

SUBSURFACE GRAVEL WETLANDS

Definition

Subsurface gravel wetlands (SGW) are wetland systems designed to maximize the removal of pollutants from stormwater runoff through settling, uptake, and chemical transformation of pollutants. Gravel wetlands direct flow through a surface marsh which then discharges to a permanently ponded subsurface gravel bed.

Purpose

Subsurface gravel wetlands are used to remove a wide range of stormwater pollutants from land development sites. SGW have been identified as a BMP that will provide significant removal of nitrogen through the combined processes of aerobic nitrification and anaerobic denitrification. Therefore, it has been identified as one of the primary BMPs to be evaluated for use in nitrogen removal within the Barnegat Bay.

Subsurface gravel wetlands can also be used in conjunction with extended detention to reduce peak runoff rates when designed as a multi-stage, multi-function facility.

Conditions Where Practice Applies

Subsurface gravel wetlands 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. However, as with any retrofit, care must be taken to ensure that no adverse downstream impacts result from the installation of the retrofit project, including but not limited to, increases in downstream flows.

Finally, gravel wetlands must have a maintenance plan and, if privately owned, must 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. In addition, the character, diversity, and hardness of the wetland vegetation must be sufficient to provide adequate pollutant removal. Selected vegetation must be non-invasive and based on the anticipated water depth within the wetlands; preference should be given to native species whenever possible. (Additional information is provided in Chapter 7: Landscaping.)

A gravel wetland is a combination of a wetland community at the surface and subsurface flow across saturated gravel. The components of a typical gravel wetland are shown in the figure and table 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.)

Subsurface gravel wetlands include a sediment forebay at the inflow area. The forebay allows for the settling of coarse particles and provides an area targeted for more frequent maintenance. The discharge from the forebay enters the first of two wetlands cells. From the first cell, the flow is discharged either through a perforated riser pipe into the subsurface gravel bed or through a cross-drain into the second wetland cell. The perforated pipe accepts flow up to the elevation of the water quality design storm and discharges it into the first of two subsurface gravel cells. The flow then passes laterally through 15 feet of gravel and is captured by another perforated pipe that discharges the flow into the second gravel cell. On the surface, a portion of the inflow into the first wetlands area is conveyed to the second wetlands cells through a cross-drain. The cross-drain has its invert at $\frac{1}{2}$ the depth of the water quality design storm in each cell. Another perforated riser pipe in the second wetlands cell captures the flow up to the elevation of the water quality design storm and conveys it to the second subsurface gravel bed. The flow once again passes through 15 feet of anaerobic gravel before discharging. The two cell system allows the smallest storm events to pass through 30 feet of gravel, while the larger storm events pass through 15 feet of gravel for anaerobic treatment of the runoff.

