Guidance on using new high performance bioretention soil mixes

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- Brandi Lubliner, November 2018: Bioretention facility in Olympia, WA

Related Information

- Publication 13-10-017: Focus on Bioretention Soil Media[1]
- Ecology's stormwater manuals: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Stormwater-manuals

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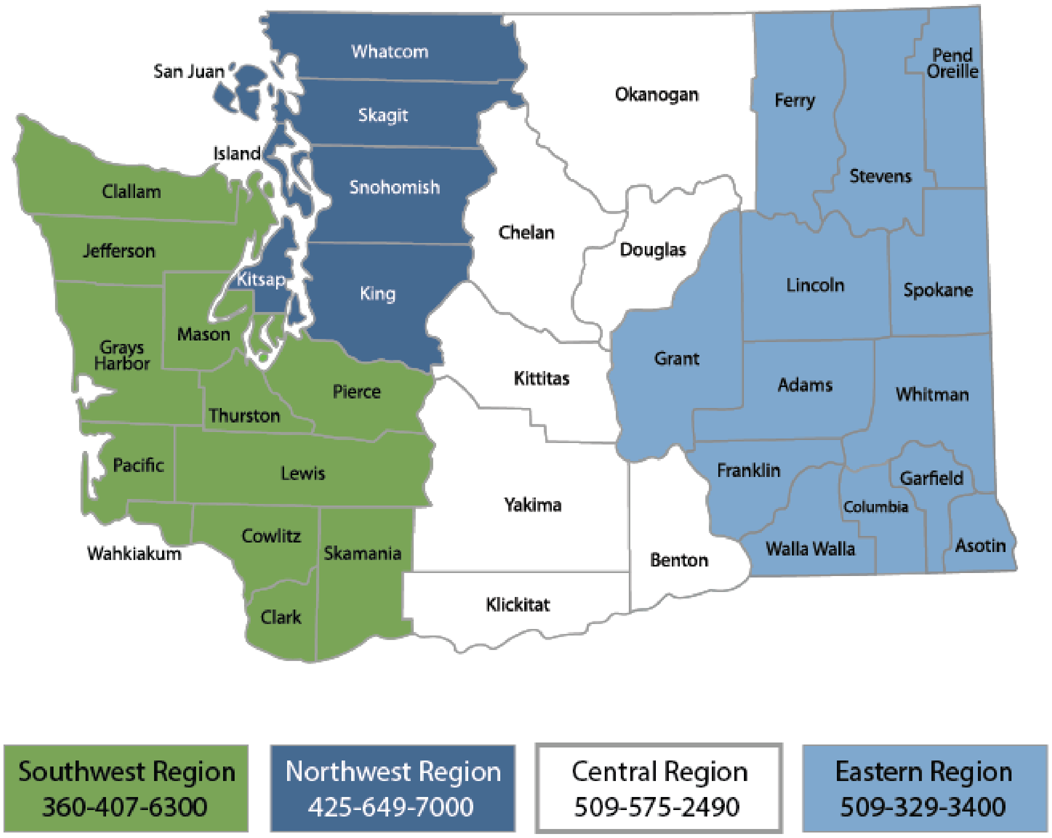

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Table of Contents

2021 update on bioretention soil mixes ... 5

Background on existing requirements ... 5

Research since 2016 on the default BSM ... 6

Copper ... 6

Nutrients ... 6

Filtration rate ... 7

Development of an alternative BSM ... 7

Approved high performance bioretention soil mix ... 7

Current guidance for municipal stormwater permittees ... 8

Appendix 1: High Performance Bioretention Soil Media (HPBSM) Specifications ... 10

Type 1: HPBSM Primary Layer ... 11

Coconut Coir Fiber ... 12

Filter Sand ... 13

High Carbon Wood Ash (Biochar) ... 14

HPBSM Polishing Layer ... 15

Activated Alumina ... 16

Iron Aggregate ... 17

Underdrain ... 18

Blending, Delivery, Protection, and Placement ... 18

References ... 19

2021 update on bioretention soil mixes

This 2021 bioretention report provides information on new alternative bioretention soil mix (BSM) that can be used in locations near phosphorus-sensitive waterbodies. This report provides the specifications for the new BSM, treatment performance of the new BSM, and the regulatory status in the municipal stormwater NPDES permit program.

