UNHSC

Subsurface Gravel Wetland

Design Specifications

June 2009

University of New Hampshire Stormwater Center (UNHSC)
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UNHSC SUBSURFACE GRAVEL WETLAND DESIGN SPECIFICATIONS JUNE 2009

NOTICE

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ACKNOWLEDGEMENTS

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UNH STORMWATER CENTER
SUBSURFACE GRAVEL WETLAND
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DESIGN SUMMARY

Category Type: Filtration system and stormwater wetland

Layout Description

The subsurface gravel wetland (SGW) is designed as a series of horizontal flow-through treatment cells, preceded by a sedimentation basin (forebay) (Figure 1). The device is designed to retain and filter the entire Water Quality Volume (WQV): 10% in the forebay, and 45% in each of the respective treatment cells. For small, frequent storms, each treatment cell filters 100% of the WQV. The SGW is designed as flow through treatment, where the stormwater passes through a gravel substrate that is a microbe rich environment. The device can be designed with a multi-staged outlet control to detain the Channel Protection Volume (CPV) and allow overflow for larger storms. By design, the WQV is contained and filtered then drains to stormwater conveyance or receiving waters. All surface basin (and forebay) side slopes are 3:1 or flatter for maintenance. Standing water of significant depth is not expected other than during large rainfall events. The wetlands cell soils are to be continuously saturated below a depth of four inches (10 cm) from the ground surface in order to both promote water quality treatment conditions and support wetland vegetation. To force this near-surface ground water condition, the system primary outlet has an invert four inches (10 cm) below the wetland ground surface (see Figure 1). Vertical perforated or slotted risers deliver the forebay outflow to the gravel below. Within the gravel layer, horizontal subdrains distribute the incoming flow, which then passes through the gravel substrate to subdrains on the downstream end. These subdrains collect the flow and deliver it into the next cell. ***Hydraulic control of the system occurs at the primary outlet. For large precipitation events, this hydraulic control throttles the flow through the system and forces stormwater inflow to be temporarily stored above the wetland surfaces***. , By design, the ponded water slowly drains down into the gravel layer below and is filtered through this layer prior to leaving the system. Precipitation events larger than the WQV will have some portion that overflows to receiving waters through an emergency spillway. At a minimum this "spilled" water will have received minor treatment much as in a traditional detention pond/wetland system.

System Functionality

System functionality has multiple components. From a unit process perspective, sedimentation, filtration, physical and chemical sorption, microbially mediated transformation, and uptake and storage predominate. There is pre-treatment by a sedimentation forebay. This is followed by treatment above the wetland cells by sedimentation akin to a dry pond. In addition, there is water quality treatment during the flow through the wetland plants as well as the minor infiltration through the wetland soil to the gravel below. Finally and predominantly, within the gravel layer there is treatment involving filtration, sorption, uptake and storage, and microbially mediated transformation. The conversion and removal of nitrogen is dependent on two conditions: an aerobic sedimentation forebay followed by subsurface anaerobic treatment cells. Aerobic conditions exist in the forebay when it is designed *and maintained* as a dry area with temporary ponding conditions during storm events. The anaerobic condition in the treatment cells is created by maintaining the high water table within the system as well as the slow flow through the gravel layer. This saturated condition drives the dissolved oxygen level down and creates conditions in which nitrate conversion to nitrogen gas occurs.

