Stormwater Management Manual

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Date: January 23, 2023

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Soil Specification for Green Streets with Underdrains & Rock Galleries

Introduction

This document provides background and supporting information for a new BES green streets soil specification requiring more combined silt and clay than BES' 2020 standard soil blend. The new specification is for all systems with underdrains or rock galleries[1]. The new specification addresses concerns about plant stress and mortality during dry periods in systems with underdrains or rock galleries, particularly in lined systems where roots don't have access to native soil. The new specification is based on BES field trials over the last ten years with soil blends containing loam. The primary source of the details for the new specification is the trial soil blend for the Slough 104B project (Project E10625/2018). BES recently completed a three-year monitoring program for that project.

Table of Contents

[1] BES continues to use the standard soil blend in infiltrating green streets facilities, where plant roots have access to native soil.

1. History and Background

The 2008 Standard Soil Specification

The 2008 BES specification for the blended soil, used in most green street facilities constructed between 2008 and 2020, required a fines content (silt and clay passing the #200 sieve) of 5-15%. The test was conducted on the final blend, including compost. The limitation on fines was based on hydraulic conductivity tests by the City of Seattle indicating higher levels of silt and clay in a similar sand/compost blend would clog the media. (Aspect Consulting, 2012). Seattle's bench tests included relatively high levels of compaction which BES eventually concluded were not representative of Portland field conditions based on BES field sampling (BES, 2012).

The GSI O&M team (previously called the Revegetation Program) expressed concern about the sandy appearance of media meeting the 2008 specification when the specification came into effect. The Sustainable Stormwater Management Program (SSMP) completed simple column tests in 2012 to confirm whether concerns were warranted about clogging for blends containing slightly more silt and clay. Staff tested blends with different percentages of sand, soil, and compost, and found blends with somewhat more fines drained adequately during the tests, even without the stabilizing presence of plant root systems. The report for the column test study recommended field trials with blends containing approximately 20% silt and clay (BES, 2012).

Construction of Test Facilities With Soil Blends Containing Loam, 2012-2017

BES built ten trial projects with soil blends meeting the general recommendations of the 2012 column study report. The soil blends included loam at approximately 30% by volume. The goal was to implement the projects as a "proof of concept", based on the recommendations of the 2012 column test report, to learn about sourcing blends containing loam, and to make field observations about potential problems including low infiltration rates. Staff didn't formally monitor plant health at the projects, but assumed the modified soil blends would improve summer conditions for plants based on academic studies showing the Available Water Holding Capacity for a sandy loam is substantially higher than for a loamy sand (OSU, 1996).

Table 1 lists the trial projects BES constructed with soil blends containing loam prior to the Slough 104B Project.

Table 1. Pre-Slough 104B projects containing soil blends with 30% loam

			% by Volume			% by Weight
Project Name, Year	Year built	Number of facilities	Sand	Loam % by volume, source	Compost % by volume	% passing the #200 sieve in the final blend
E10337. Channel Ave GSs	2013	3	30	30%, Endicott[1]	40	20-25
Brooklyn Bridge Apts.	2014	3	30	30%, Endicott[1]	40	20-24
E10686. Brookside GSs	2017	1	50	30%, S&H pit[2]	20	16
E10638. Front Ave GSs	2017	3	50	30%, S&H pit[2]	20	18

1. Lonnie Endicott Excavating, Pudding River watershed.
2. S&H Recycling, Stafford Road pit.

Staff observed slow initial infiltration rates at just one of the four projects listed in Table 1, the Channel Avenue project, where two of the facilities ponded water for extended periods during the spring months immediately after construction. Some of the plants in the bottoms of the facilities died, presumably due to the ponding, although BES no longer installs the plants that died ("dense sedge" and "ice dance sedge") in the bottoms of facilities due to mortality in that setting. Staff successfully remedied the problem the following summer by hand-augering a number of vertical 3-inch diameter holes and backfilling with well-graded sand mixed with compost. Based on periodic visual observations, drawdown rates subsequently improved.

Related Specifications From Other Jurisdictions

Some other jurisdictions allow more than 10% silt and clay in the mineral component (mixed sand and soil) in stormwater soil blends. For example, the Minnesota Stormwater Manual and Toronto's specifications allow bioretention mixes with more than 30% total fines from natural loam. These two jurisdictions also put limits on the clay content and require engineering hydraulic conductivity tests to verify infiltration rates (Minnesota Stormwater Manual, 2021; Toronto Engineering and Construction Services Division, 2021). States including New Hampshire, Maryland, Virginia, and North Carolina allow more than 10% fines in the mineral component of their blend; maximum fines contents vary between the jurisdictions. These jurisdictions limit organics to reduce export of nutrients, relying on the mineral fines for water retention and Cation Exchange Capacity.

