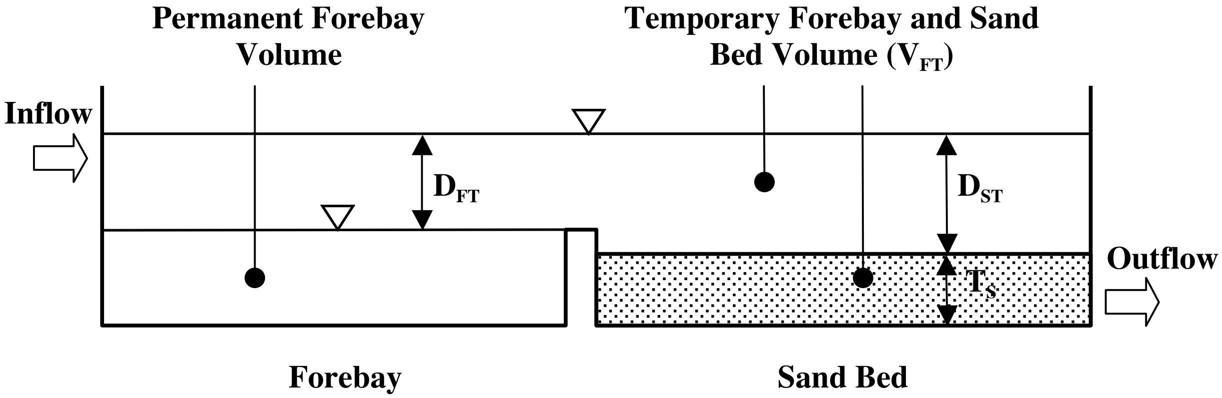
Table 9.9-1: Typical Sand Filter Design Parameters

#	Parameter Description	Parameter	Parameter Value		
			Surface Filter	**Subsurface Filter**	**Perimeter Filter**
1	Total Temporary Volume in Forebay and Sand Bed Zones[1]	V_{QS}	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume	Stormwater Quality Design Storm Runoff Volume
2	Approximate Temporary Sand Bed Volume[2]	V_{ST}	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$
3	Minimum Sand Bed Thickness	TH_S	18 Inches	18 Inches	18 Inches
4	Sand Bed Design Porosity	n	0.3	0.3	0.3
5	Sand Bed Design Permeability	k	4 Feet per Day	4 Feet per Day	4 Feet per Day
6	Sand Bed Design Drain Time	T_D	1.5 Days	1.5 Days	1.5 Days
7	Minimum Sand Bed Surface Area	A_S	See Equation 9.9-1	See Equation 9.9-1	See Equation 9.9-1
8	Approximate Temporary Forebay Volume[3]	V_{FT}	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$	$(0.5)(V_{QS})$
9	Minimum Forebay Surface Area	A_F	$(0.05)(V_{QS})$	$(0.05)(V_{QS})$	$(0.05)(V_{QS})$
10	Minimum Temporary Forebay Depth	D_{FT}	2 Feet	N/A	N/A
11	Minimum Permanent Forebay Depth	D_{FP}	N/A[4]	2 Feet	2 Feet
12	Overall Minimum Length to Width Ratio	L/W	2	2	N/A

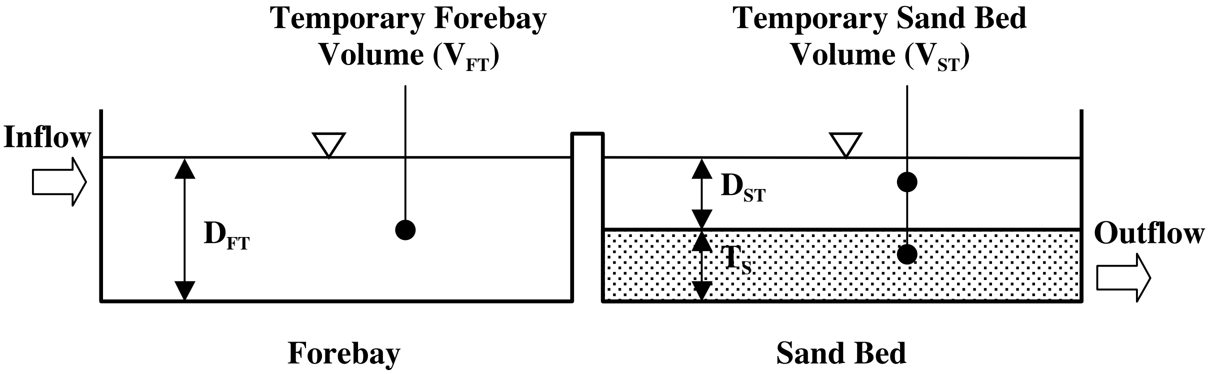
Notes:

1. Includes temporary storage volume in sand, but excludes storage volume in forebay permanent pool.
2. Includes temporary storage volume in sand.
3. Excludes storage volume in forebay permanent pool.
4. Forebay in surface sand filter typically does not have permanent pool.

Figure 9.9-4: Sand Filter Schematics



Schematic for Subsurface and Perimeter Sand Filters



Schematic for Surface Sand Filters

Source: Adapted from Claytor and Schueler, 1996.

C. General Design Procedure

Due to the number of design parameters, the design of a sand filter is generally a trial and error process to some degree. Utilizing the design parameters in Table 9.9-1 and the sand filter schematics shown in Figure 9.9-4, the general design procedure for sand filters is as follows:

1. Determine the runoff volume (V_{QS}) and peak discharge rate (Q_{QDS}) to the sand filter for the stormwater quality design storm. From Line 1 in Table 9.9-1, the total temporary storage volume in the sand filter's forebay and sand bed zones (including the storage volume within the sand bed, but excluding any permanent forebay storage volume) must equal V_{QS}.
2. Determine the approximate required volumes of the sand filter's forebay and sand bed zones. As shown on Lines 2 and 8 in Table 9.9-1, these volumes should each be approximately equal to one half of the stormwater quality design storm runoff volume (V_{QS}).
3. Estimate the maximum temporary depths in the sand bed (D_{ST}) and forebay (D_{FT}) zones for the stormwater quality design storm. This estimate should be based on an analysis of site conditions, including the difference between the invert elevation of the downstream conveyance system and the maximum ground elevation at the filter site. Analysis of this elevation difference should include consideration for the minimum sand bed thickness (T_{HS}) on Line 3 and either the minimum temporary forebay depth (D_{FT}) for surface filters on Line 10 or the permanent forebay depth (D_{FP}) for subsurface and perimeter filters on Line 11 of Table 9.9-1. As shown in Figure 9.9-4, the maximum temporary depth in the sand bed zone (D_{ST}) is measured from the top of the sand bed, while the maximum temporary forebay depth (D_{FT}) is measured from any permanent forebay water surface.
4. Compute the minimum forebay surface area (A_F). As shown on Line 9 of Table 9.9-1, this minimum area is $(0.05)(V_{QS})$. It should be noted that the 0.05 multiplier in the equation has the units of area per volume or L^2/L^3. As such, the equation yields square feet of forebay area from cubic feet of stormwater quality design storm runoff volume.
5. From the maximum temporary depth in the forebay (D_{FT}) from Step 3 and the minimum forebay area (A_F) from Step 4, compute the total temporary storage volume in the forebay (V_{FT}). Compare this volume with the approximate required forebay volume computed in Step 2. Adjust the maximum temporary forebay depth (D_{FT}) and/or forebay area (A_F) as necessary to achieve a total temporary forebay storage volume (V_{FT}) as close as practical to the required forebay volume from Step 2. While adjusting the forebay surface area (A_F) by varying its length and width, remember that the forebay will be located immediately adjacent to the sand bed zone and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.
6. As shown on Line 7 of Table 9.9-1, compute the minimum sand bed surface area (A_S) using the following equation:

$$A_S = (V_{QS})(TH_S) / [(k)(D_{ST}/2 + TH_S)(T_D)] \qquad \text{(Equation 9.9-1)}$$