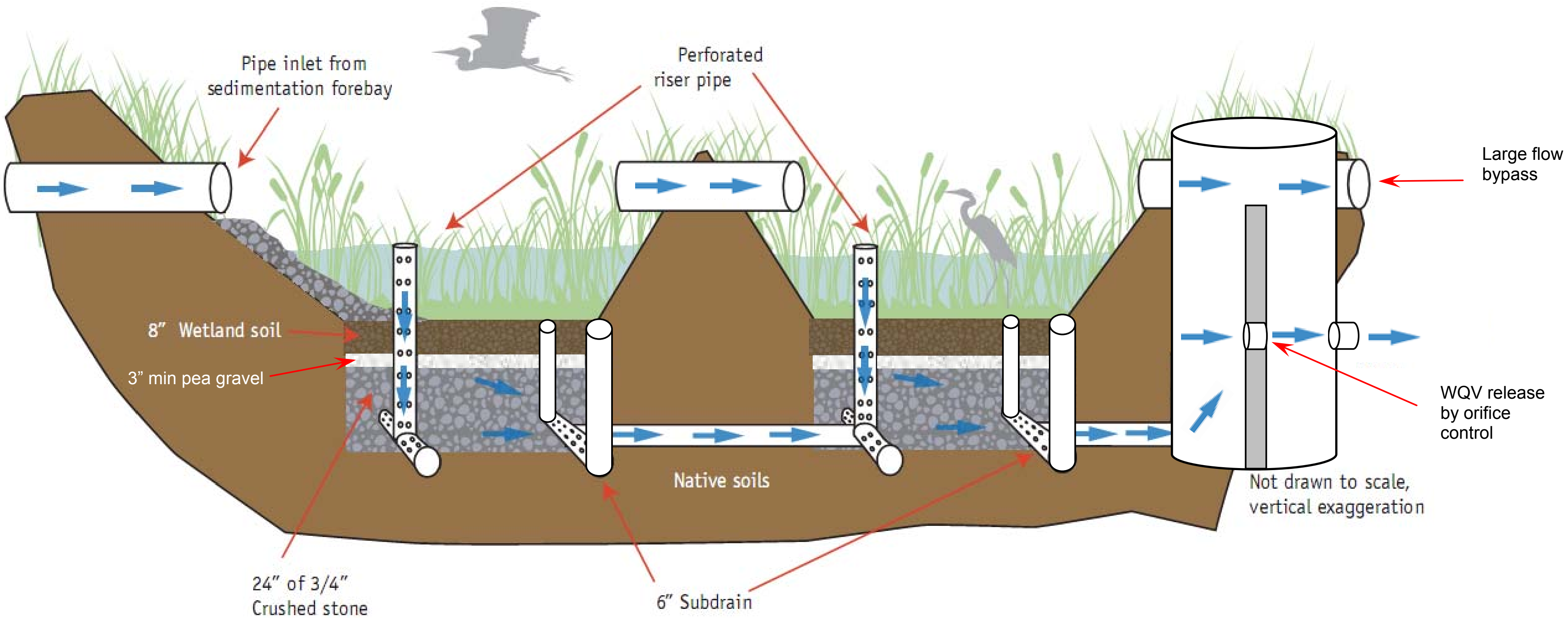
Retrofit Options

SGWs are well suited for retrofits within stormwater pond systems. These SGW systems are well suited because: 1) there is a limited hydraulic head requirement, 2) the SGW can be lined and does not require separation from groundwater, and 3) there is a straightforward placement of the system within the footprint of existing stormwater ponds. Hydraulic head requirements for gravel wetlands are approximately four inches (10 cm), whereas underdrained filtration systems may require as much as three feet (one meter) or more. Because the SGW is a horizontal porous media flow system it does require a hydraulic head to drive the water through the system. At a minimum, the driving head is the difference between the vertical distance from the ponded water level above the wetland surface and the invert of the primary outlet. To maintain the system in its saturated condition, it must be situated in low hydraulic conductivity soils or lined below the gravel layer. Because infiltration is not designed to occur, separation from groundwater is not required and the SGWs are sited much like stormwater ponds. While SGWs have a relatively large footprint for a stormwater quality treatment technology, they easily fit within the footprint of existing stormwater ponds that were sized for flood control. When retrofitting a SGW system into a stormwater pond, it is located towards the outlet of the pond. The area within the pond preceding the SGW is used for pretreatment. A wet pond retrofit would require a conversion to a dry pond by the elimination of the permanent pool.

SPECIFICATIONS SUMMARY

- May be preceded by pre-treatment: hydrodynamic separator, swale, forebay. Pre-treatment should normally be capable of holding 10% of the WQV.
- Two treatment cells.
- A subsurface water level is maintained through the design of the outlet invert elevation (invert just below the wetland soil surface).
- Retain and filter the entire Water Quality Volume (WQV), 10% in the forebay, and 45% above each of the respective treatment cells.
- Option to retain the Channel Protection Volume (CPV) for 24-48 hrs.
- No-geotextile or geofabric layers are used within this system, but may be used to line walls.
- If a native low hydraulic conductivity soil is not present below the desired location of the SGW, a low permeability liner or soil (hydraulic conductivity less than 10^{-5} cm/s = 0.03 ft/day) below the gravel layer should be used to minimize infiltration, preserve horizontal flow in the gravel, and maintain the wetland plants (Figure 2).
- Gravel length to width ratio of 0.5 (L:W) or greater is needed for each treatment cell with a minimum flow path (L) within the gravel substrate of 15 feet (4.6 m).
- 8 in. (20 cm) minimum thickness of a wetland soil as the top layer. (See description in Surface Infiltration Rates section for details (Figure 2)). This layer is leveled (constructed with a surface slope of zero).