2. The 2020 Standard Soil Specification

BES' current standard soil specification is contained in section 1040.14(d) of the 2020 City of Portland standard specifications. BES posts a copy of the soil specification on the website for the BES Stormwater Management Manual (standard soil specification).

The 2020 specification made three significant updates to the 2008 specification. The first is an explicit requirement for inclusion of topsoil; previously the specification called for "any blend" meeting the gradation requirements of the specification. The second is a requirement for more fines. The 2020 specification calls for 10-20% passing the #200 sieve rather than the 5-15% required by the 2008 specification. The third change is a requirement for conducting the sieve test on the blended sand and soil prior to adding compost in the final step of the blending process. See Figure 1 for a schematic showing general blending proportions for the 2020 standard specification.

Figure 1. Schematic: composition of the 2020 standard soil blend

Components, by volume	Sand+Topsoil: 60-70%	Compost: 30-40%		
% passing #200 sieve, by wt.	---------- 10-20% silt+clay ----------			

Testing the gradation of the mineral blend, rather than the final blend, should improve the accuracy and repeatability of sieve test results. Sieve results for final blends, including compost, have proven to be inconsistent. Washed sands from BES vendors typically contain <2% fines and USCC yard-debris compost typically contains <5% fines by weight. However, results for final blends sometimes indicate there's a higher percentage of fines in the final blend than in the mineral blend before adding compost. Examples include results from BES' 2012 column tests, in which BES staff tightly controlled the blending process

and produced several different blends using the same feedstocks. The same was true for the gradation results obtained during the making of the trial blend for the Slough 104B project. The opposite should be true based on the dilution of the fines content with the addition of compost, and these outcomes contributed to the conclusion by staff that blenders of the 2008 standard soil blend were meeting the specified fines content (5-15%) by blending sand and compost without any addition of topsoil.

3. The Slough 104B Trial Soil Blend ("High-fines Blend")

Composition of the Blend

In 2018 BES constructed the Slough 104B Project, a neighborhood green streets project including 53 facilities. About half the facilities were built with a trial blend that's the basis for the new soil specification. The other half were built with a soil blend meeting BES' 2008 standard specification. The project incorporated an experimental design allowing comparison of infiltration, soil moisture, and plant health results for the two different blends and other design variables.

BES staff selected the composition of the 104B trial blend based on the recommendation of a 2017 memorandum which summarizes results from prior BES trials with blended soils containing loam (Herrera, 2017). The Slough 104B trial blend is 50% sand, 30% loam, 10% aged dark hemlock mulch, and 10% compost. The tested fines content (silt+clay) was roughly 19% in the mineral blend and the estimated fines content in the final blend, including compost, was about 15% based on the mixing proportions and the typical fines content of compost. The tested fines content in the final blend was about 18% - see discussion in the preceding section about the potential for inconsistencies in results for sieve tests containing compost.

The Slough 104B trial blend contains about 1/3rd the percentage of compost contained in the 2008 standard soil blend. The hypothesis is that with less compost the blend will export lower levels of nutrients; BES is beginning year four of a four-year water quality monitoring program to confirm the hypothesis. Note that other jurisdictions such as the State of Maryland have had long-term success using bioretention soil blends without compost to limit the nutrient export associated with compost.

Substituting some of the compost with aged, dark bark mulch makes sense for multiple reasons. It should be more stable and consistent. Staff have observed wide variation in the appearance and particle size distribution of yard-debris compost. Some of the variability can be attributed to changes in feedstocks over the course of the year: sometimes feedstocks are dominated by grass cuttings; at other times the composition is mostly trimmed woody material and leaves. Yard debris decomposes relatively quickly; aged bark mulch should break down more slowly and provide a longer-term source of carbon for the system. Given the age of the bark mulch - six months is the standard minimum aging time in the industry - the material is already partly decomposed and unlikely to cause significant immobilization of nutrients by microbes. It's more fibrous and rigid than yard-debris compost, providing more soil structure (porosity) as a bulking agent.

The Slough 104B trial soil specification includes a requirement for surface mulch. Without mulch an exposed soil with more silt and clay is likely vulnerable to erosion and separation of the fines from the coarser particles, which can result in deposition of fines, crusting, and sealing. Mulch also provides some protection from compaction by foot traffic. In 2012 BES conducted field tests comparing summer soil moisture in the imported soil blend in green street facilities with and without mulch (BES, 2012). The

results confirmed the soil in the facilities with surface mulch remained more moisture than the soil in systems without mulch.

