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Memorandum

Date:	21 June 2017
To:	San Diego Region BMP Sub-workgroup
From:	Myles Gray, Aaron Poresky, Adam Questad, Geosyntec Consultants
Subject:	Regional Bioretention Media Survey and Specification Review

INTRODUCTION

Bioretention soil media (BSM) is an important component of stormwater best management practices (BMPs) used in the San Diego Region, including bioretention and biofiltration BMPs. BSM serves a number of roles, including removing stormwater pollutants, retaining stormwater, and providing soil structure, nutrients, and water retention for healthy plant growth. Goals of maintaining adequate permeability and avoiding pollutant washout often must be balanced with the goals of retaining moisture and supporting healthy plants. Controlling BSM quality and composition, particularly the amount of fine materials and the quantity and quality of organic material, is important to help maintain this balance.

Both the City of San Diego and the County of San Diego have detailed specifications for BSM. These specifications include provisions that apply to the overall BSM and to components of the BSM. Based on input from permittees, project applicants, and suppliers, these specifications have been difficult to fully satisfy. Additionally, there is a regional desire to unify these specifications.

This study involved surveying the regional availability of BSM materials and conducting analytical tests on the quality of these materials. The underlying purpose of this study was to support refinements to current BSM specifications to evolve toward simpler, regionally-available and regionally-applicable specifications that reasonably balance BSM goals. Key study questions included:

- Are BSM blends and components regionally available that meet the existing City and County specifications?
- Are BSM blends and components regionally available that can meet more stringent requirements for use in water quality impaired areas in the City?
- How variable are BSM blends and components sourced from different regional suppliers?

- Are there elements of the existing specifications that can be relaxed or simplified to improve achievability without sacrificing BSM performance goals?
- Are new limits required to prevent the use of problematic materials?
- Can specifications updates be combined into a single merged BSM specification for both the City and the County?
- Are materials regionally available from which alternative media blends could be produced to meet either existing standard specifications or more stringent water quality requirements.

This memorandum introduces the current specifications, describes the study methodology, summarizes intermediate findings, and presents recommendations for updates to current specifications. A draft updated specification that unifies current City and County specifications in "Green Book" format is included as Attachment A.

SUMMARY OF CURRENT SPECIFICATIONS

Key differences between the existing specifications are summarized in Table 1. Full specifications are listed in sample analysis data tables in the Results section.

Table 1. Major requirements for City and County bioretention soil media.

Component	City Requirement	County Requirement
BSM Material Composition	Sand: 70-85% by volume Compost: 15-30% by volume	Sand: 65% by volume Topsoil: 20% by volume Compost: 15% by volume
Alternative Blends Acceptable?	Yes, but they must meet performance based specifications	Yes, but they must meet performance based specifications
Sand Type	ASTM C33 Washed Concrete Sand	Washed Sand
Topsoil Type	Topsoil not part of standard mix; could be approved as alternative mix	Sandy loam with clay < 15%
Compost Type	US Composting Council Seal of Testing Assurance certified	From a CalRecycle regulated facility. Neither biosolids nor manure derived materials are acceptable
BSM Permeability	8-20 inches/hour for BMPs without outlet control; 15-40 inches/hour for BMPs with outlet control; testing is required to demonstrate.	Greater than 5 inches/hour. This only needs to be tested if an alternative BSM is proposed.

Component	City Requirement	County Requirement
Agronomic Suitability Requirements	Limits for salts and potential toxins	Upper and lower limits for most macro and micro nutrients.
Water Quality Related Limits?	Requirements related to specific pollutants when water quality of receiving waters is impaired for those pollutants.	No additional requirements when water quality standards apply

The most substantial difference between the specifications is topsoil being a standard component in the County specification but not the City specification. There are also differences between sand type, permeability, and agronomic suitability provisions. Additionally, the City specification includes water quality provisions that apply when projects are located in areas with water quality impaired receiving waters. Both specifications allow the use of alternative BSM blends that deviate from the material based requirements so long as they meet all analytical requirements.

SURVEY AND ANALYSIS METHODS

Potential media suppliers in the San Diego region were identified in consultation with City and County personnel and by conducting simple web searches. The intent was to identify the most common BSM and component suppliers for bioretention projects in the region. Potential suppliers were contacted by phone and by email, and at least two attempts were made to contact each. A total of ten suppliers were contacted. Of those, seven were responsive to inquiries.