Figure 1: Gravel Wetland—Concept Design



- 3 in. (8 cm) minimum thickness of an intermediate layer of a graded aggregate filter is needed to prevent the wetland soil from moving down into the gravel sub-layer. Material compatibility between layers needs to be evaluated.
- 24 in. (0.6 m) minimum thickness of ¾-in (2 cm) crushed-stone (gravel) sub-layer. This is the active zone where treatment occurs (Figure 2).
- The primary outlet invert shall be located 4" (10 cm) below the elevation of the wetland soil surface to control groundwater elevation. Care should be taken to not design a siphon that would drain the wetland: the primary outlet location must be open or vented. In contrast to Figure 1, the primary outlet can be a simple pipe.
- An optional high capacity outlet at equal elevation or lower to the primary outlet may be installed for maintenance. Thus outlet would need to be plugged during regular operation. This optional outlet allows for flushing of the treatment cells at higher flow rates. If it is located lower, it can be used to drain the system for maintenance or repairs.
- The Bypass outlet (emergency spillway, or secondary spillway) is sized to pass designs flows (10-year, 25-year, etc.). This outlet is sized by using conventional routing calculations of the inflow hydrograph through the surface storage provided by the subsurface gravel wetland system. Local criteria for peak flow reductions are then employed to size this outlet to meet those criteria.
- The primary outlet structure and its hydraulic rating curve are based on a calculated release rate by orifice control to drain the WQV in 24-48 hrs. For orifice diameter calculations refer to the NY Stormwater Manual (2001) or HDS 5 (FHWA, 2005) for details.
- The minimum spacing between the subsurface perforated distribution line and the subsurface perforated collection drain (see Figure 1) at either end of the gravel in each treatment cell is 15 ft (4.6 m): there should be a minimum horizontal travel distance of 15 ft (4.6 m) within the gravel layer in each cell.
- Vertical perforated or slotted riser pipes deliver water from the surface down to the subsurface, perforated or slotted distribution lines. These risers shall have a maximum spacing of 15 feet (4.6 m) (Figure 1). Oversizing of the perforated or slotted vertical risers is useful to allow a margin of safety against clogging with a minimum recommended diameter of 12" (30 cm) for the central riser and 6" (15 cm) for end risers. The vertical risers shall not be capped, but rather covered with an inlet grate to allow for an overflow when the water level exceeds the WQV.
- Vertical cleanouts connected to the distribution and collection subdrains, at each end, shall be perforated or slotted only within the gravel layer, and solid within the wetland soil and storage area above. This is important to prevent short-circuiting and soil piping.
- Berms and weirs separating the forebay and treatment cells should be constructed with clay, or non-conductive soils, and/or a fine geotextile, or some combination thereof, to avoid water seepage and soil piping through these earthen dividers.
- The system should be planted to achieve a rigorous root mat with grasses, forbs, and shrubs with obligate and facultative wetland species. In northern climates refer to the NY Stormwater Manual (http://www.dec.state.ny.us/website/dow/toolbox/swmanual/) or approved equivalent local guidance for details on local wetland plantings.
- Standard design approach for stormwater ponds should be followed as per the NY Stormwater Manual (2001) or approved equal with regards to forebay, spillways, bypass,

side slopes, erosion control, use of rip rap for stabilized regions at outlets and other locations of concentrated flow. etc.

SURFACE INFILTRATION RATES AND HYDROGEOLOGIC MATERIALS

Wetland Soil

The surface infiltration rates of the gravel wetland soil should be similar to a low hydraulic conductivity wetland soil (0.1-0.01 ft/day = 3.5 x 10^{-5} cm/sec to 3.5 x 10^{-6} cm/sec)). This soil can be manufactured using compost, sand, and some fine soils to blend to a high % organic matter content soil (>15% organic matter). Avoid using clay contents in excess of 15% because of potential migration of fines into subsurface gravel layer. Do not use geotextiles between the horizontal layers of this system as they will clog due to fines and may restrict root growth.