Where:

A_S = Minimum Sand Bed Surface Area (in square feet)
V_{QS} = Runoff Volume from the Stormwater Quality Design Storm (in cubic feet)
TH_S = Thickness of Sand in Sand Bed (in feet)
k = Sand Bed Design Permeability (in feet per day)
D_{ST} = Maximum Temporary Sand Bed Depth (in feet)
T_D = Sand Bed Drain Time (in days)

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-1 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Permeability (k) = 4 feet per day
Sand Bed Design Drain Time = 1.5 days

7. Compute the total temporary storage volume in the sand bed zone (V_{ST}) from the following equation:

$$V_{ST} = (A_S)(D_{ST}) + (A_S)(TH_S)(n) \qquad \text{(Equation 9.9-2)}$$

Where:

V_{ST} = Temporary Sand Bed Storage Volume (in cubic feet)
A_S = Sand Bed Surface Area (in square feet)
D_{ST} = Maximum Temporary Sand Bed Depth (in feet)
TH_S = Thickness of Sand in Sand Bed (in feet)
n = Sand Bed Design Porosity

As shown in Table 9.9-1, the following parameter design values for Equation 9.9-2 are recommended:

Minimum Sand Thickness in Sand Bed (TH_S) = 18 inches
Sand Bed Design Porosity (n) = 0.3

8. Compare the total temporary sand bed storage volume (V_{ST}) with the approximate required sand bed zone volume computed in Step 2. As shown on Line 2 of Table 9.9-1, this temporary sand bed storage volume should be approximately one half of the stormwater quality design storm runoff volume (V_{QS}). In addition, add the total temporary sand bed volume (V_{ST}) to the total temporary forebay storage volume (V_{FT}) to determine the total temporary storage volume in the sand filter. As shown on Line 1 of Table 9.9-1, this total temporary storage volume must equal the stormwater quality design storm runoff volume (V_{QS}). Adjust the maximum temporary sand bed depth (D_{ST}) and/or sand bed area (A_S) as necessary to achieve a total temporary sand bed storage volume (V_{ST}) as close as practical to the required sand bed volume from Step 2 and a total filter volume equal to V_{QS}. Once again, while adjusting the sand bed surface area (A_S) by varying its length and width, remember that the sand bed will be located immediately adjacent to the forebay and that the recommended minimum overall length to width ratio of these combined zones in surface and subsurface filters is two to one.

D. Filter Bed Sand

The sand used in the sand bed must meet the specifications for clean medium aggregate concrete sand in accordance with AASHTO M-6 or ASTM C-33. This must be certified by a professional engineer licensed in the State of New Jersey.

E. Gravel Layer and Underdrain

The gravel layer serves as bedding material for the underdrain pipes. It must have sufficient thickness to provide a minimum of 2 inches of gravel above and below the pipes. It should consist of 0.5” to 1.5” clean broken stone or pea gravel (AASHTO M-43).

The underdrain piping must be rigid Schedule 40 PVC pipe in accordance with AASHTO M278. Perforated underdrain piping should have a minimum of 3/8-inch diameter perforations at 6-inch centers with four perforations per annular row. The portion of drain piping beneath the sand bed must be perforated. All remaining underdrain piping, including cleanouts, must be nonperforated. 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 to or above the surface of the sand bed. Additional cleanouts should be installed as needed.

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 infiltration rates at least twice as fast as the design infiltration rate of the sand bed.

Additional details of typical sand filter underdrains are shown in Figure 9.9-5.

F. Overflows

All sand filters must be able to safely convey overflows to 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. Sand filters that are 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 weir or orifice, or a surface feature such as a swale or open channel, as filter location and site conditions allow.

G. 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 or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

H. On-line and Off-line Systems

In general, most sand filters are constructed off-line. In off-line sand filters, most or all of the runoff from storms larger than the stormwater quality design storm bypass the filter through an upstream diversion. This not only reduces the size of the required filter overflow, but also reduces the filter's long-term pollutant loading and associated maintenance and the threat of erosion and scour caused by larger storm inflows. However, sand filters may also be constructed on-line. On-line filters 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 filters also store and attenuate these larger storms to provide runoff quantity control. In such filters, the invert of the lowest stormwater quantity control outlet is set at or above the maximum stormwater quality design storm water surface.

Maintenance

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

A. General Maintenance

All sand filter 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 inlets and diversion structures, forebays, sand beds, and overflows.

Sediment removal should take place when all runoff has drained from the sand bed and the sand is reasonably dry. In addition, runoff should be drained or pumped from forebays with permanent pools before removing sediment. 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

In surface sand filters with turf grass bottom surfaces, mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also be inspected at least annually for erosion and scour. The filter bottom must be inspected for unwanted underbrush and tree growth at least once a year.

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 during both the growing and non-growing season at least twice annually. 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 must not compromise the intended purpose of the sand filter. 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 top of the filter's sand bed. This normal drain or drawdown time should then be used to evaluate the filter's actual performance. If significant increases or decreases in the normal drain time are observed, the filter's sand bed, underdrain system, 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 filter.

The sand bed should be inspected at least twice annually. The infiltration rate of the sand bed material may also be retested. If the water fails to infiltrate 72 hours after the end of the stormwater quality design storm, corrective measures must be taken.

Considerations

A. Forebay and Sand Bed Drains

Wherever possible in subsurface and perimeter filters, a drain and valve should be provided in the forebay to permit draining of all standing water and facilitate sediment removal. This drain and valve can be connected to the sand bed underdrain system.

B. Drainage Area Stabilization

No runoff should enter the filter's sand bed until the upstream drainage area is completely stabilized and site construction is completed.

C. Watertight Construction

Underground sand filters should always be constructed completely watertight, especially if treating runoff from "hotspots" or over extremely sensitive groundwater areas.

D. Pretreatment

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

As shown in Figures 9.9-1, 9.9-2, and 9.9-3, forebays at the inflow points to sand filters can capture coarse sediments, trash, and debris, which can simplify and reduce the frequency of filter maintenance. A forebay should be sized in accordance with Table 9.9-1 to hold the sediment volume expected between clean-outs.

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CHAPTER 9.10

Standard for Vegetative Filters

Definition

A vegetative filter is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. The vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. It is important to note that all runoff to a vegetated filter strip must both enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's pollutant removal capabilities.

The total suspended solid (TSS) removal rate for vegetative filters will depend upon the vegetated cover in the filter strip. Table 9.10-1 below presents the adopted TSS removal rates for various vegetated covers.

Table 9.10-1: Adopted TSS Removal Rates for Vegetated Filter Strips

Vegetated Cover	Adopted TSS Removal Rate
Turf grass	60 %
Native Grasses, Meadow, and Planted Woods	70 %
Indigenous woods	80 %

For filter strips with multiple vegetated covers, the final TSS removal rate should be based upon a weighted average of the adopted rates shown above in Table 9.10-1. This weighted average removal rate should be based upon the relative flow lengths through each cover type. For example, a 50-foot long vegetated filter strip (measured in the direction of flow) that has turf grass in the upper 25 feet and native grasses in the lower 25 feet would have a TSS removal rate of (25/50)(60%) + (25/50)(70%) or 65 percent.