Responsive suppliers were asked a standard set of questions during brief phone interviews to ascertain whether they typically supply BSM and components (i.e. sand, topsoil, and compost), what types of materials they supply, available testing information, and approximate costs of these materials. Of the seven responsive suppliers, six (Table 2) were selected for inclusion in the material survey based on responsiveness, material availability, and whether they were common BSM suppliers. Geosyntec coordinated with each supplier to source samples in person from May 2 through May 4, 2017. Suppliers were provided copies of both the City and the County specifications but were encouraged to provide samples of the materials that they typically supply for use in BMPs, including up to three pre-blended BSM mixtures and one each of sand, compost, and topsoil. Suppliers were also asked questions about their familiarity with existing specifications and whether they had any concerns or changes they would recommend to specifications or the approvals process. Finally, suppliers were asked whether they supplied alternative media components including specialty sands, biochar, coconut coir pith, and peat.

Approximately two gallons of each sample were collected by Geosyntec personnel. BSM samples were blended by material suppliers, not by Geosyntec. Samples were divided into two subsamples. One subsample was shipped to Wallace Laboratories in El Segundo, California for analysis. Wallace Laboratories is a well-regarded and commonly used agronomic soil laboratory. The other subsample was retained by Geosyntec for potential additional analysis or other needs. The parameters analyzed for each sample varied by material type, summarized as follows. These tests provided the information needed to assess conformance with existing specifications.

- Sand: Sieve analysis.
- Topsoil: Texture (percent gravel, sand, silt, clay)
- Compost: Organic matter content, bulk density, pH, salinity, compost maturity (Solvita method), seedling emergence, total carbon and nitrogen, total and water soluble nutrients, and sieve analysis.
- Pre-blended BSM: Organic matter content, pH, salinity, sodium absorption ratio, total carbon and nitrogen, ammonia, nitrate, total, water soluble (saturated extract), and plant available nutrients (including P, K, and other essential nutrients), texture (percent gravel, sand, silt, clay), and sieve analysis.

Results are tabulated and compared to existing specifications in the Results section.

RESULTS

Suppliers and Supplier Comments

In total, 23 samples were received from 6 suppliers. Table 2 presents supplier information, samples received, and general comments from each of the suppliers. More detail on each sample is included in following sections. Supplier names were anonymized for the purpose of this memorandum. The following bullets summarize input from suppliers:

- Most suppliers stated that they were willing to make custom blends and several suppliers stressed the importance of tailoring BSM to plant palettes.

- Some, but not all, suppliers were familiar with existing specifications for both the City and the County.

- Several suppliers said the specifications were too complicated and that they had had trouble getting alternative BSM blends approved.

- Suppliers who were aware of the differences between the specifications generally preferred the County specification because it includes topsoil which was viewed favorably for promoting healthier plants.

- Supplier #1 pointed out that locally produced compost is very high in chloride because local greenwaste is derived from plants that are watered with high chloride water (derived from the Colorado River). Plants grown with this water have high tissue chloride levels which then results in high compost chloride levels. Mixing BSM in the specified proportions thus results in BSM with chloride levels as high as 500 ppm, much higher than the 150 ppm limit in both specifications. However, because local plants are adapted to such levels, this BSM can still provide a good medium for plant growth.

- Suppliers commented that the current upper limits for pH and SAR could both be adjusted up while still being supportive of plants.

- Supplier #1 commented that saturation extract (water soluble) chemicals can accumulate during stockpiling, but some of this would flush through rapidly (dissolved solids, nitrate) during the first storm events. Therefore testing could be conducted after a minor amount of media rinsing to avoid biased results.

Table 2. BSM suppliers, samples received, and comments.