Background on existing requirements

In 2013, Ecology published guidance based on findings from grant-funded studies that a best management practice (BMP) called bioretention used to treat stormwater runoff exports nitrogen, phosphorus, and some dissolved copper. The 2013 bioretention focus sheet advised stormwater managers, designers, and permittees to not use bioretention in project locations with surface discharges to phosphorous-sensitive receiving waters (Ecology, 2013). In May 2016, Ecology updated the same focus sheet, advising that a minimum one-quarter mile distance from phosphorus-sensitive receiving waters would be needed for bioretention BMPs if the site's underlying soils did not meet the site suitability criteria for runoff treatment or if the design used an underdrain that would route to those waters (Ecology, 2016). Ecology updated the stormwater manuals in 2019 to reflect the 2016 focus sheet update.

Phosphorus-sensitive receiving waters is not a defined term but is meant to be inclusive of surface waters such as lakes or wetlands that are sensitive to eutrophication and those that are being managed to control phosphorus inputs such as a lake management plan, algal bloom management plan, and water clean-up plan.

Bioretention is a commonly used BMP to treat and infiltrate stormwater onsite. Bioretention is BMP T7.30 in the 2019 Stormwater Management Manual for Western Washington (SWMMWW) and BMP T5.31 and F6.23 in the 2019 Stormwater Management Manual for Eastern Washington (SWMMEW), (stormwater manuals). Bioretention uses low impact development (LID) principles, provides runoff treatment, and controls runoff flows. Few stormwater BMPs satisfy all three stormwater management objectives, which is a primary reason bioretention is so commonly used in Washington State. The BSM itself is the 'filter layer', and can be composed of either a default or a custom mix per the stormwater manuals.

The default BSM specification is 60% sand and 40% compost by volume (default BSM), and it provides filtration of stormwater to achieve runoff treatment. The 2019 stormwater manuals discourage use of this default BSM in bioretention facilities at locations within one-quarter mile of a phosphorus-sensitive receiving water if the underlying soils do not meet site suitability criteria for runoff treatment, due to the phosphorus export from the compost material. The initial export of phosphorus from the newly mixed default BSM occurs in quantities of concern for downstream phosphorus-sensitive surface waters such as lakes and wetlands. The 2019 stormwater manuals also advise against underdrains in bioretention with the default BSM when the under-drained water would be routed to a phosphorus-sensitive receiving water due to the phosphorus export from the compost material. There are no changes to the existing guidance on use of the default BSM for bioretention in this publication.

Research since 2016 on the default BSM

The default BSM has been robustly studied locally. Early research indicated nitrogen, phosphorus, and copper export from the default BSM (we now know the compost fraction of the BSM) can occur at levels of concern for receiving waters (Herrera, 2016; King County 2017; Davis and McIntyre, 2016; King County 2019). Studies show that over time, the concentrations of nutrient export from the BSM decreases (King County and Herrera, 2020; McIntyre et al., 2020). Evaluations of other parameters show that the BSM provides substantial reduction in pollutants: 80-100% reduction of total suspended solids, total lead (Pb) and zinc (Zn), fecal coliform, E.coli, and a variety of organic compounds including PAHs and PCBs (King County 2017; Davis and McIntyre, 2016; King County, 2020; King County and Herrera , 2020; McIntyre et al., 2020).