Purpose

A vegetative filter is intended to remove pollutants from runoff flowing through it. Vegetated filter strips can be effective in reducing sediment and other solids and particulates, as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients. The pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake, and microbacterial activity.

Vegetated filter strips with planted or indigenous woods may also create shade along water bodies that lower aquatic temperatures, provide a source of detritus and large woody debris for fish and other aquatic organisms, and provide habitat and corridors for wildlife.

Condition Where Practice Applies

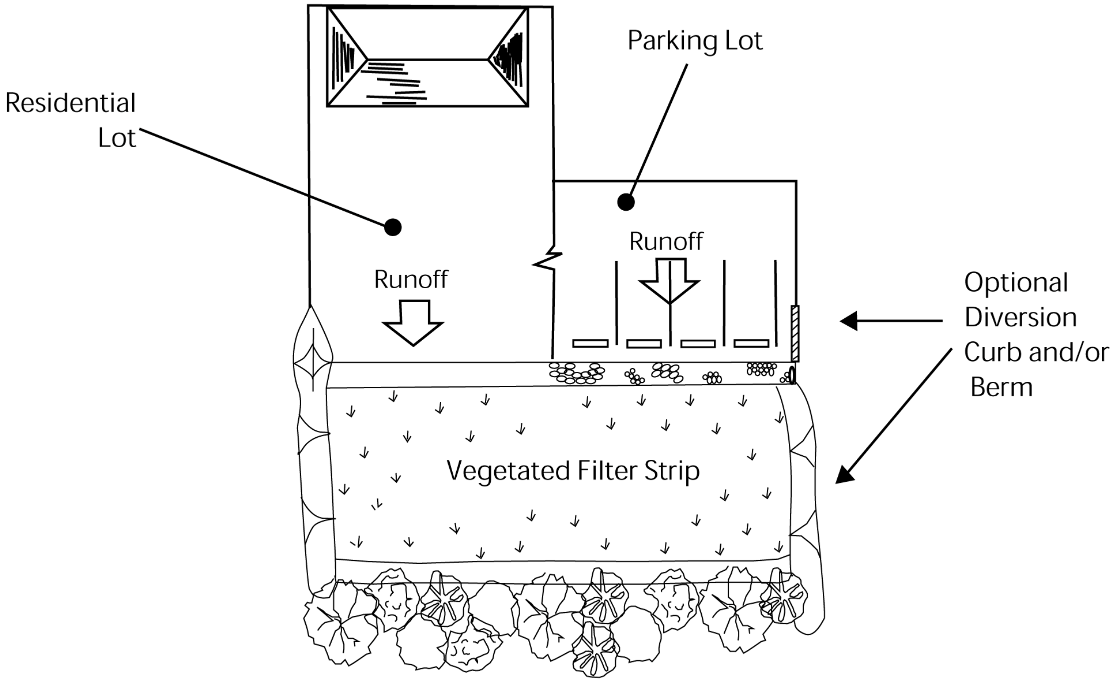
A vegetative filter can be effective only where the runoff entering and flowing through the strip remains as sheet flow and does not concentrate. This sheet flow requirement limits the use of vegetated filter strips in two ways. First, the area used for the filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. Second, since the runoff to a filter strip must enter the strip as sheet flow, the drainage area to the strip must also be uniformly graded and have a relatively horizontal downstream edge where it meets the upstream end of the filter strip. Such drainage areas may include yards, parking lots, and driveways where runoff flows as sheet flow. As a result, an area with irregular grading and other surface features that cause runoff to concentrate could neither be used as a vegetated filter strip nor have its runoff treated by one. For the same reasons, vegetated filter strips are also not intended to treat concentrated discharges from storm sewers, swales, and channels.

As detailed below in *Design Criteria*, additional factors must be considered. First, the vegetation in all filter strips must be dense and remain healthy and, in the case of planted or indigenous woods, have an effective mulch or duff layer. In addition, a vegetated filter strip must have a maintenance plan and be protected by an easement, deed restriction, or other legal measure that guarantees its existence and effectiveness in the future. Depending upon their TSS removal rate, vegetated filter strips can be used separately or in conjunction with other stormwater quality practices to achieve an overall pollutant removal goal.

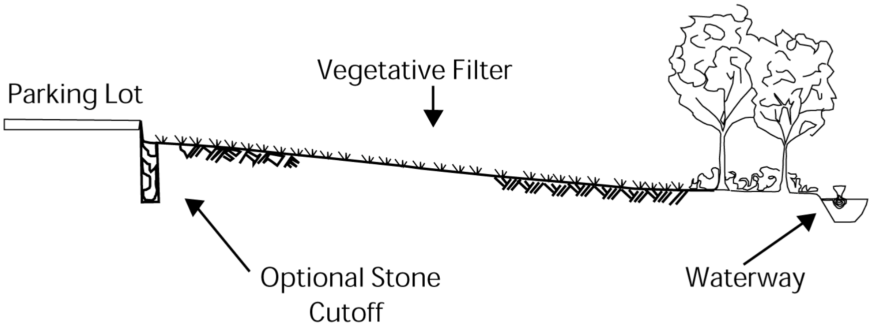
Design Criteria

The primary design parameters for a vegetated filter strip are its slope, type of vegetated cover, and the type of soils within its drainage area. These three parameters are then used to determine the standard filter strip length required to achieve the adopted TSS removal rates shown above in Table 9.10-1. In addition, since runoff from the stormwater quality design storm must enter and continue as sheet flow over this length, the peak runoff rate must be sufficiently low and uniformly distributed to ensure such conditions. This peak runoff rate is achieved by limiting the sheet flow length that runoff will flow before entering the filter strip. This length limitation, in turn, limits the size of the drainage area to the filter strip and, consequently, the peak runoff rate. Details of these and other design parameters are presented below. The components of a typical vegetated filter strip are shown in Figure 9.10-1.

Figure 9.10-1 Vegetative Filter Components



Plan View



Profile View

Source: Adapted from Schueler and Claytor 1996.

A. Drainage Area and Runoff Characteristics

As noted above, runoff from a drainage area may be directed to flow through a filter strip provided it enters the filter strip and continues through it as sheet flow. In addition, the peak rate and maximum depth of runoff entering the filter strip must be low enough to allow the strip's vegetated cover to serve as an effective filter. As such, the maximum drainage area to a vegetated filter strip will be limited to an area 100 feet long for impervious surfaces and 150 feet long for pervious surfaces. These lengths are to be measured in the direction of flow to the upstream edge of the filter strip.

In addition, the interface of the drainage area and the upstream edge of the filter strip must be as horizontal as possible (perpendicular to the flow direction) so that runoff will be evenly distributed along the upstream edge of the strip. As shown in Figure 9.10-1, a stone cutoff trench, recessed curb, or other measure may be used along the filter's upstream edge to help distribute the runoff and dissipate some of its energy as it enters the filter strip.

As noted above, the required strip lengths are based in part upon the type of soils within the filter strip's drainage area. Table 9.10-2 below lists the various types of soils and their associated Hydrologic Soil Groups that will affect the strip's required length. County Soil Surveys and onsite soil investigations can be used to determine these soil types. Where more than one type of soil exists in a drainage area, the soil with the smallest particle size (and, consequently, the longest filter strip length) should be used in the filter strip's design.

B. Filter Strip Cover

As noted above, the vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. The type of vegetation used in the filter strip can be very broad, although the best performance is associated with those with dense growth patterns such as turf-forming grasses and dense forest floor vegetation. All vegetation must be dense and healthy. In addition, planted woods must have a mulch layer with a minimum thickness of 3 inches, while indigenous woods must have at least a 1 inch thick natural duff layer.

