BIORETENTION AND GRAVEL WETLAND SOIL MEDIA TESTING GUIDANCE

Bioretention systems and gravel wetlands are two commonly implemented stormwater best management practices, described in the 2017 Vermont Stormwater Management Manual Rule (2017 VSMM).

Bioretention relies on a "planting soil" media that filters stormwater runoff and sustains plantings recommended by the practice.

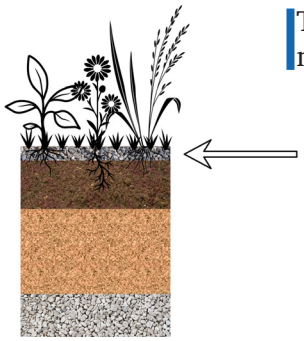
Gravel wetlands filter stormwater through a subsurface gravel/stone layer that lies beneath a wetland soil surface, intended to support vegetation.

Soil media specifications need to balance several goals including the ability to store and filter stormwater, sustain plants, reduce the potential for phosphorus (P) leaching, and when possible, be sourced locally in Vermont. Over the past few years, researchers at the University of Vermont and Watershed Consulting LLC., have been studying the performance of these systems in the field and laboratory. This document presents research-based soil media recommendations for designers and contractors to achieve desired total P removal efficiencies and runoff volume reduction.

Gravel wetland installation at Burlington's Waterfront Park. Credit: Rebecca Tharp

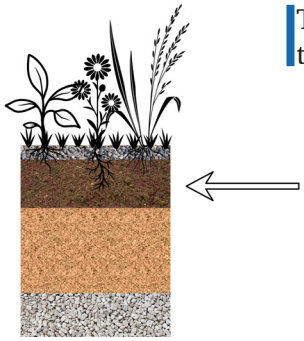
Bioretention

Bioretention design consists of a 24–48-inch deep bioretention soil media (depending on the requirements of the proposed vegetation). When not designed for infiltration, the system shall include an underdrain embedded within a stone layer per the design requirements of the 2017 VSMM. The ponding area should be designed for at least 6 inches of ponding depth and must fully drain within 24–48 hours. The bioretention soil media shall consist of a surface treatment, an upper media layer, and a lower media layer as follows:



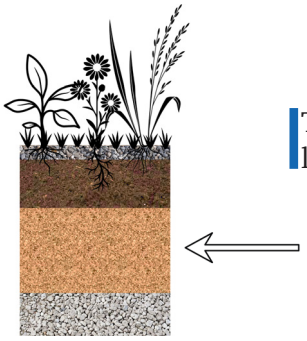
The **surface treatment** shall suppress weed growth, and consist of mulch, stone or other inert material that minimizes exposed soil.

- If mulch is used, it should be shredded hardwood mulch that is well aged (stockpiled or stored for at least 6 months), uniform in color and free of other materials, such as weeds, seeds, soil, roots, etc. A finely shredded, well-aged organic dark pine mulch may be accepted. Mulch should be applied to a maximum depth of 3 inches. Bark dust mulches and wood chips are not acceptable because they float and move to the perimeter of the bioretention area during a storm event. Grass clippings should not be used as mulch material.
- Pea-stone should be 3/8-1/2-inch diameter rounded and washed.
- Acceptable alternatives to mulching include mulching only around shrubs, planting with perennial groundcover, or grass seeding.



The **upper media layer** consists of the upper 12 inches immediately below the surface treatment.

- It shall consist of a mix of organic matter and USDA sand to loamy sand classification, and generally meet the following gradation: sand 85-95%, with no more than 25%of the sand as fine or very fine sands, no more than 15% silt and clay, with 2-5% clay content, by volume.
- If organic matter in the form of compost is incorporated into the upper media layer it shall comprise no more than 3% by volume. If the organic matter consists of a material other than compost, such as peat, it shall comprise no more than 3-7% of the upper media layer.
- In all cases, when bioretention is designed with an underdrain and compost is utilized and mixed within the upper media layer, the overall soil media as mixed shall meet the P-testing requirement, as described below.
- For infiltrating bioretention systems, without an underdrain pipe, the soil media as mixed shall meet the P-testing requirement if it is located within one-quarter mile of a receiving water body.
- Alternatively, the upper media layer may be free of organic matter that is directly mixed with the sand, and any compost or organic matter that is added must be limited to specific planting locations or at the base of individual plants (side-dressing, also known as spot-applying). In this case, P-testing of the compost is not required, provided that the compost utilized is not a manure-based or biosolids-based compost.



The **lower media layer** is located directly below the upper media layer, and above the stone layer that includes the underdrain, generally extending down to a maximum of 48 inches.

- This layer shall consist of USDA sand to loamy sand and generally meet the same gradation as the upper media layer. The lower media layer must not have compost or other organic matter component, unless required to support planting a tree, and if so, organic matter shall only be spot applied in that specific location.

Gravel Wetlands

Gravel wetlands are composed of a surface gravel wetland soil layer, a transition layer between the wetland soil and the gravel cell(s), and a subsurface gravel layer. These layers should meet the following guidelines.

The **gravel wetland soil layer** ensures that runoff does not infiltrate through the soil to the subsurface gravel wetland treatment media. Runoff should predominantly enter the gravel wetland treatment media through the perforated riser pipe(s) and secondary stone inlet. The soil layer shall have a minimum thickness of 8 inches and shall be level, constructed with a surface slope of zero.