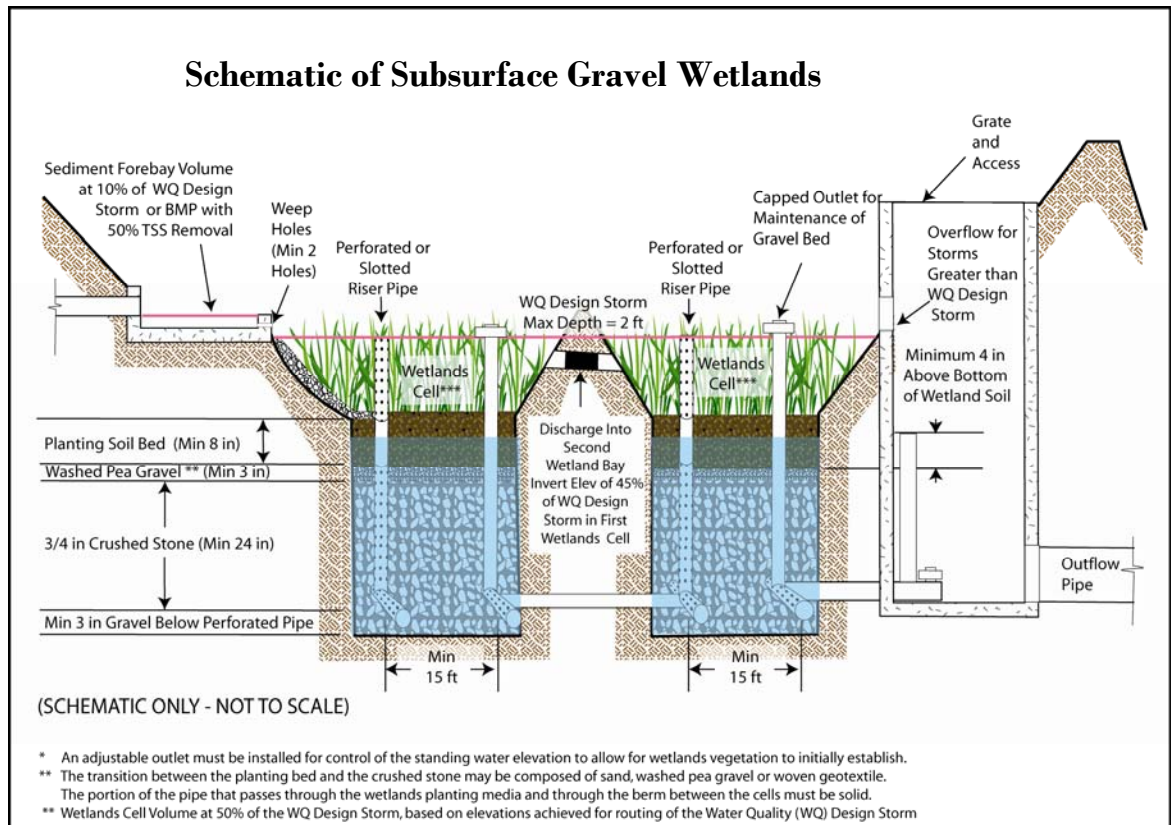
The SGW must be design to drain the water quality design storm between 24 to 48 hours. The drain time is controlled by an orifice at the outlet structure, placed four (4) inches above the bottom of the wetland soil bed. If designs include flow through the subsurface gravel significantly greater than 30 feet, additional analysis should be performed to determine whether the orifice or the losses through the subsurface gravel system controls the drain time. In addition, the riser pipes or underdrains must be sized with sufficient capacity that that they do not control the drain time of the system..

1. Wetlands Areas

Water quality treatment in the wetland surface is primarily provided through uptake, nitrification and settling. A minimum soil depth of eight inches must be provided for the vegetation. The soil mix must provide sufficient growing media and have low permeability rates since the flow into the gravel media must pass through the pipe and not through the wetlands soil.

The wetlands soils must have low hydraulic conductivity and should be mixed using a combination of compost, sand, silt, and clay, with the clay component not exceeding 15% by volume. The soil shall be silt loam with 10% to 20% organic content by mass. The organic matter should consist of leaf compost or peat. Leaf compost should be properly matured and at least one year old. The leaf compost should be made exclusively of fallen deciduous leaves with less than 5% dry weight of woody or green yard debris or other materials. The compost should be generally free of trash and

other debris. Leaf mulch, composted mixed yard debris, wood chips, biosolids, mushroom compost or composted animal manures are not acceptable sources of organic matter.



The wetlands soils must be continuously inundated at a depth of four inches from the bottom of the wetland soil 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. The transition between the planting bed and the crushed stone may be also composed of a combination of sand and washed pea gravel. This transition layer is necessary to prevent the finer portion of the wetland soil from migrating down into the gravel cells. The transition area must be designed to ensure that the wetland soil does not migrate to the gravel cell below. Pea gravel/sand must be used instead of filter fabric because the fine components of the wetland soil may clog the filter fabric and restrict root growth. The portion of the pipes that pass through the wetlands planting media and through the berm between the cells must be solid as shown above.