Further information and references are presented in *Chapter 7: Landscaping*.

C. Filter Strip Grading

As noted above, the area used for a vegetated filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. As such, indigenous areas such as meadows and woods under consideration as vegetated filter strips should be surveyed and inspected during runoff events to determine runoff flow patterns. Indigenous areas with surface features that obstruct or retard runoff flow, cause ponding, and/or disperse runoff are acceptable, while those with surface features that cause runoff to concentrate are not. It should be noted that such observations must be made with consideration for the proposed volume and peak rate of runoff that the area would receive as a vegetated filter strip.

D. Maximum Filter Strip Slope

In addition to the soils within a vegetated filter strip's drainage area, the soils within the filter strip itself are also important for determining filter strip's maximum allowable slope. Table 9.10-2 below presents maximum filter strip slopes for various vegetated covers and soil types within the filter strip. County Soil Surveys and onsite soil investigations can be used to determine the soil type within a filter strip.

Table 9.10-2: Maximum Filter Strip Slope

Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Grasses, and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8

E. Required Filter Strip Length

To achieve the adopted TSS removal rates shown above in Table 9.10-1, the required filter strip length can be determined from Figures 9.10-2 to 6 below based upon the filter strip's slope, vegetated cover, and the soil within its drainage area. As shown in the figures, the minimum length for all vegetated filter strips is 25 feet.

Figure 9.10-2: Vegetated Filter Strip Length
Drainage Area Soil: Sand HSG: A

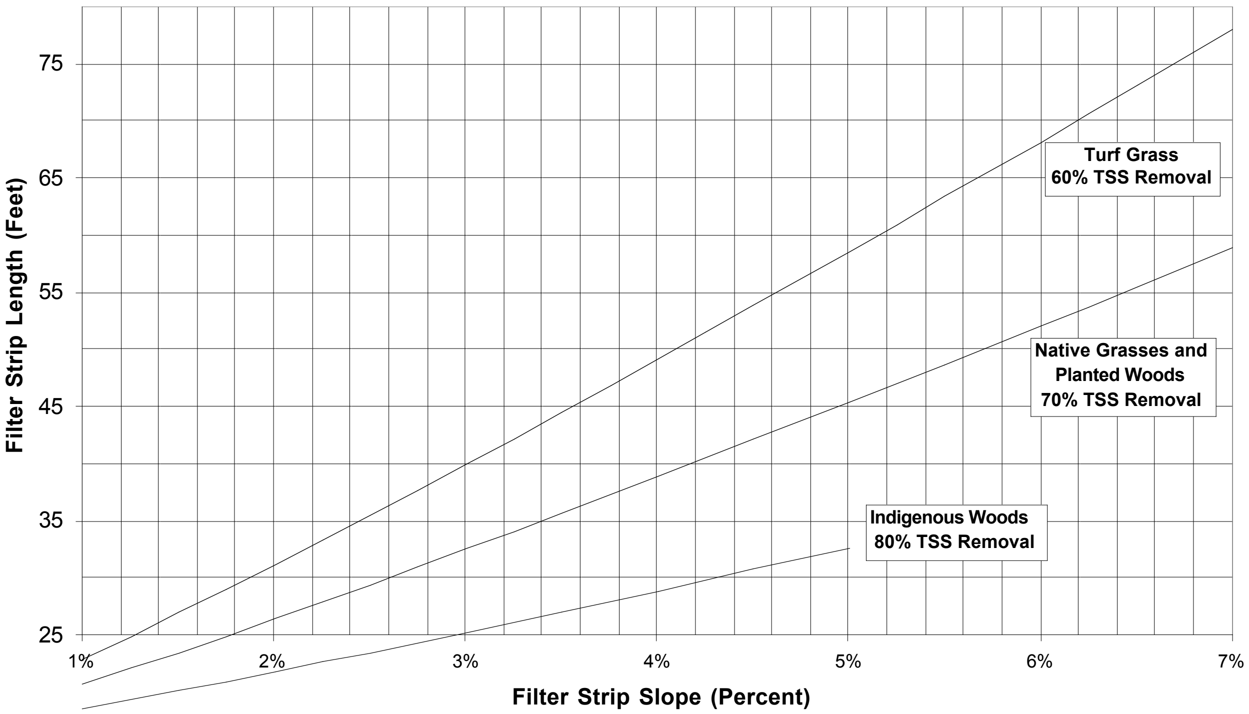


Figure 9.10-3: Vegetated Filter Strip Length
Drainage Area Soil: Sandy Loam HSG: B

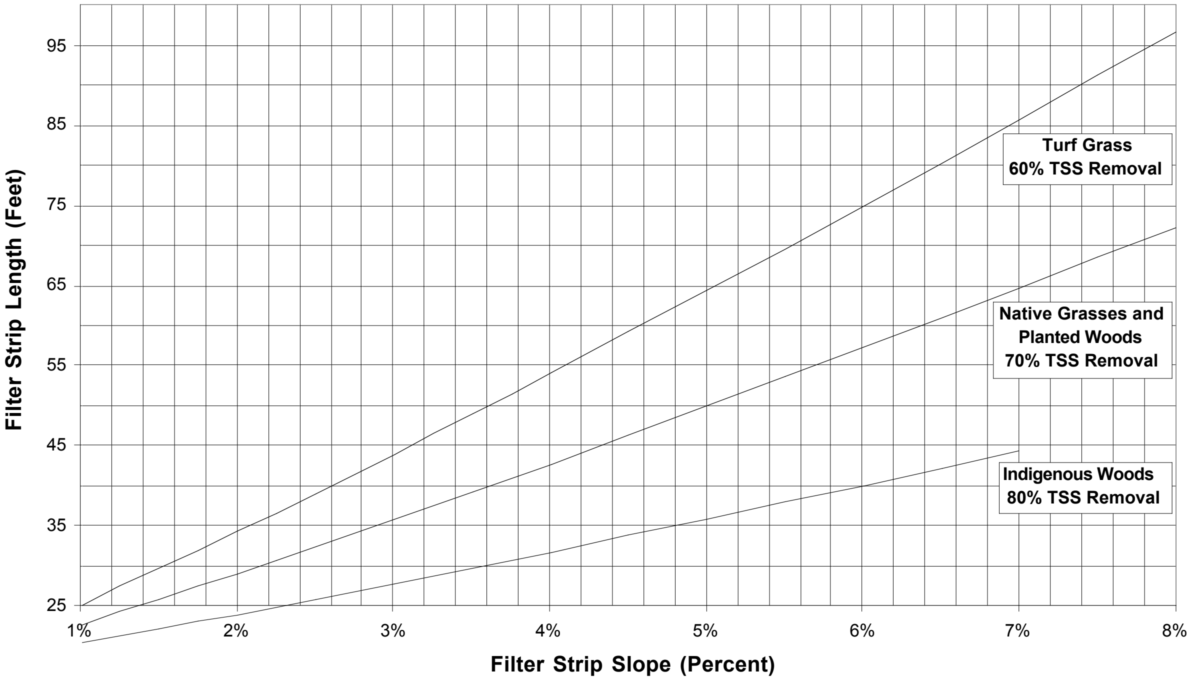


Figure 9.10-4: Vegetated Filter Strip Length
Drainage Area Soil: Loam, Silt Loam HSG: B