Copper

Concentrations of dissolved copper (Cu) exported from the default BSM are a concern within the first year (Herrera, 2016). However, recent research on bioavailability shows that enough dissolved carbon from the default BSM is also exported during the establishment phase of a new bioretention BMP to effectively bind metals, making them unavailable to harm biota (Davis and McIntyre, 2016; McIntyre et al., 2020). McIntyre et al., 2020 found that bioretention BMPs with vegetation provide some additional dissolved copper treatment.

Stormwater treatment effectiveness studies are commonly designed to report on percent change in concentration when comparing effluent to influent concentrations, inadvertently making influent concentration a predictor of BMP success. As a result, improper conclusions can be made. For example, influent and effluent copper concentrations are often very low numbers and while results may be statistically significant they may not be environmentally relevant, i.e. a 50% difference between the values of 1 ug/L vs 2 ug/L. With this in mind, Ecology does not consider the mixed results regarding dissolved copper treatment combined with the information on bioavailability to be compelling enough to drop the metals treatment (also known as enhanced treatment in the SWMMWW) designation for bioretention built with imported compost.

Nutrients

The compost and, to a lesser extent, the mulch overlay, are reported to be the source of the nitrogen and phosphorus export from the bioretention BMP designs. This is unsurprising, as compost provides nutrients and water holding capacity for plant growth. However, the dissolved inorganic (ortho) phosphorus leaching condition appears to decrease substantially after 2 years for bioretention with plants, and after one year for bioretention with a fungal inoculated mulch amendment (McIntyre et al., 2020).

Filtration rate

Ecology's guidance for bioretention design and sizing relies on a given initial infiltration rate for the BSM of 12 inches per hour. Site-specific safety factors are then applied to ensure the size of the BMP is adequate for flow control for the lifespan of the BMP, to prevent under-sizing, and to prevent excessive maintenance needs. We have learned over the last decade from local studies that BSM filtration rates start much higher and slow down incrementally, but to a varied extent after initial establishment and use. Ecology does not yet know the full lifespan (under proper maintenance) of bioretention BMPs regionally. SAM studies on properly installed and maintained bioretention BMPs that are up to 10-12 years old appear to maintain double digit infiltration rates with the exception of trash, seasonal freezing, and leaf litter blockages (Taylor et al., 2018 and 2020). Future SAM studies will evaluate the end-of-life timeframes for both flow control and runoff treatment. At this time Ecology's guidance remains the same, to use 12 inches per hour as the initial filtration rate and apply site-specific safety factors, with the intent to prolong the functional lifespan of the BMP.

Development of an alternative BSM

Ecology and the Stormwater Action Monitoring (SAM) program have funded research since 2013 and 2015 respectively to find new alternative BSMs that will not export nutrients or copper. This new guidance is based on the following studies:

- Ecology stormwater Grants of Regional or Statewide Significance program funded a study with Kitsap County (Herrera, 2015) to evaluate BSM components and blends to form the basis of an alternative BSM.
- SAM funded King County to test alternative BSMs in a bench-scale study. The goals were: low phosphorus export, treatment of suspended solids and metals treatment, affordability, and reduced toxicity to aquatic life. The phosphorus export reduction goal was met using iron aggregate and activated alumina in a 'polishing layer' (King County and Herrera, 2020).
- Ongoing Ecology grants to the City of Bellingham and Whatcom County are evaluating full-scale bioretention performance using high performance media to treat phosphorus and meet phosphorus TMDL goals in Lake Whatcom.

Approved high performance bioretention soil mix

Ecology approves of the high performance bioretention soil mixes (HPBSMs) shown in Table1.

