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. There are two types of constructed wetlands for stormwater runoff treatment: standard wetlands and and subsurface gravel wetlands. Standard constructed wetlands direct flow through an open vegetated marsh system. Subsurface gravel wetlands, also direct flow through a surface marsh which then discharges to a permanently ponded subsurface gravel bed. The TSS removal rate for constructed stormwater wetlands is 90.

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

Standard constructed wetlands require sufficient drainage areas and dry weather base flows to function properly. The minimum drainage area to a constructed stormwater wetland is 10 to 25 acres, depending on the type of wetland. The depth to the SHWT must be considered as part of the water budget evaluation. See E below for additional information.

Subsurface gravel wetlands (SGW) do not have a minimum drainage area requirement. They are well suited for retrofit applications since draindown through the subsoil is not required to provide water quality treatment and the hydraulic head requirement is smaller than that of standard wetlands. In addition, gravel wetlands are not dependent on the depth to the seasonal high water table (SHWT.) SGW can be placed within the footprint of an existing stormwater BMP to enhance the water quality function of the BMP, and is particularly effective in nitrogen removal.

Constructed 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.

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 any type of constructed 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 the standard wetlands with extended detention. In addition, the character, diversity, and hardiness of the wetland vegetation must be sufficient to provide adequate pollutant removal. Selected of vegetation must be non-invasive and based on the anticipated water depth within the wetlands. (Additional information is provided in Chapter XX: Landscaping.)

A constructed wetland must be able to maintain its permanent pool level. If the soil at the surface of a wetland site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary. Details of these and other design parameters are presented below.

A. Standard Wetlands

Standard 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 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 standard 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 6.2-1 below presents pertinent design criteria for each type of standard constructed 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 6.2-1, the detention time in the semi-wet zone of an extended detention wetland must meet a minimum of 24-hour detention time, which is the time from when the maximum storage volume is achieved until only 10 percent of the maximum volume remains in an extended detention wetland. The minimum diameter of any outlet orifice in all wetland types is 2.5 inches.

The components of a typical standard stormwater wetland are illustrated in Figure 6.2-1. Pertinent design criteria for each component are presented in Table 6.2-1. Additional details of each type of constructed stormwater wetland and the components of each are described below.

1. Pool Zone

Pools 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 consists of a pond, micropond, and/or forebay, depending on their relative sizes and depths. Descriptions of the pond and micropond are presented below. See C. Forebays for a discussion of the forebay zone.

a. Pond

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

b. Micropond

Microponds have a standing water depth of 4 to 6 feet, but are 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.

Table 6.2–1: Design Criteria for Standard Constructed Wetlands

Wetland Design Feature	Type of Standard Constructed 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 24 hour detention time requirement. (see text above).

2. 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.

a. 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.

b. 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.

3. 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.

4. Types of Standard Constructed Wetlands

a. 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.