Selection of vegetation must be based on the duration of inundation. Additional information is provided in Chapter 7: Landscaping.

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
Distance of outlet invert above 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 15-foot distance between the inflow and outflow of the each gravel bed.

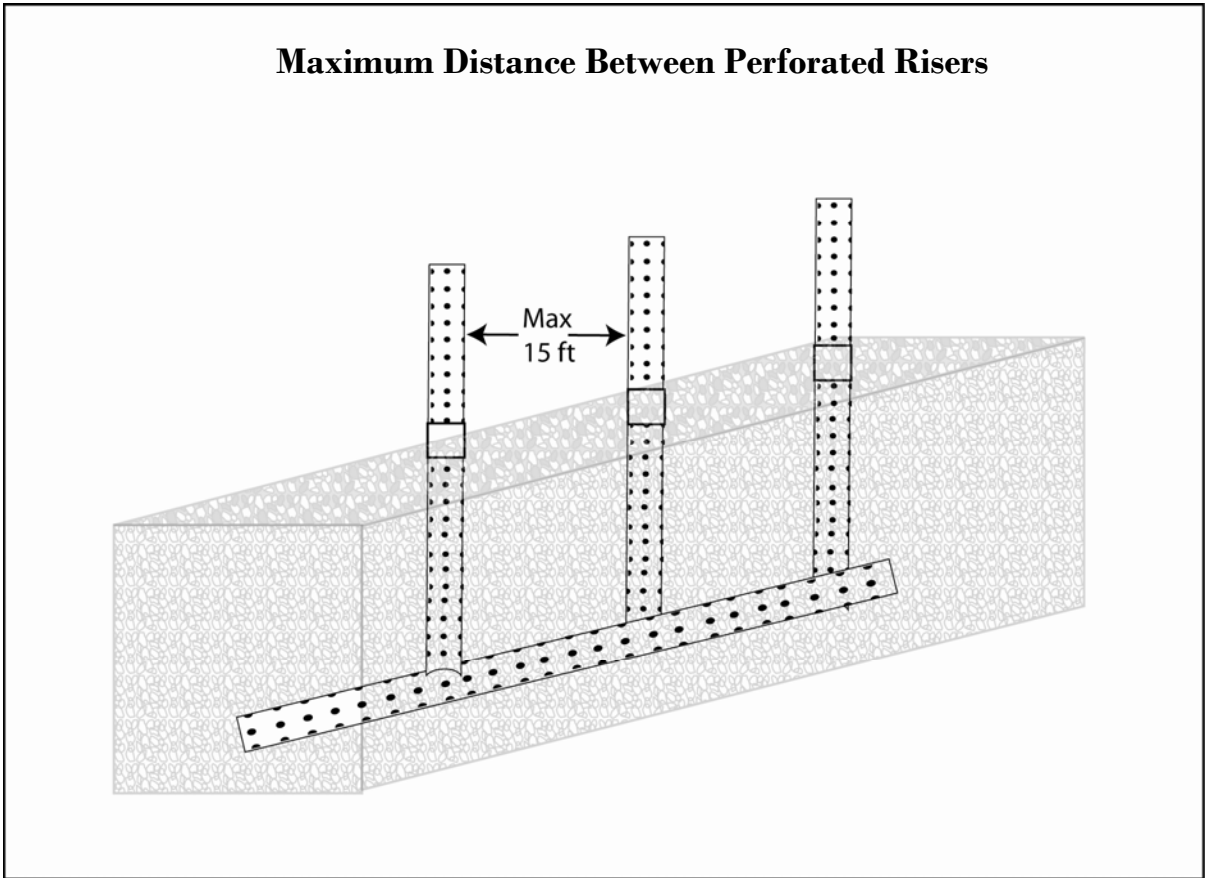
The bottom of the gravel wetlands does not require a separation from the SHWT. However, the bottom of the gravel bed must be enclosed with a liner or other impervious material to ensure that the gravel bed remains saturated, and to prevent the migration of the stormwater into the adjacent groundwater table and to prevent the drawdown of the existing adjacent groundwater. The elevation of the outlet pipe and box, including bedding materials must be at or above the seasonal high groundwater table or lined to prevent the migration of the stormwater into adjacent groundwater table and to prevent the drawdown of existing adjacent groundwater.