Table 1. Approved high performance BSM (HPBSM) for runoff treatment in bioretention

Performance Goals for Runoff Treatment	Achieves suspended solids treatment (≥80% reduction)	Achieves dissolved metal treatment (≥30% copper and ≥60% zinc reduction)	Achieves phosphorus treatment (≥50% reduction)	Achieves additional LID objectives and water quality objectives [a]
Type 1: 18" HPBSM Primary layer. HPBSM primary layer consists of 70% sand, 20% coir, and 10% high carbon wood ash (biochar) by volume.	X	X		
Type 2: 18" HPBSM Primary layer plus 12" HPBSM Polishing Layer. HPBSM Polishing layer consists of 90% sand, 7.5% activated alumina, and 2.5% iron aggregate by volume.	X	X	X	
Type 3: 18" HPBSM Primary Layer plus 12" HPBSM Polishing Layer plus 2"Compost Surface Layer [b, c]. Compost must meet bioretention compost specifications in Ecology's stormwater manuals.	X	X	X	X

[a] The 2" Compost Surface layer is anticipated to improve success of plantings, due to improved water holding capacity (McIntyre et al., 2020). Additionally, based on the King County and Herrera, 2020 study this mix was successful in meeting all treatment goals (basic, copper, zinc, and phosphorus) as well as some protection against the acute toxicity to *C. dubia* and *D. rerio* found in the influent (untreated) stormwater.
[b] Do not use the HPBSM Primary Layer (Type 1) with the Compost Surface Layer without the HPBSM Polishing Layer. The HPBSM Polishing Layer is necessary to limit phosphorus and nitrogen export from the Compost Surface Layer.
[c] Carbon or organic matter components of the mixes such as compost and mulch are believed to be an important factor to capture organic compounds in stormwater runoff (King County and Herrera, 2020, McIntyre et al., 2020).

Current guidance for municipal stormwater permittees

Stormwater infrastructure is usually publically funded and Ecology recognizes the need for confidence in bioretention effectiveness for flow control and runoff treatment.

Bioretention BMPs are among the most cost-effective stormwater management options, but we do not yet know their full life span. We anticipate it to be in the range of 20-40 years. Ecology will continue to require permittees to remove barriers to LID in their codes and local ordinances. Ecology continues to support the use of bioretention within the 2019 SWMMWW and 2019 SWMMEW.

These three HPBSM options are now approved for use as the engineered soil layer for bioretention BMP designs in Washington State.

Use of HPBSM in bioretention BMPs ***is*** allowed within one-quarter mile of a known or suspected phosphorus-sensitive receiving water. Designers can install the HPBSM Polishing

Layer directly beneath the HPBSM Primary Layer, or as the second stage in a two-stage treatment train to attain treatment of phosphorus in stormwater runoff.

This document on HPBSM specifications is available in the interactive online stormwater manuals as an “Additional Resource”.

Ecology anticipates incorporating these alternatives for BSM in the bioretention BMP design when we next update the stormwater manuals. Ecology requests that project proponents report back any issues they may have with obtaining materials that meet these specifications so that we can further refine the criteria prior to the next manual updates.

Appendix 1: High Performance Bioretention Soil Media (HPBSM) Specifications

This appendix provides the specifications for making the HPBSM that were studied as part of the SAM study. King County, Herrera Environmental Consultants, Inc. and Whatcom County are acknowledged for working with Ecology to develop and test specifications for this publication.

The high performance bioretention soil mixes (HPBSM) shown in Table 1 are the engineered soil layer for bioretention BMP designs in Washington State to achieve specific runoff treatment performance goals. Two of the three new BSM types are approved for phosphorus treatment.

Figures 1 and 2 present typical cross sections of the HPBSM. Figure 1 is an example of the HPBSM with the primary layer but no polishing layer or compost layer (Type 1), and Figure 2 is a typical cross section of the HPBSM with the primary layer, polishing layer, and compost layer (Type 3).