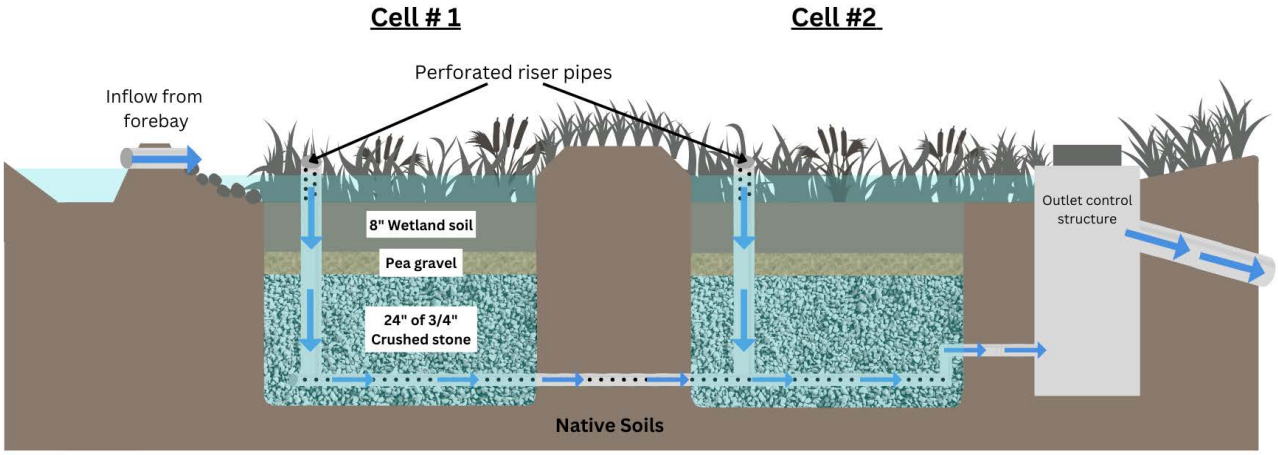
- The soil media shall have low saturated hydraulic conductivity (Ksat) measured between 0.1-0.01 ft/day or with a soil texture conforming to Hydrologic Soil Group D.
- Soil pH should between 6.0 and 7.0.
- Utilization of onsite material to manufacture the soil layer is encouraged provided the soil will meet specifications, either as a standalone product or by amendment with outside material.
- In all cases, the gravel wetland soil shall be tested in accordance with the P-testing procedure described below.

The **transition layer**, when present, is located between the gravel wetland soil layer and the subsurface gravel cell(s) and serves to prevent wetland soil from migrating to the gravel cells below.

- The transition layer may be composed of either pea gravel or a combination of sand and pea gravel.

The **subsurface gravel layer** is designed to accept stormwater inflow through the perforated riser pipe in each cell and from any secondary stone inlet. It is essential that discharge from the gravel cells leaves only via the outlet structure.

- The subsurface gravel layer shall be a minimum of 24 inches in depth and consist of ¾-inch crushed stone.
- Designers must document through onsite soil characterization that native subsoils are sufficiently impermeable to support a seasonal high-water table (SHWT) within the gravel layer. A liner below the subsurface gravel layer is required in cases where native subsoils cannot support this SHWT.



Conceptual diagram of gravel wetland flow path, adapted from Fig. 1, Ballestero et al. (2016).

Phosphorus Testing Requirement

P testing is required for **upper media layer of bioretention systems** and **gravel wetland soil layers**. Final mixes must have a Phosphorus Saturation Ratio (PSR) less than or equal to 0.10. PSR is to be determined using the following protocol:

1. Samples are to be air dried and sieved through 2 mm prior to testing
2. Air-dried, sieved soil samples are to then be extracted with the Mehlich-3 solution (0.2 M CH_3COOH + 0.25 M NH_4NO_3 + 0.015 M NH_4F + 0.013 M HNO_3 + 0.001 M EDTA) by shaking a soil-solution suspension for 5 minutes at a 1:10 ratio (soil mass in grams: solution volume in mL), followed by filtering to remove particles (pore size of 2 µm is recommended, max pore size = 8 µm).
3. Extracts from the Mehlich-3 procedure are to be analyzed for P, Fe, and Al by ICP-OES.
4. The Phosphorus Saturation Ratio (PSR) is then calculated as follows:

$$PSR = \frac{\left(\frac{P_{M3}}{31}\right)}{\left(\frac{Fe_{M3}}{56}\right)+\left(\frac{Al_{M3}}{27}\right)}$$

where,

- P_{M3}= Mehlich-3 P in mg P per kg dry soil
- Fe_{M3} = Mehlich-3 Fe in mg Fe per kg dry soil
- Al_{M3}= Mehlich-3 Al in mg Al per kg dry soil

Mehlich-3 extractions follow the above protocol (for more details, see Wolf and Beegle, 2009). Other soil test extractions, including Modified Morgan Tests, Oxalate Extractions, Water Extractions, or extractions used to quantify total elements, are ***not*** acceptable for this requirement.

In cases where ingredient mixing has not yet occurred, ingredients can be mixed at the intended volumetric proportions in a small batch (at least one quart in volume) for testing purposes. If this small batch testing approach is taken, the final material to be used during installation must be re-tested to confirm acceptable PSR.

Soil Analysis

Soil samples for P, Fe, and Al analysis via Mehlich-3 extraction can be submitted to the Agricultural and Environmental Testing Laboratory (AETL) located at UVM. Each sample costs $15. Please allow least 3-4 weeks for analysis.

How to take a soil sample [go.uvm.edu/soil-sampling]
Submitting a soil sample [go.uvm.edu/uvm-soil-lab]

References

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Bioretention at ECHO, Leahy Center for Lake Champlain. Credit: Holly Greenleaf

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