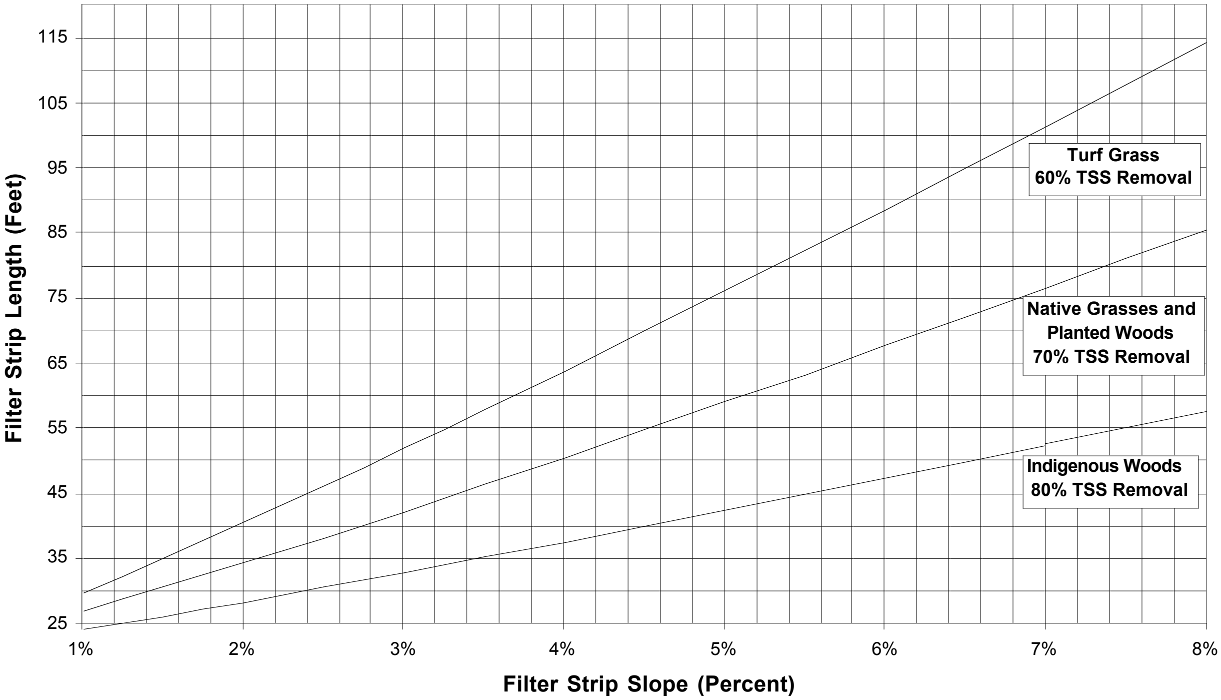


Figure 9.10-5: Vegetated Filter Strip Length
Drainage Area Soil: Sandy Clay Loam HSG: C

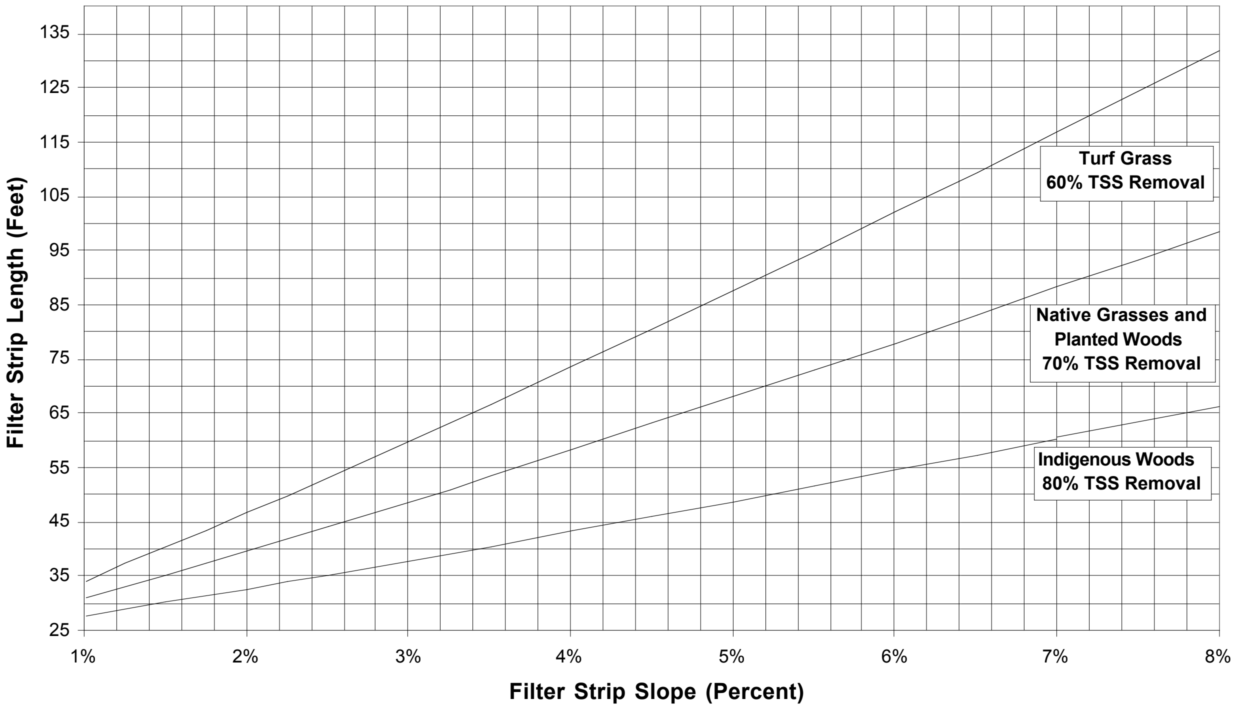
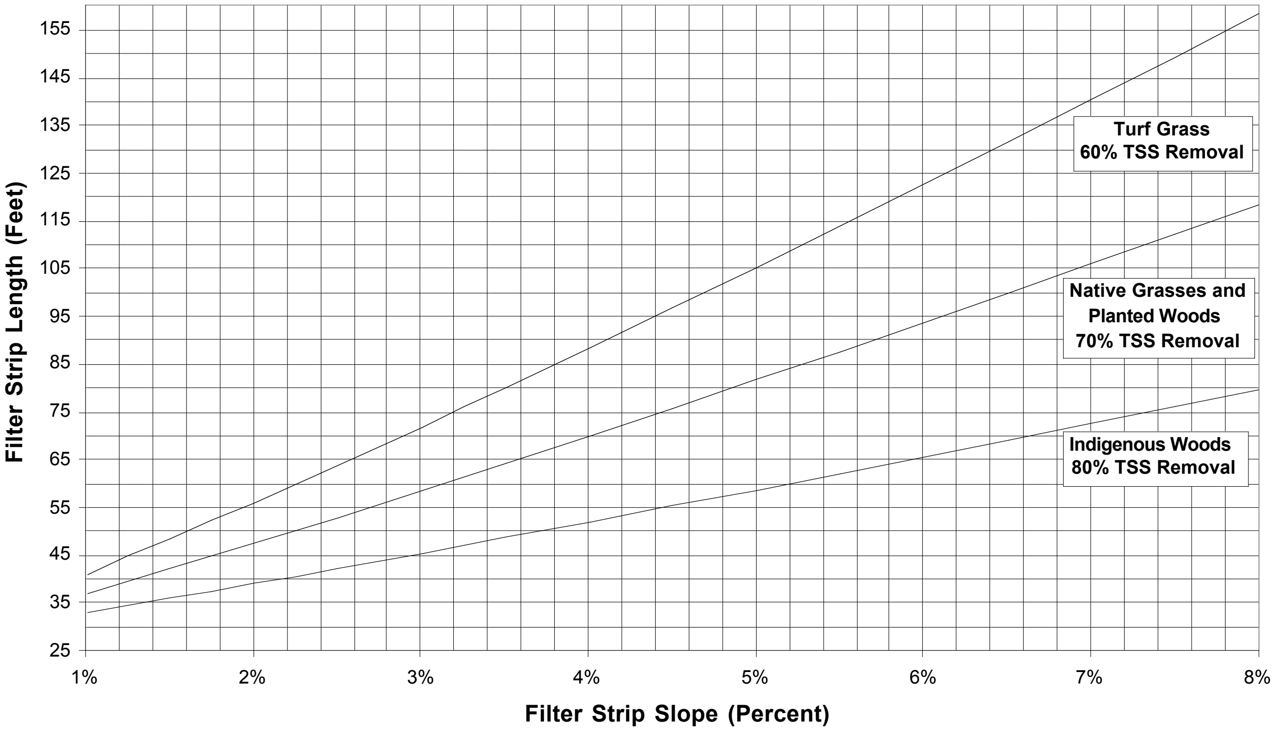