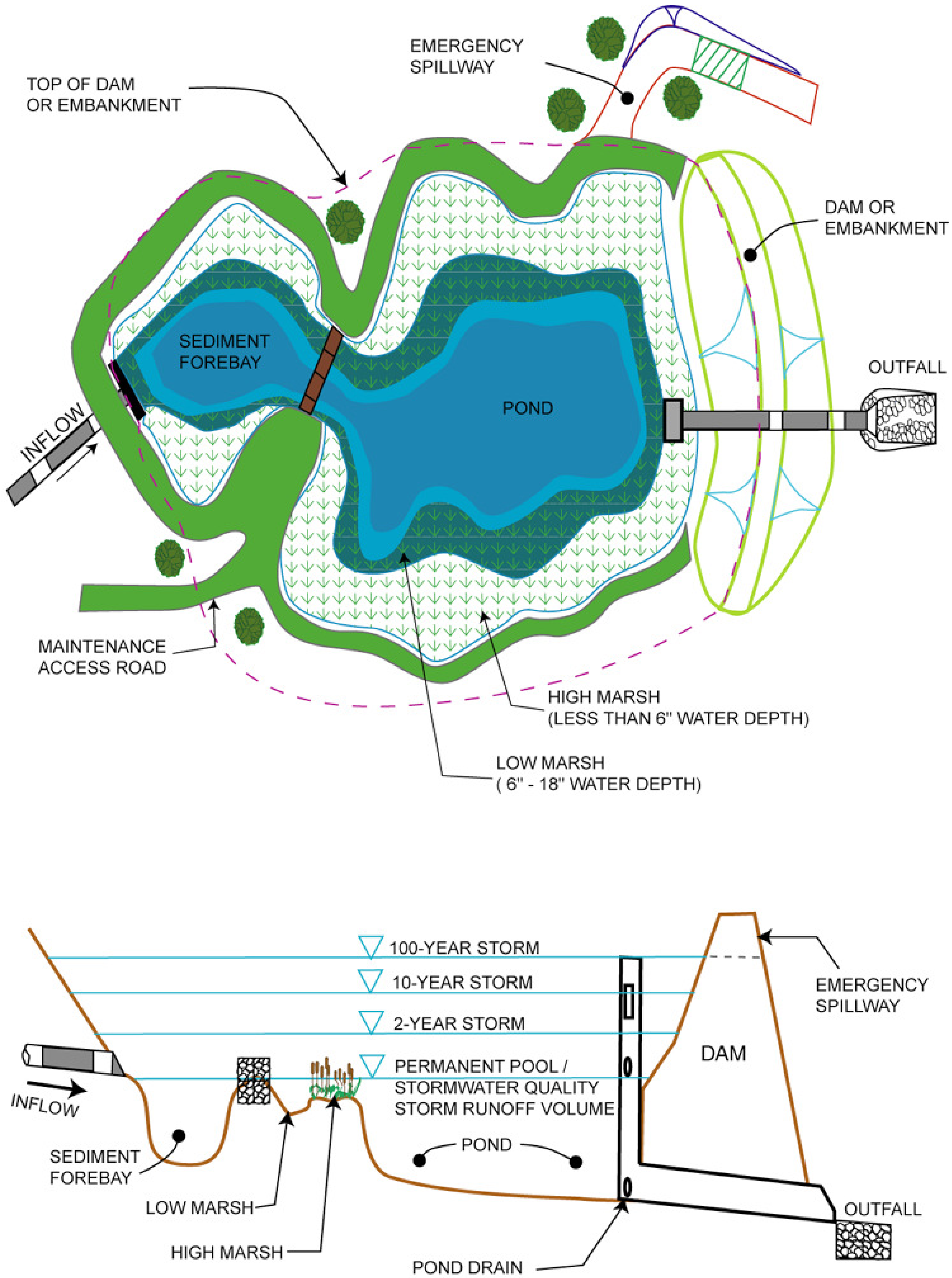
Pond wetlands require less site area than marsh wetlands and generally achieve a higher pollutant removal rate than the other types of constructed stormwater wetland. See Table 6.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component.

b. 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 6.2-1 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.

Figure 6.2-1: Components of a Standard Constructed Wetland



c. 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 6.2-1 for the relative stormwater quality design storm runoff volumes to be provided in each wetland component. The detention time in the semi-wet zone of an extended detention wetland must meet a minimum of 24-hour detention time. The detention time is determined based on time of the maximum basin storage volume above the permanent pool to the time when a minimum of 10 percent of the maximum storage volume remains above the permanent pool. The minimum diameter of any outlet orifice in all wetland types is 2.5 inches.

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.

B. Subsurface Gravel Wetlands

A gravel wetland is a combination of a standard constructed wetlands, described above, and a subsurface system that moves flow horizontally across saturated gravel. The components of a typical gravel wetland are shown in Figures 6.2-2 and Table 6.2-2 below. As shown in the table, the design of a gravel wetland system is based on the runoff volume from the water quality design storm: 10% in the forebay and 50% on the elevation above the wetlands soil in each wetland cell. (Note: The volume of the forebay is not deducted from the sizing of the wetlands cells.)