Supplier	Samples Received				Alternative Components Available?	Supplier Comments
	Sand	Topsoil	Compost[1]	BSM		
Supplier #1	1	1	1	3	No	• Thinks both specifications are too long and complicated • Recommends that all BSM contain some topsoil • Thinks BSM should be tailored to plant palette • Encountered problems getting alternative BSM with topsoil approved for City projects • Recommended specific changes to City specification based on inherent nature of locally produced compost and native plants: o In F.4.2.1 allow pH 6.0-8.0 instead of 6.0-7.5 o In F.4.2.1. allow SAR < 5.0 instead of SAR < 3.0 o In F.4.2.1 allow chloride < 500 ppm instead of <150 ppm o In F.4.2.1 specify all tests after samples are rinsed • Does not think hydraulic suitability tests in F.4.2.3 are repeatable
Supplier #2	1	1	1	1	Yes – coconut coir, biochar, perlite	• Thinks both specifications are too complicated • Thinks topsoil should be included in all BSM
Supplier #3	1	1	1	1	Yes – peat, perlite pumice, redwood bark	• Typically supplies BSM to county specification but also makes custom blends.
Supplier #4	1	1	1	2	Yes – coconut coir, peat, pumice, perlite, redwood bark	• None
Supplier #5	1	0	1	1	Yes – redwood bark	• Typically supplies 60/40 sand/compost BSM without topsoil • Limited familiarity with existing City or County specifications • Willing to produce custom blends • Thinks that any blend must be tailored to the plants that will be grown
Supplier #6	0	0	1	0	No	• None

[1]Compost also includes other organic amendments such as nitrolized wood chips. Further detail is included in Table 5

Sand Results and Proposed Specification Changes

Sand samples were submitted by five of the six suppliers. Samples were of the same sands that are used in BSM blends from each supplier. Photos of the five samples are presented in Figure 1.

Sieve analysis results are presented in Table 3. Overall, sand quality was consistently good, with four of the five sand samples meeting all particle size distribution limits contained in both existing specifications. The Supplier #1 sample had minor deviations in two particle size fractions compared to the City specification. Both of the unwashed samples (Supplier #4 and Supplier #5) were within all of the particle size distribution limits in both specifications.

The proposed unified specification includes the following changes:

- Sand Type: Change to prefer, rather than require washing. Survey results indicate that some of the unwashed sands met existing City and County particle size distribution limits, so washing should be preferred but not required.

- Particle Size Distribution Percent Passing: Use existing County limits which are somewhat broader than the existing City limits. The County limits still ensure that sand will not contain an overly large fraction of either coarse materials or fine materials, both of which can be detrimental. Additionally, the required particle size and textural class testing of blended BSM still ensure that blended BSM will not be overly fine or coarse.

Supplier #1 C33 Sand:

Supplier #2 C33 Sand:

Supplier #3 SDG&E Sand:

Supplier #4 Screened Fill Sand

Supplier #5 Unwashed Sand:

Figure 1. Photos of sand samples.

Table 3. Analysis results and descriptive information for sand samples and pertinent City, County, and proposed updated specifications. Cells shaded gray do not meet the City specification while values in bold and italics do not meet the County specification.

Sand Supplier	**Supplier #1**	**Supplier #2**	**Supplier #3**	**Supplier #4**	**Supplier #5**	**Specifications[1]**		
						City	**County**	**Proposed Update**
Approximate Pricing (per cubic yard)	Not sold individually	Not available	$40	$40	Not available			
Sand Type	ASTM C33	ASTM C33	SDG&E	Screened Fill Sand	Unwashed	ASTM C33	Washed	Washed preferred
Washed?	Yes	Yes	Yes	***No***	***No***			
Percent Passing[2]								
3/8 inch (% passing)	100	100	100	100	100	100	100	100
# 4 sieve (% passing)	100	100	100	100	99	95-100	90-100	90-100
#8 sieve (% passing)	82	84	91	99	92	80-100	70-100	70-100
#16 sieve (% passing)	45	54	62	82	74	50-85	40-95	40-95
#30 sieve (% passing)	19	36	43	49	52	25-60	15-70	15-70
#40 sieve (% passing)	14	29	35	34	41		5-55	5-55
#50 sieve (% passing)	8	20	25	19	26	5-30		
#100 sieve (% passing)	2.2	*8.0*	10	*7.1*	7.4	<10	<15	<15
#200 sieve (% passing)	0.5	2.0	3.8	2.2	1.5	<5	<5	<5

[1] Specification cells without values indicate that no requirements are included in the existing specification.
[2] Percent passing data are based on dry weight

Topsoil

Topsoil samples were submitted by four of the six suppliers. Suppliers were instructed to supply the same topsoil used in typical BSM blends. A photo of each sample is presented in Figure 2.