Figure 1. Typical Cross Section of Type 1 HPBSM

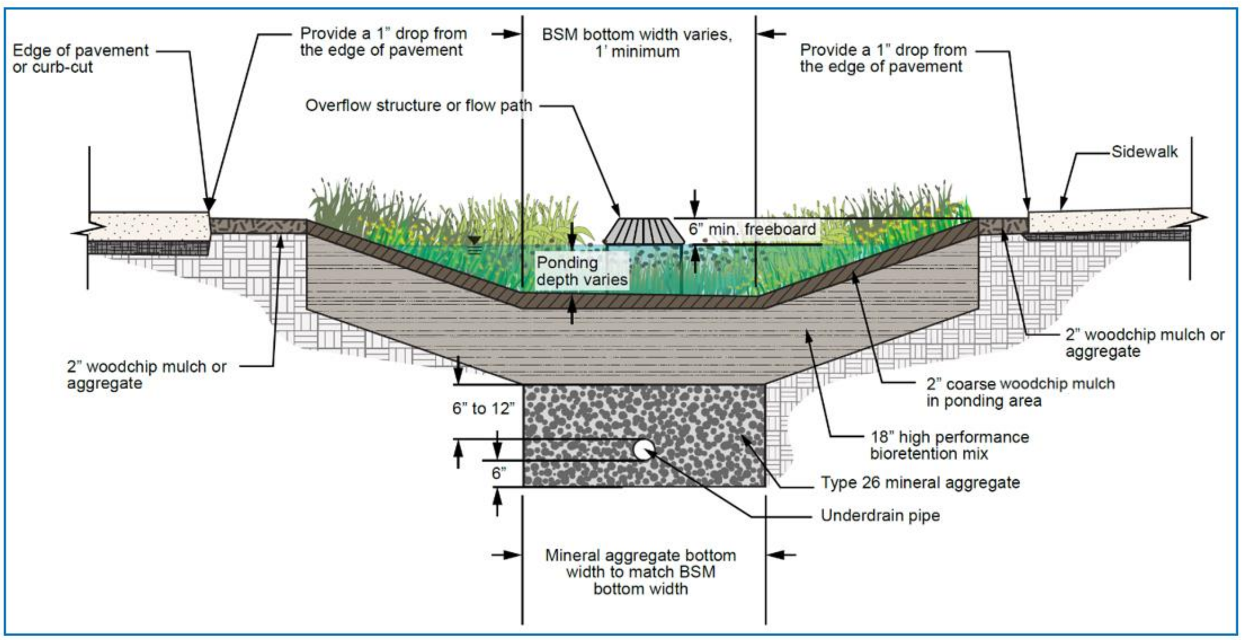
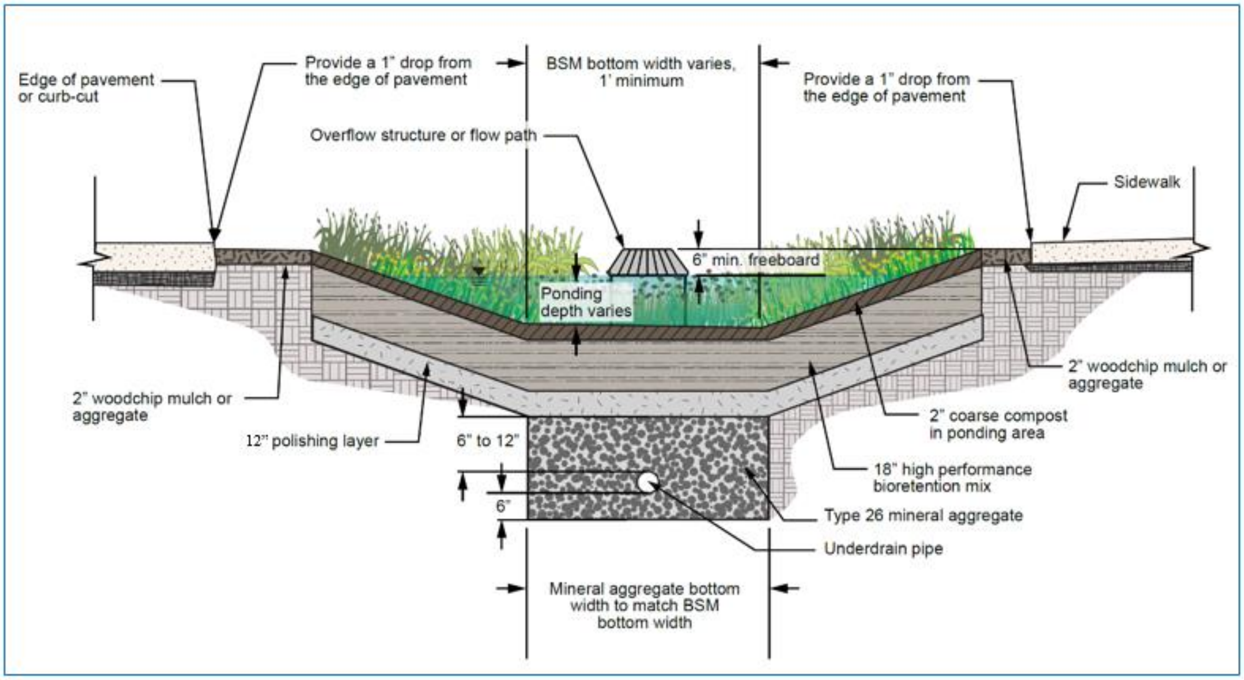