Monitoring Results – Winter Infiltration Rates and Moisture Retention

The potential for unacceptably low infiltration rates is one of the primary concerns about bioretention soil blends containing more than a small percentage of loam. It therefore was an important part of the monitoring program for the Slough 104B project to confirm drawdown rates at facilities containing the trial soil blend.

In February 2022 BES staff completed drawdown tests at seven lined facilities containing the trial soil blend. The systems were constructed in 2018 and had fully-established plantings[2] by the time of the testing. Final drawdown results ranged from 5-12 in/hr after four successive fillings during the day-long testing. That range is substantially lower than the range for a group of lined facilities containing the standard blend that BES tested using a similar approach in 2017 (BES, 2017). However the average for the final drawdown results is well above BES' design infiltration assumption of 6 in/hr (2020 SWMM). There have been no reports of extended ponding or evidence of clogging in any of the 27 Slough 104B facilities containing the trial soil blend.

Since January 2022 BES has been comparing average soil moisture in three facilities with the standard soil blend vs. results for three facilities with the trial soil blend. There are three moisture sensors in each facility, installed at 8 inches below grade. The preliminary results indicate that after draining against gravity the trial soil consistently retains more moisture than the standard soil blend.

BES will provide more detailed results concerning infiltration and soil moisture in separate reports.

4. The 2023 Soil Specification for Green Streets with Underdrains

Composition of the Blend

The new soil specification is a modified version of the trial soil blend used in the Slough 104B Project. In August 2022 a committee of BES staff[3] endorsed the new specification after reviewing results from the Slough 104B project and supporting information. See Figure 2 for a schematic showing the general blending proportions for the new specification.

Figure 2. Schematic: composition of the new soil specification

Components, by volume	Sand+Topsoil: 70%	Compost: 20%	Fir Bark: 10%
% passing #200 sieve, by wt.	---------- 20-30% silt+clay ----------		

The total organic percentage by volume, including compost and aged fir bark, is similar to the organic content for the 2020 standard specification. The new specification is not designed to address concerns about nutrient export, so a significant percentage of compost is included to promote good plant establishment. Aged bark mulch is added as a bulking agent to help maintain porosity given the higher fines content in the blend; aged bark is stiffer and degrades more slowly than compost. Fir bark is

[2] Although there was some plant mortality during the extreme summer conditions in 2021, most of the tested facilities received "good" or "excellent" ratings for plant cover and health in June 2022.

[3] The committee included representatives from GSI O&M, Materials Testing Lab (MTL), Engineering Services, Construction Management and Inspection, and Codes, Rules, and Manuals (CRM).

specified, rather than the hemlock bark used in the Slough 104B Project, given the much wider availability of fir bark compared with hemlock. As of fall 2022 it had become quite difficult to source hemlock bark mulch.

The range for particles passing the #200 sieve allows blends with more silt and clay than the Slough 104B trial blend. However, vendors are likely to target blends at the very low end of the allowed range (close to 20%) given their practice of minimizing the use of topsoil due to the potential for problems such as clumping and the difficulty of producing homogenous blends containing topsoil. In the judgement of BES staff, a specification allowing 20-30% fines presents a better balancing of potential risks than a range with 15-25%. The latter could result in the acceptance of blends with close to 15% fines, the mid-point of the range for the standard soil blend, with little potential for improving water retention.

The washed-sieve test for the new specification is the same as for the standard blend, but the ranges allowed for material passing the smaller sieves (e.g., #40 and #100) have been increased to accommodate more silt and clay. It is common for silty loams in the Portland area to contain more than 50% combined silt and clay. Blends meeting the new specification are unlikely to meet standard definitions for being "well graded", but the goal is to continue to promote a broad range of particle sizes with a matrix of sand particles to provide stability. Table 2 shows the sieve ranges for the new specification.

Table 2. Sieves and allowed ranges

Sieve Size	Percent Passing
1 inch	100
#4	85-100
#10	50-100
#40	30-90
#100	20-60
#200	20-30

Other Components of the Specification

- The specification requires blending on a clean, hard surface such as asphalt or concrete for improved quality control.
- Two inches of surface mulch is required to protect the soil surface from erosion and compaction. The aged, dark fir bark specified for inclusion in the soil blend is also specified for the surface mulch given research showing aged organic material has a higher density and resists movement more than fresh organic material.

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