Figure 9.10-6: Vegetated Filter Strip Length
Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D



Example 9.10-1: Computing Required Vegetated Filter Strip Length

A vegetated filter strip is to be installed at a uniform 5 percent slope to treat the runoff from a drainage area consisting of a paved parking lot and turf grass lawn. Runoff from the parking lot and lawn will enter the filter strip as sheet flow. The maximum sheet flow lengths across the parking lot and lawn do not exceed 100 and 150 feet, respectively. The soil in the drainage area is a silt loam. Compute the required filter strip length if the strip is to be vegetated with turf grass.

1. Determine the Hydrologic Soil Group of the drainage area soil. From Table 9.10-2, a silt loam is in Hydrologic Soil Group B.
2. Determine the maximum slope of the filter strip. Also from Table 9.10-2, the maximum slope of a turf grass filter strip with Hydrologic Soil Group B soils is 8 percent, which is greater than the 5 percent slope of the proposed filter strip.
3. Determine the required length of the filter strip. From Figure 9.10-4 for silt loam soils, the required length of a turf grass filter strip with a 5 percent slope is approximately 76 feet. The resultant TSS removal rate for the turf grass filter strip will be 60 percent.

Maintenance

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

A. General Maintenance

All vegetated filter strip 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 and after every storm exceeding 1 inch of rainfall. Such components may include vegetated areas and stone cutoffs and, in particular, the upstream edge of the filter strip where coarse sediment and/or debris accumulation could cause inflow to concentrate.

Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply 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 should be mowed at least once a month during the growing season. 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 during both the growing and non-growing season at least twice annually. 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 must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs.

C. Other Maintenance Criteria

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

Considerations

A number of factors should be considered when utilizing a vegetated filter strip to treat stormwater runoff. Most importantly, an adequate filter area and length of flow must be provided to achieve the desired treatment. Slopes of less than 5 percent are more effective; steeper slopes require a greater area and length of flow to achieve the same effectiveness. Good surface and subsurface drainage is necessary to ensure satisfactory performance. The designer should also be aware of potential ponding factors during the planning stage. Dry period between flows should be achieved in order to reestablish aerobic soil conditions.

Filter strip vegetation must be fully established before incoming stormwater flow is allowed. At least one full growing season should have elapsed prior to strip functioning as part of the stormwater management system. Further information and references on filter strip vegetation are presented in *Chapter 7*. Species must be appropriate for the region, soil, and shade condition. Mulching is required for both seeded and planted filter strips.

Perhaps the most common, naturally occurring filter strips are those upland vegetative stands associated with floodplains or found adjacent to natural watercourses. In some cases, preservation of these upland areas will allow them to continue to function as filter strips. To help ensure the longevity of these natural areas under altered and perhaps increased pollutant loading, a top dressing of fertilizer and supplemental plantings may be necessary.

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CHAPTER 9.11

Standard for Wet Ponds

Definition

A wet pond is a stormwater facility constructed through filling and/or excavation that provides both permanent and temporary storage of stormwater runoff. It has an outlet structure that creates a permanent pool and detains and attenuates runoff inflows and promotes the settlement of pollutants. A wet pond, also known as a retention basin, can also be designed as a multi-stage facility that also provides extended detention for enhanced stormwater quality design storm treatment and runoff storage and attenuation for stormwater quantity management. The adopted TSS removal rate for wet ponds is 50 to 90 percent depending on the permanent pool storage volume in the pond and, where extended detention is also provided, the duration of detention time provided in the pond.

Purpose

Wet ponds are used to address both the stormwater quantity and quality impacts of land development. A wet pond's permanent pool can retain runoff from the stormwater quality design storm, thereby promoting pollutant removal through sedimentation and biological processing. The permanent pool can also protect deposited sediments from resuspension. Higher stages in the basin can also be used to provide additional stormwater quality treatment through extended detention and/or attenuate the peak rates of runoff from larger storms through the use of multi-stage outlets for flood and erosion control. Wet ponds can also provide aesthetic and recreational benefits as well as water supply for fire protection and/or irrigation.

Conditions Where Practice Applies

Wet ponds require sufficient drainage area and, in turn, dry weather or base flow to maintain the volume and environmental quality of the permanent pool. Therefore, the minimum drainage area to a wet pond must be 20 acres.

Wet ponds should not be located within the limits of natural ponds or wetlands, since they will typically not have the full range of ecological functions as these natural facilities. While providing some habitat and aesthetic values, wet ponds are designed primarily for pollutant removal and erosion and flood control.

It is important to note that a wet pond must be able to maintain its permanent pool level. If the soil at the site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary.

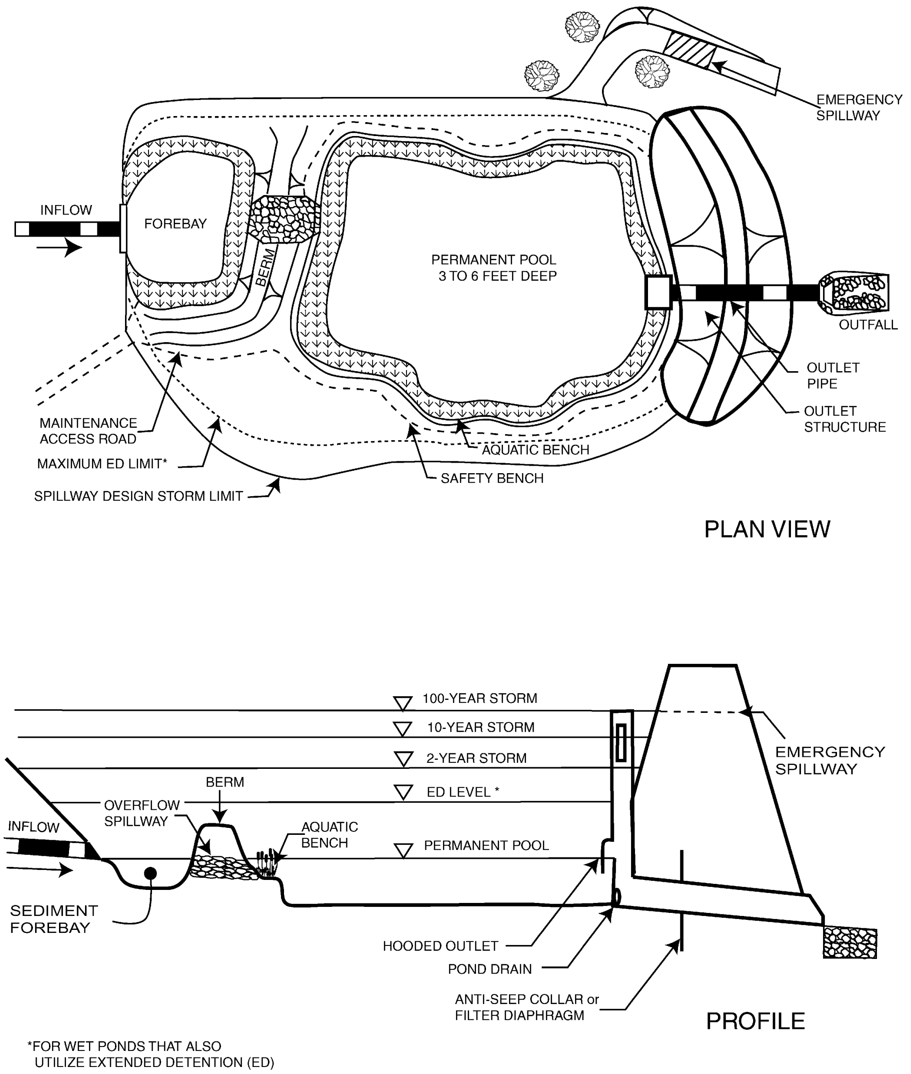
Wet ponds may be limited by the potential for discharge water to be heated in the permanent pool during summer months and should not be used if the receiving waters are ecologically sensitive to temperature change.