Figure 2. Typical Cross Section of Type 3 HPBSM



Type 1: HPBSM Primary Layer

The HPBSM Primary Layer media should be a blend of the following components in the following ratios:

Component	Ratio (by volume)
Filter Sand	70% (+/- 3%)
Coconut Coir Fiber	20% (+/- 2%)
High Carbon Wood Ash	10% (+/- 1%)

Coconut Coir Fiber

The Coconut Coir Fiber should be double rinsed and buffered, meeting the following requirements for quality:

Test / Method	Testing Responsibility [a]	Criterion	Requirement
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	Proponent	NO_3+NO_2	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Proponent	Total Phosphorus	0.15 mg/L (Max.)
		Ortho-phosphorus	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Proponent	Copper	10 µg/L (Max.)
Test Methods for the Examination of Compost and Composting (TMECC) Method 04.10-A	Manufacturer	Electrical Conductivity	1.0 mmhos/cm (Max.)

[a] Though the manufacturer will provide many of the tests indicated in this table, project proponents are encouraged to test the exact material which will be provided for their projects. Manufacturer tests are only run periodically on the source material not on the exact material supplied for the project.

Filter Sand

The aggregate shall be sand meeting the gradation below and the requirements of Section 9-03.1(2)B (Class 1) of the Washington State Department of Transportation Standard Specifications, and shall have a Coefficient of Uniformity of four (minimum). The filter sand gradation tolerances herein apply to the aggregate in the HPBSM Primary Layer media as well as the HPBSM Polishing Layer media (if used):

Sieve Size	Percent Passing Min.	Percent Passing Max.
3/8”	99	100
No. 4	95	100
No. 8	68	86
No. 16	47	65
No. 30	27	42
No. 50	9	20
No. 100	0	7
No. 200	0	2.5

The filter sand shall be thoroughly cleaned and free of dirt, clay, silt, asphalt, organic material, or other foreign matter and all aggregate passing the No. 200 sieve size shall be non-plastic. The filter sand shall meet the following requirements for quality:

Test / Method	Testing Responsibility [a]	Criterion	Requirement
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	Proponent	NO3+NO2	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Proponent	Total Phosphorus	0.15 mg/L (Max.)
		Ortho-phosphorus	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Proponent	Copper	10 µg/L (Max.)

[a] Though the supplier will provide many of the tests indicated in this table, project proponents are encouraged to test the exact material which will be provided for their projects. Supplier tests are only run periodically on the source material not on the exact material supplied for the project. This is particularly important for the aggregate gradation which has the strongest influence on system hydraulics.