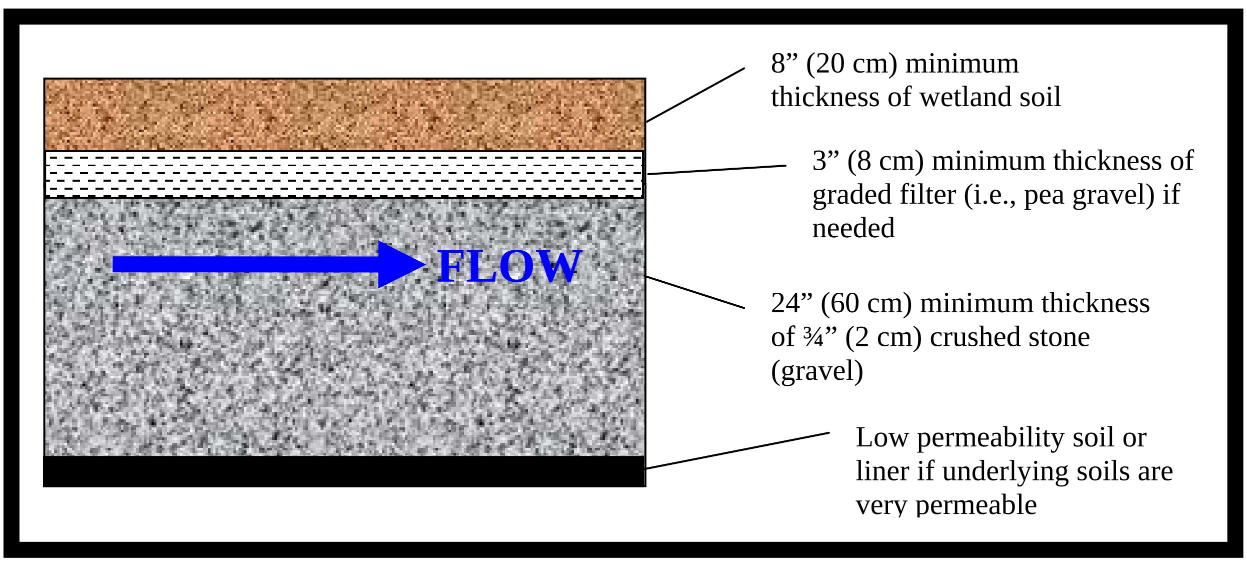
An intermediate layer of a graded aggregate filter (i.e., pea gravel) is needed to prevent the wetland soil from migrating down into the crushed-stone (gravel) sub-layer. This is to prevent migration of the finer setting bed (wetland soil) into the coarse sublayer. Material compatibility should be evaluated using FHWA criteria (see Ferguson, 2005):

Criteria 1: $D_{15,\,COARSE\ \ SUBLAYER} \le 5\,x\,D_{85,\,SETTING\ \ BED}$

Criteria 2: $D_{50,\,COARSE\ \ SUBLAYER} \le 25\,x\,D_{50,\,SETTING\ \ BED}$

Below the wetland soil and pea gravel is a crushed stone (gravel) sublayer with a 24 in. (0.6 m) minimum thickness. Angular crushed stone is needed with a minimum size ~3/4–in (2-cm). Large particle, angular coarse to very coarse gravel is needed to maintain system longevity.

Figure 2: Gravel Wetland Materials Cross -Section



Native Materials and Liner
If native a low hydraulic conductivity native soil is not present below the gravel layer, a low permeability liner or soil should be used to: minimize infiltration, preserve horizontal flow in the gravel, and maintain the wetland plants. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches (15 – 30 cm) of clay soil (minimum 15% passing the #200 sieve and a minimum permeability of 1 x 10^{-5} cm/sec), (b) a 30 ml HDPE liner, (c) bentonite, (d) use of chemical additives (see NRCS Agricultural Handbook No. 386, dated 1961, or Engineering Field Manual), or (e) a design prepared by a Professional Engineer.

DESIGN SOURCES

The primary design sources for the development of the subsurface gravel wetland are listed below, in the order of use.