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

Design Criteria

The basic design parameter for a wet pond is the ratio of its permanent pool volume to the volume of runoff entering the pond. This ratio is used to determine the pond's TSS removal rate. This removal rate can be increased if extended detention storage is also provided above the permanent pool level. Details of these and other design parameters are presented below and summarized in Table 9.11-1. The components of a typical wet pond both with and without extended detention are shown in Figure 9.11-1.

Figure 9.11-1: Wet Pond Components



Source: Adapted from Schueler and Claytor 2000.

A. Storage Volumes

Wet ponds should be designed to treat 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 resultant TSS removal rate for a wet pond will depend on the ratio of its permanent pool volume to the stormwater quality design storm runoff volume. Figure 9.11-2 presents the range of approved TSS removal rates for various permanent pool to runoff volume ratios. As can be seen in the figure, the minimum required permanent pool volume in a wet pond is equal to the stormwater quality design storm runoff volume to the pond. At this 1:1 volume ratio, a wet pond would have a TSS removal rate of 50 percent. This removal rate increases to 80 percent for wet ponds with permanent pool volumes that are three times the stormwater quality design storm runoff volume (i.e., volume ratio of 3:1).

Also shown in Figure 9.11-2 are TSS removal rates in wet ponds that also provide extended detention above the permanent pool water surface. As shown in Figure 9.2-2, a wet pond with a permanent pool to runoff volume ratio of 3:1 that also provides 24 hours of extended detention would have a TSS removal rate of 90 percent. TSS removal rates for other combinations of permanent pool to runoff volume ratios for extended detention times of 12 and 18 hours are also shown in Figure 9.11-2. Definitions and details of extended detention are presented in Section 9.4: Extended Detention Basins.

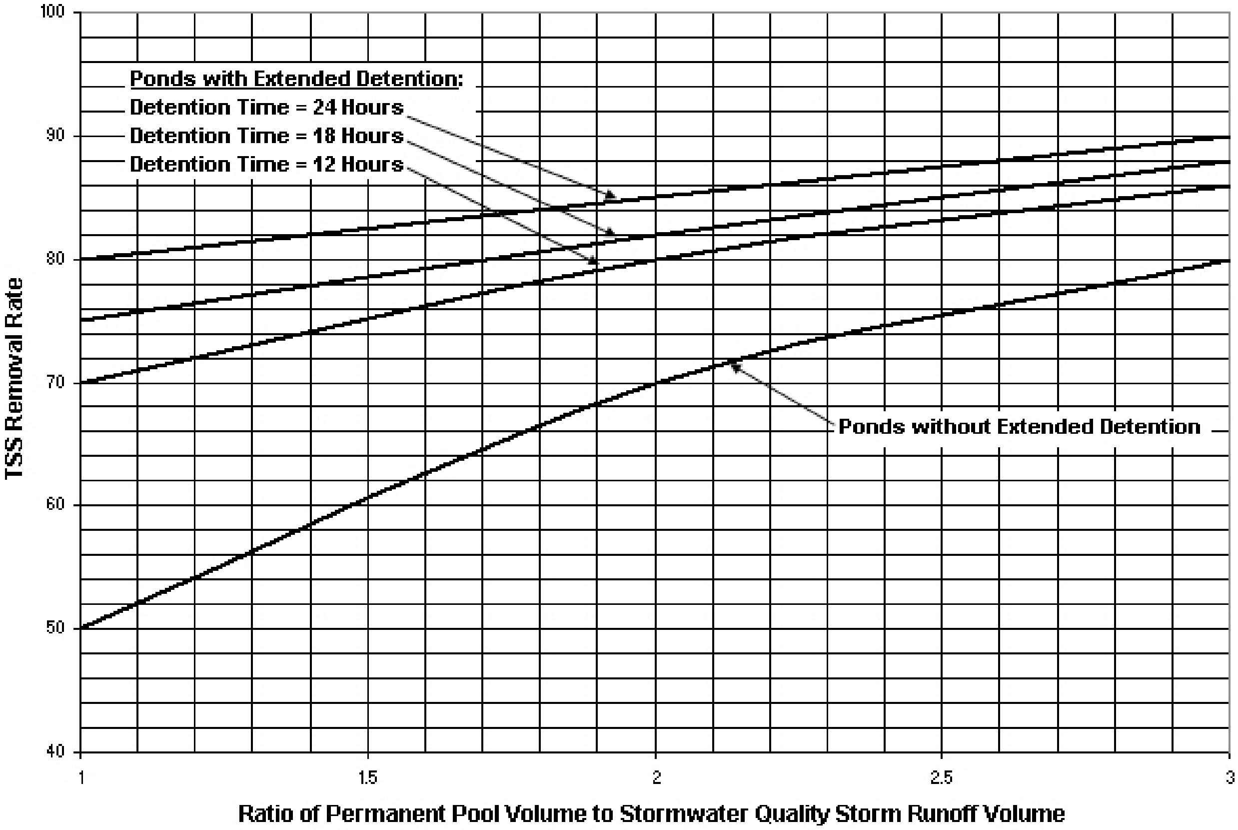
B. Permanent Pool Depth

The depth of a wet pond's permanent pool is an important design parameter. The permanent pool should be shallow enough to avoid thermal stratification and deep enough to minimize algal blooms and resuspension of previously deposited materials by subsequent storms and strong winds. Prevention of thermal stratification will minimize short-circuiting and maintain aerobic bottom waters, thus maximizing pollutant uptake and minimizing the potential release of nutrients to the overlying waters. The mean depth of the permanent pool is obtained by dividing the storage volume by the pool surface area. A mean depth of three to six feet is normally sufficient to maintain a healthy environment within the permanent pool. The outlet structure or riser should be located in a relative deep area to facilitate withdrawal of cold bottom water to help mitigate any downstream thermal impacts. If maintained at the recommended three to six foot depth, the permanent pool can better serve as an aquatic habitat.

C. Permanent Pool Surface Area

The surface area of a wet pond's permanent pool is also an important design parameter as it directly affects the settling rate of particulate solids in the runoff to the pond. The surface area of a permanent pool will depend on site topography, minimum and maximum pool depths, and the desired settling rate. The minimum permanent pool surface area is 0.25 acres.