High Carbon Wood Ash (Biochar)

The High Carbon Wood Ash (HCWA) should consist of screened and processed organic and inorganic residue remaining after the thermal processing of biomass in an oxygen-controlled environment. The biomass feed-stocks should be limited to clean cellulosic material from the 1) woody by-products of pacific northwest forestry operations (including cut residues left after a timber harvest, cut trees that are not marketable as lumber), 2) chipped trees and brush from biomass reduction operations (i.e. commercial tree trimming), and 3) agricultural residues such as nut shells, straw, orchard pruning, seeds, hulls, and pits. The biomass feedstocks should not include any post-consumer or post-industrial sourced woody biomass (i.e., construction or demolition waste, wood contaminated with paints or sealers, metal, plastic, or other deleterious materials).

The HCWA should be classified as a "Class 1" Biochar following the International Biochar Initiative (IBI) guidelines (IBI 2015).

The HCWA should be sourced from a producer with at least 5-years of experience producing HCWA for soil amendments and/or water filtration and meet the following requirements for quality and grading:

Test / Method	Testing Responsibility [a]	Criterion	Requirement
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	Proponent	NO3+NO2	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Proponent	Total Phosphorus	0.15 mg/L (Max.)
		Ortho-phosphorus	0.15 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Proponent	Copper	10 µg/L (Max.)
Total C and H analysis by dry combustion-elemental analyzer (EPA Method 440.0). Inorganic C analysis by determination of CO_2-C content with 1N HCl, as outlined in ASTM D4373 Standard Test Method for Rapid Determination of Carbonate Content of Soils. Organic C calculated as Total C – Inorganic C.	Manufacturer	Organic Carbon (C_{org})	60% (Min.)
		H: C_{org}	0.7 (Max.)
Proximate Analysis (ASTM D1762)	Manufacturer	Volatile matter	20% (Max.)
		Ash	40% (Max.)
Metals (EPA Method 6020)	Manufacturer	Arsenic	20 ppm (Max.)

		Cadmium	10 ppm (Max.)
		Lead	150 ppm (Max.)
		Mercury	8 ppm (Max.)
		Molybdenum	9 ppm (Max.)
		Nickel	210 ppm (Max.)
		Selenium	18 ppm (Max.)
		Zinc	1400 ppm (Max.)
Total polycyclic aromatic hydrocarbons by US EPA 8270 (2007) using Soxhlet extraction (US EPA 3540) and 100% toluene as the extracting solvent	Manufacturer	PAH	300 ppm (Max.)
Dioxins/Furans TEQ EPA 8290 (2007)	Manufacturer	PCDD/Fs	17 ppb WHO-TEQ [b] (Max.)
Cation Exchange Capacity (USEPA Method 9081)	Manufacturer	milliequivalents CEC/100 g dry soil	Report
Gradation (ASTM D422)	Manufacturer	# 6	100% Passing
		#100	10 % Passing (Max.)

[a] Though the manufacturer will provide many of the tests indicated in this table, project proponents are encouraged to test the exact material which will be provided for their projects. Manufacturer tests are only run periodically on the source material not on the exact material supplied for the project.

[b] Toxic Equivalency (TEQ) is calculated by multiplying the concentration of each PCDD/F by its World Health Organization (WHO) Toxic Equivalency Factor (TEF) and summing the products.

HPBSM Polishing Layer

The HPBSM Polishing Layer media should be a blend of the following components in the following ratios:

Component	Ratio (by volume)
Filter Sand	91% (+/- 1%)
Activated Alumina	6.5% (+1% / - 0%)
Iron Aggregate	2.5% (+0% / -0.25%)

The HPBSM Polishing Layer media should be mechanically blended to produce a homogeneous mix by a blending vendor/contractor with at least 5-years of soil blending experience.