Descriptive information and textural class analysis results for topsoil are presented in Table 4 along with applicable specifications and proposed updates. Existing City specifications do not include topsoil in standard BSM, so only specification limits for the County are listed. Overall, topsoil samples were good quality, except for the Supplier #3 decomposed granite material that had a very high gravel content. Decomposed granite is not a true "topsoil" by most definitions. Among the other three samples, only the Supplier #2 sample met all applicable County specifications, but deviations for the other two samples were minor.

The proposed unified specifications contain several changes (to the existing County specification) to ensure that quality topsoils are accepted while rejecting materials with too much gravel. The following changes are proposed:

- Topsoil Type: Add provision that decomposed granite is not permitted. Decomposed granite is not topsoil and does not provide the same benefits for soil structure, plant health, and moisture retention as a topsoil.

- Textural Class: Modify to permit sandy loam or loamy sand. There is only a small difference in actual composition between these soil textural classes, and both provide the benefits of topsoil without overly restricting flow rates.

- Gravel content: add a provision for gravel content < 25% to reject overly coarse materials which could be problematic and would not provide the intended benefits of topsoil.

- Textural Fraction Limits: Remove all limits except clay < 15%. More than 15% clay can result in reduced flow rates. Given that the percent of sand and silt are considered in defining the soil texture, separate limits for sand and silt are not needed.