Figure 9.11-2: TSS Removal Rates for Wet Ponds



D. Drainage Area Size

As noted above, wet ponds require sufficient drainage area and dry weather base flow to function properly. A reliable base flow must be available to maintain the volume and quality of the permanent pool. Therefore, the minimum drainage area to a wet pond is 20 acres. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater inflow is available.

E. Pond Configuration

The length to width ratio of a wet pond should as large as possible to simulate conditions found in plug flow reaction kinetics. Under ideal plug flow conditions, a plug or pulse of runoff enters a pond and is treated by chemical reactions as well as the physical processes of dispersion and settlement as the pulse travels the length of the wet pond. Therefore, the pond's length to width should be at least 3:1 to maximize these treatment processes. In cases where it is impractical to construct wet ponds with these lengths, internal baffles or berms may be added within the pond to the increase the travel length and residence time.

F. Safety Ledges

Safety ledges must be constructed on the slopes of all wet ponds with a permanent pool deeper than three feet. Two ledges must be constructed, each 4 to 6 feet in width. The first or upper ledge must be located between 1 and 1.5 feet above the permanent pool level. The second or lower ledge must be located approximately 2.5 feet below the permanent pool level.

G. Outlet Structure

The riser structure should be equipped with a bottom drain pipe, sized to drain the permanent pool within 40 hours so that sediments may be removed mechanically when necessary. The drain pipe should be controlled by a lockable valve that is readily accessible from the top of the outlet structure. Additional information regarding outlet structures can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

H. Overflows

All wet ponds must be able to safely convey system overflows to downstream drainage systems. The capacity of the overflow must be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Wet ponds that are 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, including safe conveyance of the wet pond's spillway design storm.

I. Tailwater

The hydraulic design of the outlet structure, outlet pipe, and emergency spillway in a wet pond must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the permanent pool level is below the flood hazard area design flood elevation of the receiving stream.

J. Other Components

Information regarding embankments, emergency spillways, bottom and side slopes, trash racks, conduit outlet protection, and vegetative cover can be found in both the Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

Table 9.11-1: Summary of Design Parameters

Design Parameter
Minimum Permanent Pool Volume = Stormwater Quality Design Storm Runoff Volume
Mean Permanent Pool Depth = 3 to 6 Feet
Minimum Permanent Pool Surface Area = 0.25 Acres
Minimum Drainage Area Size = 20 Acres
Maximum Permanent Pool Drain Time = 40 Hours
Recommended Minimum Pool Length to Width Ratio = 3:1

Maintenance

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

A. General Maintenance

All wet pond 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 one inch of rainfall. The primary location for debris and particularly sediment accumulation will be within a wet pond's permanent pool. Additional components may include forebays, inflow points, trash racks, outlet structures, and riprap or gabion aprons.

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.

Studies have shown that readily visible stormwater management facilities like wet ponds receive more frequent and thorough maintenance than those in less visible, more remote locations. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must also 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 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 season. 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 ensure optimum vegetation health must not compromise the intended purpose of the wet pond. 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. All outlet valves are to be inspected and exercised at least four times annually.

D. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take to completely drain the maximum design storm runoff volume and return the pond to its permanent pool level. This normal drain time should then be used to evaluate the pond's actual performance. If significant increases or decreases in the normal drain time are observed, the pond's outlet structure and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements.

Considerations

A. Permanent Pools

The primary component of a wet pond is its permanent pool. To maintain water quality, oxygen levels, control mosquito breeding, and prevent stagnation, an adequate and regular inflow of surface and/or ground water is necessary. Where sufficient oxygen levels and mixing will be difficult to achieve, a fountain or aerator may be included. However, such conditions may be indicative of larger site suitability problems that must be thoroughly investigated before a wet pond is selected for use at a land development site. The potential effects of sediment loading on the permanent pool must also be considered when determining whether a site is suitable for a wet pond. The use of existing lakes and ponds as wet ponds for treatment of stormwater is prohibited.

A well-designed wet pond will accumulate considerable quantities of sediment. The cleanout cycle for a wet pond in a stabilized watershed can vary, with an average cycle of approximately 10 years. Sediment removal at each cycle may cost as much as 20 to 40 percent of the initial construction cost. It should be noted that the exact cleanout cycle and cost will depend on the specific character of the wet pond and its watershed. Therefore, periodic inspections of sediment accumulation in a wet pond are vital to determining how often and how much sediment must be removed. See *Maintenance* above for more information.

In cases where relatively permeable soils are encountered, the risk of seepage losses may be minimized by installing a clay or synthetic liner along the bottom of the pond.

B. Thermal Effects

Thermal effects of the wet pond must be considered since the permanent pool can act as a heat sink between storm events during hot weather. When the water is displaced from the pool, it may be as much as 10 degrees Fahrenheit warmer than the naturally occurring baseflow in the downstream waterway. Runoff to wet ponds from large impervious surfaces can also significantly raise the temperature of runoff during hot weather. The net result of elevated pool temperatures may have an adverse impact on downstream coldwater uses such as trout production.

Therefore, wet pond designers should pay special attention to the potential of thermal effects on downstream water bodies supporting cold water fisheries. Thermal impacts of wet ponds in such areas may be mitigated by:

- Using a deep permanent pool and positioning the outlet pipe to discharge the relatively colder water from near the bottom;
- Planting shade trees on the periphery of the pool to reduce solar warming; and
- Employing a series of pools in sequence rather than a single one.

C. Vegetation

Aquatic vegetation plays an important role in the pollutant removal dynamics of a wet pond. Soluble pollutants, especially nutrients, are removed through biological assimilation by both phytoplankton and macrophytes. Wetland plants can help keep algal proliferation in check by limiting the amount of nutrients available to the phytoplankton. In addition, an organically enriched wetland substrate will provide an ideal environment for bacterial populations to metabolize organic matter and nutrients. Aquatic vegetation may also aid in the regulation of pond water temperature.

Marsh vegetation can also enhance the appearance of the wet pond, stabilize the side-slopes, serve as wildlife habitat, and temporarily conceal unsightly trash and debris. As such, a wet pond may be designed to promote dense growth of appropriate wetland plant species along the banks. A 10 to 15 foot wide wetland vegetation bench starting one foot below the pool surface may be established along the perimeter of the pond. Water tolerant species of vegetative cover for wet pond surfaces should be used. To promote lasting growth, grasses and other vegetative covers should be compatible with prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. An adequate depth of topsoil should be provided below all vegetative covers in uplands. A minimum thickness of six inches is recommended.

D. Designing for Pollutant Removal

Two alternative approaches may be used to design wet pond pollutant removal. The first approach is based on solids settling and assumes that all pollutant removal within the pond occurs due to sedimentation. The Design Criteria section above is based primarily on this approach. The second approach treats the wet pond as a lake with controlled levels of eutrophication to account for the biological and physical/chemical processes that are principal mechanisms for pollutant removal. Both approaches relate the pollutant removal efficiencies to hydraulic residence time.

Design approach should be selected based on the target pollutants as well as site and economic constraints. The controlled eutrophication approach requires longer residence times and larger storage volumes comparable to those of the solids settling approach. However, where the chief concern is to control nutrient levels in waters such as lakes and reservoirs, it is advantageous to use the controlled eutrophication approach. If the major goal is the removal of a broad spectrum of pollutants, especially those adsorbed onto suspended matter (as discussed in *Chapter 4: Stormwater Pollutant Removal Criteria*), it is generally preferable to base the design on the sedimentation approach.

E. Pretreatment

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

As shown in Figure 9.11-1, forebays at the inflow points to a wet pond can capture coarse sediments, trash and debris, which can simplify and reduce the frequency of pond maintenance. A forebay should be sized to hold the sediment volume expected between clean-outs.

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