Activated Alumina

The Activated Alumina should meet the following requirements for quality and grading:

Test / Method	Testing Responsibility [a]	Criterion	Requirement
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	Proponent	NO_3+NO_2	0.1 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Proponent	Total Phosphorus	0.1 mg/L (Max.)
		Ortho-phosphorus	0.1 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Proponent	Copper	1 µg/L (Max.)
Producer Analysis	Manufacturer	Alumina (Al_2O_3) content	90% (Min.)
	Manufacturer	Bulk density	760 Kg/m^3 (Min.)
	Manufacturer	Surface area	300 m^2/g (Min.)
Gradation (ASTM D422)	Manufacturer	#14 US Standard Sieve	100% Passing
	Manufacturer	#28 US Standard Sieve	0% Passing

[a] Though the manufacturer will provide many of the tests indicated in this table, project proponents are encouraged to test the exact material which will be provided for their projects. Manufacturer tests are only run periodically on the source material not on the exact material supplied for the project.

Iron Aggregate

The Iron Aggregate should be ground Iron meeting the following requirements for quality and grading:

Test / Method	Testing Responsibility [a]	Criterion	Requirement
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	Proponent	NO3+NO2	0.1 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Proponent	Total Phosphorus	0.1 mg/L (Max.)
	Proponent	Ortho-phosphorus	0.1 mg/L (Max.)
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Proponent	Copper	1 µg/L (Max.)
Producer Analysis	Manufacturer	Iron Content by weight	80% - 97%
Gradation (ASTM D422) or Producer Analysis	Manufacturer	#4	100% passing
	Manufacturer	#8	95 -100% passing
	Manufacturer	#16	75-90% passing
	Manufacturer	#30	25-45% passing
	Manufacturer	#50	0-10% passing
	Manufacturer	#100	0-5% passing
	Manufacturer	#200	0-2.5% passing

[a] Though the manufacturer will provide many of the tests indicated in this table, project proponents are encouraged to test the exact material which will be provided for their projects. Manufacturer tests are only run periodically on the source material not on the exact material supplied for the project.

Underdrain

If the project proponent plans to bed an underdrain below the HPBSM Polishing Layer, it should be minimum 4-inch Schedule 40 PVC slotted well screen with a maximum slot width of 0.030 inches and a minimum open area of 9 square inches per foot. This underdrain can serve cells with a bottom area 4-15 feet wide depending on infiltration rate.

Blending, Delivery, Protection, and Placement

The blending, handling, and placement of the HPBSM Primary and Polishing Layers needs to be done carefully to ensure a successful installation. The contractor should prepare a Blending, Delivery, Protection, and Placement plan and submit it to the designer for review. The HPBSM Primary and Polishing HPBSM Layer media shall be mechanically blended to produce a homogeneous mix by a blending vendor/contractor with soil blending experience. The blending should occur on an impervious (asphalt or concrete) surface pad that has been thoroughly washed clean (e.g., pressure washed) prior to blending or in purpose-built soil blending equipment that has been washed. The blending pad shall be large enough to be able to turn and mix the media without introducing contamination. The blending pad shall be free of standing water before blending and shall be protected from stormwater run-on from areas off of/adjacent to the pad.

The measurement of the components to be blended shall be by dry weight on scale equipment capable of measuring within 1 pound or in full vessels of a known volume. Estimating the volumes of materials of partially full buckets or vessels shall not be used. Prior to blending, the coconut coir fiber shall be loose and hydrated such that its density is 4-5 pounds per cubic foot. The materials shall be blended until they are in a homogenous mixed state and then protected from contamination or saturation during storage, delivery, stockpiling, and placement.

The HPBSM layers should not be placed if the area is frozen, has standing water, is excessively wet or saturated, or has been subjected to more than 1/2 inch of precipitation within 48 hours before placement, unless approved otherwise by the Engineer. Do not place the HPBSM layers if adequate temporary erosion and sediment control measures are not in place to protect the media from contamination by silt laden run-off.

Place HPBSM layers loosely and evenly, no deeper than these specifications unless otherwise approved by the Engineer, on a properly prepared subgrade. After each lift, rake the surface to a uniform grade. Consolidate the entire surface area of each lift by boot compaction or a lawn roller and rake again to scarify before placing subsequent lifts or planting.

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