- University of New Hampshire Stormwater Center 2002, http://www.unh.edu/erg/cstev//
- Claytor, R. A., and Schueler, T. R. (1996). Design of Stormwater Filtering Systems, Center for Watershed Protection, Silver Spring, MD.
- Georgia Stormwater Management Manual, Volume 2: Technical Handbook, August 2001, prepared by AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, Atlanta Regional Commission.
- New York State Stormwater Management Design Manual, October 2001, prepared by Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043, for New York State, Department of Environmental Conservation, 625 Broadway, Albany, NY 12233.

MAINTENANCE

Maintenance and Inspection Recommendations are largely adapted from CTDEP (2004) Stormwater Quality Manual for filtration systems. Inspection schedules have two periods: i) 1st Year Post-Construction, ii) Post-Construction Routine Monitoring. Maintenance is critical for the proper operation of subsurface gravel wetland systems. 1st Year Post-Construction monitoring differs primarily by its increased frequency to assure proper vegetative establishment and system functioning. Post-Construction Routine Monitoring is based on USEPA requirements for Good Housekeeping practices.

Unlike other filtration systems, a subsurface gravel wetland is a subsurface, horizontal filtration system and does not rely upon the surface soils for treatment. As such, surface infiltration rates are expected to be low and are not used for the criteria for cleaning/maintenance. Rather, stormwater access to the subsurface gravel layer is the critical hydraulic performance measure.

Inspection and Maintenance

❍ ***1st Year Post-Construction:*** Inspection frequency should be after every major storm in the first year following construction.

- ❑ Inspect to be certain system drains within 24-72 hrs (within the design period, but also not so quickly as to minimize stormwater treatment)).
- ❑ Watering plants as necessary during the first growing season
- ❑ Re-vegetating poorly established areas as necessary
- ❑ Treating diseased vegetation as necessary
- ❑ Quarterly inspection of soil and repairing eroded areas, especially on slopes
- ❑ Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.

❍ ***Post-Construction:*** Inspection frequency should be at least every 6 months thereafter, as per USEPA Good House-Keeping Requirements. Inspection frequency can be reduced to annual following 2 years of monitoring that indicates the rate of sediment accumulation is less than the cleaning criteria listed below. Inspections should focus on:

- ❑ Checking the filter surface for dense, complete, root mat establishment across the wetland surface. Thorough revegetation with grasses, forbs, and shrubs is necessary. Unlike bioretention, where mulch is commonly used, complete surface coverage with vegetation is needed.
- ❑ Checking the gravel wetland surface for standing water or other evidence of riser clogging, such as discolored or accumulated sediments.
- ❑ Checking the sedimentation chamber or forebay for sediment accumulation, trash, and debris.
- ❑ Inspect to be certain the sedimentation forebay drains within 24 to 72 hrs.
- ❑ Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.
- ❑ Removal of decaying vegetation, litter, and debris.

❍ ***Cleaning Criteria for Sedimentation Forebay***: Sediment should be removed from the sedimentation chamber (forebay) when it accumulates to a depth of more than 12 inches (30 cm) or 10 percent of the pretreatment volume. The sedimentation forebay should be cleaned of vegetation if persistent standing water and wetland vegetation becomes dominant. The cleaning interval is approximately every 4 years. A dry sedimentation forebay is the optimal condition while in practice this condition is rarely achieved. The sedimentation chamber, forebay, and treatment cell outlet devices should be cleaned when drawdown times exceed 60 to 72 hours. Materials can be removed with heavy construction equipment; however this equipment should not track on the wetland surface. Revegetation of disturbed areas as necessary. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

❍ ***Cleaning Criteria for Gravel Wetland Treatment Cells***: Sediment should be removed from the gravel wetland surface when it accumulates to a depth of several inches (>10 cm) across the wetland surface. Materials should be removed with rakes rather than heavy construction equipment to avoid compaction of the gravel wetland surface. Heavy equipment could be used if the system is designed with dimensions that allow equipment to be located outside the gravel wetland, while a backhoe shovel reaches inside the gravel wetland to remove sediment. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

❍ ***Draining and Flushing Gravel Wetland Treatment Cells***: For maintenance it may be necessary to drain or flush the treatment cells. The optional drains will permit simpler maintenance of the system if needed. The drains need to be closed during standard operation. Flushing of the risers and horizontal subdrains is most effective with the entire system drained. Flushed water and sediment should be collected and properly disposed.

REFERENCES

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- CTDEP (2004). Connecticut Stormwater Quality Manual. Hartford, CT.
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