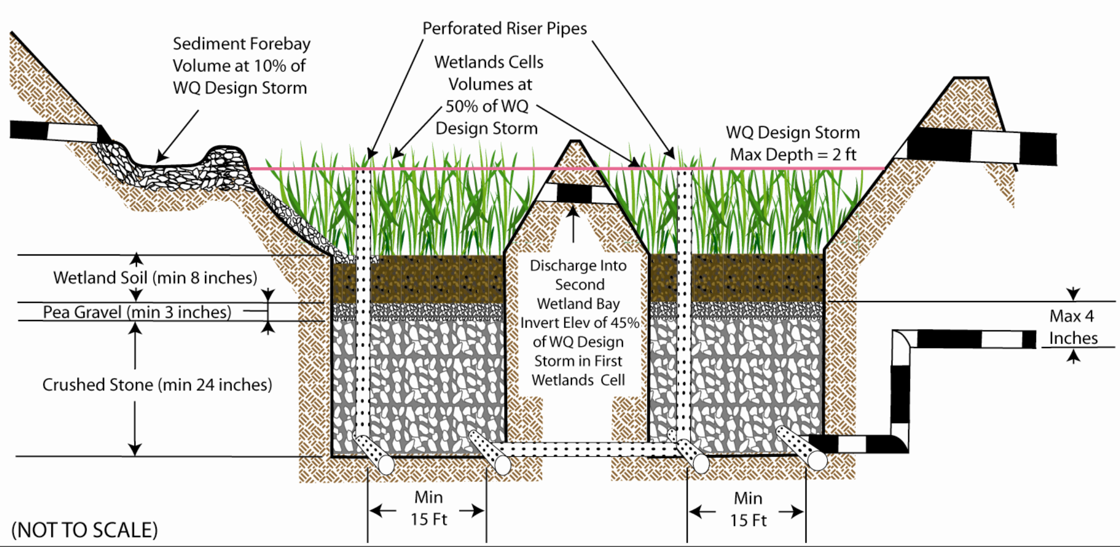
Gravel wetlands include a sediment forebay at the inflow area, for settling coarse particles and as a location more frequent maintenance. The discharge from the forebay enters the first of two wetland cells. A perforated riser conveys flow into the first subsurface gravel cell, which is maintained in a saturated condition to provide anaerobic transformations particularly necessary for the denitrification process. Underdrains capture the flow and then discharge it at an elevation that is a maximum of 4 inches below the bottom of the wetland soil.

At the elevation based on the volume of 45% of the water quality design storm, a cross-drain conveys flow from the first wetlands cell to a second wetlands cell. All rainfall events up to the water quality design storm are conveyed through perforated riser pipes into subsurface gravel bays. (As a result, some of the runoff from the WQ design storm and many smaller storm events will pass through a minimum of 30 feet of gravel during annual storm events and some of the runoff volume will only pass through a minimum of 15 feet of gravel.) At the down gradient end of the gravel cells, a perforated pipe conveys the runoff into a discharge pipe.

Note: Gravel wetlands rely on a fully saturated gravel layer. Caution must be taken that the outlet structure does not function as a siphon that will drain the gravel bed by ensuring that the outlet for the water quality design storm is vented or does not discharge in a submerged condition.

The drawdown time is controlled by a combination of the surface storage and the elevation difference (driving head) of the water surface elevation within the wetlands and the outlet pipe. The stormwater quality design storm runoff volume must take a minimum of 24 hours and a maximum of 36 hours to drain from the maximum elevation of the water quality design to the top of the wetlands soil, using the discharge from the gravel beds as the only outlet. In addition to the assessment of the draindown, the hydraulic capacity of the perforated riser pipes and underdrains must exceed that of the discharge pipe.

Figure 6-2.1 Schematic of Subsurface Gravel Wetlands



1. Wetlands Areas

Water quality treatment in the wetland surface is similar to that discussed for the constructed wetlands with surface flow, discussed above. In a gravel wetland, a minimum soil depth of eight inches must be provided for the vegetation. The wetlands soils must have low hydraulic conductivity (0.005 to 0.05 in/hour) and can be mixed using a combination of compost, sand, silt, and clay, with the clay component not exceeding 15% by volume. The soil mix must provide sufficient growing media and meet the permeability rates described above since it is the flow into the gravel media must pass through the pipe and not through the wetlands soil.

The wetlands soils must be continuously inundated at a depth of four inches from ground surface in order to support wetland vegetation and to maintain anaerobic conditions in the gravel cells below. This is controlled by the primary outlet, which has an invert four inches above the bottom of the wetland soil. A three inch pea gravel layer is required between the wetland soil and the subsurface gravel cells. This layer is necessary to prevent the finer portion of the wetland soil from migrating down into the gravel cells. This size of the gravel must be evaluated to ensure that the wetland soil does not migrate to the gravel cell below. Pea gravel must be used instead of filter fabric because the fine components of the wetland soil may clog the filter fabric and restrict root growth.

Selection of vegetation must be based on the duration of inundation. Additional information is provided in Chapter XX: Landscaping.