3. Other Components

The cross drain from the first to the second wetland cell should be sized to convey, at a minimum, the peak inflow from the water quality design storm. The perforated or slotted riser pipes discharging to the gravel beds should be spaced at a maximum distance of fifteen (15) feet apart as shown below.

The perforated riser pipes that discharge into the gravel cells as well as the underdrain pipes for the gravel beds should be sized to convey twice the anticipated maximum inflow rates in order to address future clogging and to ensure that the drain down times are not based on the perforated/slotted pipes. A minimum diameter of twelve (12) inches is recommended for the vertical risers. Lockable cleanout pipes for maintenance are also required.

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



C. Forebay

Forebays serve as pretreatment measures by removing coarser sediments, trash, and debris. Forebays can be earthen, constructed out of riprap, or made out of concrete. Forebays must provide a minimum storage volume of 10% of the runoff from the Water Quality Design storm. Concrete forebays must provide a minimum of two weep holes and ensure the forebay drains within nine hours, to enable maintenance of the forebay. 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 available both in *Chapter 6.7 –Manufactured Treatment Devices* and at <http://www.njstormwater.org/treatment.html>.

E. Outlet Structure

The outlet structure must have an adjustable outlet to allow vegetation to initially establish. Once the vegetation is established, the outlet structure must maintain the water elevation at four (4) inches above the bottom of the wetlands soil.

Subsurface gravel wetlands should be equipped with a bottom drain pipe valve at an elevation a minimum of three (3) inches above the bottom of the gravel bed for maintenance. **It must clearly indicate on the maintenance plan that all valves for maintenance are to remain closed except as**

necessary for specific maintenance activities, such as the temporary draindown or backflush of the subsurface wetlands cell if necessary. Such drains must be controlled by a lockable valve that is readily accessible from 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

Subsurface gravel wetlands must be able to convey overflows to downstream drainage systems in a safe and stable manner. SGWs 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

Gravel 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 off-line gravel wetlands, 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.

Maintenance

Effective subsurface gravel wetland performance requires regular and effective maintenance. *Chapter 8: Maintenance of Stormwater Management Measures* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including constructed stormwater wetlands. Additional maintenance requirements for gravel wetlands are presented below. These requirements must be included in the maintenance plan.

A. General Maintenance

All subsurface gravel 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. The forebay must be cleaned when it accumulates to either six (6) inches or 10% of the forebay volume or if it remains wet nine (9) hours after the end of a storm event.

The subsurface gravel wetland system has many components that allow portions of the system to drain for maintenance purposes or for the initial establishment of vegetation. The standard status of these valves or other controls must be clearly indicated in the maintenance plan to ensure that the hydraulics function as designed.

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. The wetlands vegetation must be harvested at least once every three years and no more frequently than 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 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 subsurface gravel 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 system must take between 24 hours and 72 hour to drain. If the drain time is significant longer than 72 hours or shorter than 24 hours for a storm event of one-inch or more, the wetland’s outlet structure, perforated pipe performance, forebay, valves, and other components that may provide hydraulic controls must be evaluated and appropriate measures taken to comply with the minimum and maximum drain time requirements and maintain the proper functioning of the subsurface gravel wetland. All the components that must be checked in such cases must be listed in the maintenance plan for the system.

Note: The Considerations section below are provided only to assist the designer in enhancement of constructed stormwater wetlands and are not required for the design of subsurface gravel wetlands.

Considerations

A gravel 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.

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