Table 6.2-2 Design Criteria for Gravel Wetlands

Wetland Design Feature	Size
Minimum wetland soil depth	8 inches
Minimum pea gravel depth	3 inches
Minimum crushed stone depth	24 inches
Minimum distance flow length in gravel substrate cell	15 ft (for each cell)
Drain time of wetlands cells	30 to 48 hours
Forebay Volume	10% of WQV
Temporary Wetlands Volume (Per Cell)	50% of WQV
Height of outlet invert depth below bottom of wetland soil	4 inches

2. Submerged Gravel Cells

A number of different processes occur in the gravel cells beneath the wetland surface including microbially mediated transformation, particularly denitrification. The gravel cells must be a minimum of 24 inches deep filled with ¾-inch crushed stone. It is essential that the gravel cells remain submerged in order for denitrification to occur. In addition, sufficient time in the anaerobic environment is necessary and is provided by the minimum 15-foot distance between the inflow and outflow of the each gravel bed.

3. Other Components

The bottom of the gravel wetlands does not require a separation from the SHWT. However, if the bottom of the gravel bed or any components of the gravel wetlands is within 2 feet of the SHWT, the area must be enclosed with a liner or other impervious material to prevent the migration of the stormwater into the adjacent groundwater table and to prevent the drawdown of the existing adjacent groundwater.

In addition, berms between the wetland cells must be constructed out of material that prevents seepage or piping through the material.

C. Forebay

Forebays are required in any type of constructed stormwater wetland and are located at points of concentrated inflow. They serve as pretreatment measures by removing coarser sediments, trash, and debris. Forebays can be earthen, constructed out of riprap, or made out of concrete.

The designer has the option to use a manufactured treatment device instead of a forebay provided the device is designed for the New Jersey Water Quality Design storm with a TSS removal rate of at least 50%. Information on manufactured treatment devices is presented in *Chapter 6.7 –Manufactured Treatment Devices.*

D. Drainage Area and Water Budget

Constructed Wetlands with Surface Flow: The minimum drainage area to a constructed stormwater wetland generally varies from 10 to 25 acres, depending on the type of constructed wetland. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater inflow is available. The detailed analysis must include a water budget demonstrating the availability of water to sustain the stormwater wetland. The water budget must demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate. Drying periods of longer than two months have been shown to adversely affect plant community richness, so the water balance should confirm that drying will not exceed two months (Schueler 1992). (See also A-4. Types of Constructed Stormwater Wetlands with Surface Flow above.)

Gravel Wetlands with Subsurface Flow: Gravel wetlands do not have a minimum drainage area requirement. While a specific water budget is not necessary for gravel wetlands, the gravel beds remain permanently ponded with water to the elevation of the invert of the primary outlet.

E. Outlet Structure

Surface flow constructed wetlands should be equipped with a bottom drain pipe, sized to drain the permanent pool within 40 hours so that sediments may be removed when necessary. Constructed wetlands should be equipped with drains to allow the draindown or backflush of the wetlands cell if necessary. Such drains must 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 N.J.A.C.7:8-6, Soil Erosion and Sediment Control Standards for New Jersey and the NJDEP Stormwater Management Facilities Maintenance Manual.

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 2.5 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 X: Maintenance 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 twice annually and as needed. Such components may include forebays, bottoms, trash racks, outlet structures, and riprap or gabion aprons.

Because the forebay in gravel wetlands provides part for of the aerobic treatment for nitrogen removal, the forebay must be cleaned when it accumulates to either 10% of the forebay volume, to a depth of six inches, or if it remains wet 72 hours after the end of a storm event.

Disposal of debris, trash, sediment, and other waste material must be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing 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 must be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area must 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.

Note: The Considerations and Recommendations sections below are provided to assist the designer in enhancement of constructed stormwater wetlands. However, consistency with these recommendations and considerations is not required in order to receive the TSS nor the Nitrogen removal rate for this BMP.

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 a surface constructed wetland bed prior to planting (Claytor and 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.

D. Effectiveness

A review of the existing performance data indicates that the removal efficiencies of surface constructed stormwater wetlands are 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. 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.

C. Outlet Configuration

A hooded outlet with an invert or crest elevation at least 1 foot below the normal pool surface should be considered to prevent the discharge of floating oils and grease and to reduce the temperature of the discharge. However, the bottom elevation of the hood should be above the anticipated maximum sediment depth in the pond.

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