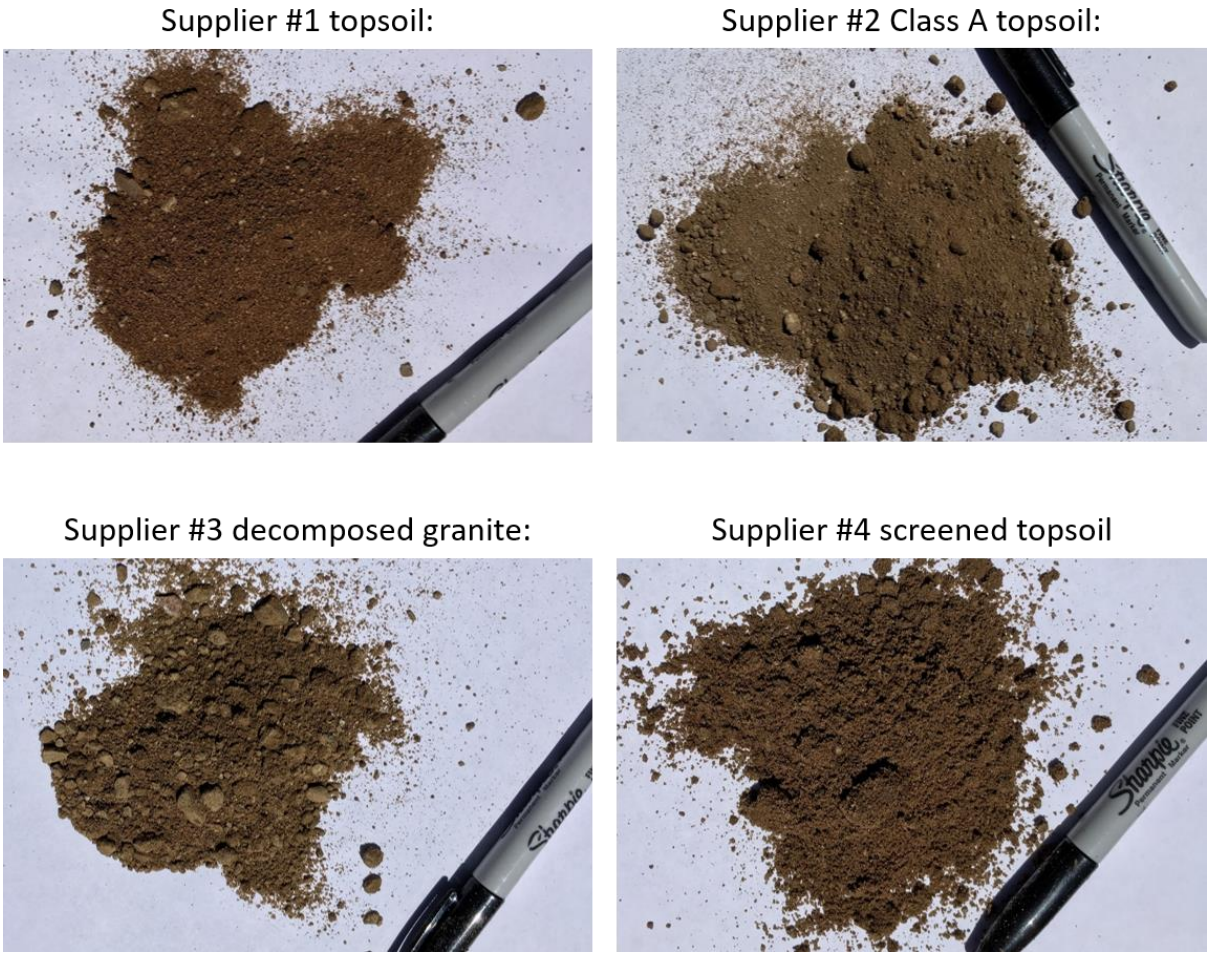

Figure 2. Photos of topsoil samples.

Table 4. Analysis results and descriptive information for topsoil samples presented with pertinent City, County, and proposed updated specifications. Cells shaded gray do not meet the City specification while values in bold and italics do not meet the County specification.

Topsoil Supplier	Supplier #1	Supplier #2	Supplier #3	Supplier #4	Specifications[1]		
					City	County	Proposed Update
Approximate Pricing (per cubic yard)	$15	Not available	$25	$20			
Topsoil Type	Typical	Typical	Decomposed granite	Screened			Decomposed granite not permitted
Textural Class	sandy loam	sandy loam	***gravelly sandy loam***	***loamy sand***		Sandy Loam	Sandy loam or loamy sand
Textural Fractions[2,3]							
Gravel	4.4	17	56	4.0			<25%
Non-Gravel	95.6	83	44	96			
Non-Gravel Fractions							
Sand	***79***	61	65	***81***		50-74	
Silt	11	26	26	12		0-48	
Clay	10	13	8.8	6.7		2-15	<15% (<10% preferred)

[1] Specification cells without values indicate that no requirements are included in the existing specification.

[2] Textural class fractions are based on dry weight.

[3] Textural class fractions are presented in the customary format with fractions for sand, silt, and clay equal to the fraction of dry weight of the non-gravel portion of a sample. Gravel fractions represent the percent of dry weight of the total sample.

Compost

Compost samples were submitted by each of the six suppliers in the survey. Suppliers were instructed to submit composts that are used in typical BSM. Some of the compost samples being used in BSM would not typically be considered compost (e.g. "nitrolized wood shavings"). A photo of each sample is included in Figure 3.

Descriptive information and analytical results for compost are presented in Table 5 along with applicable specifications and proposed unified specifications. Overall, compost samples were quite variable, so reviewing compost submittals should be a key element during the material review process. None of the six samples fully met the City or the County specifications, although several samples had only minor deviations.

Among the three BSM component classes, compost is considered to have the most significant impact on the potential for BSM to leach/washout pollutants and on the ability of BSM to provide and retain nutrients for healthy plant growth. As such, fairly extensive updates are proposed for inclusion in the unified specification with the intent of reducing variability and preventing the use of poor quality materials while still ensuring that at least three high quality compost products available in the region will meet specification requirements. The following changes are proposed:

- Feedstock: Change to allow manure as long as other requirements are met, including compost tests for pathogens, maturity, and excess nutrients.
- CalRecycle Permited: Require materials to be produced at permitted composting facilities. This will reject any materials that are not compost including nitrolized wood which should not be permitted.
- USCC STA Certified: Change to "prefer" USCC STA certified materials rather than "require." This program requires periodic compost testing and ensures that the most recent test results are provided upon inquiry, thus providing contractors the ability to determine compliance with specifications prior to sourcing materials and performing additional required testing. However, this program also requires periodic fees and paperwork, so it may present a burden for some producers.
- Bulk Density: Remove limits. Four of the six compost samples did not meet the existing County specifications. Compost bulk density does not have a direct effect on compost quality with respect to BSM.
- Moisture content: Change to allow 25-60%. This broader range would still prevent use of overly wet or dry materials which may not have been properly composted.

- Particle size percent passing: Change to require 97-100% passing ½" and 40-90% passing 2 mm. Eliminate % passing requirements for 6.3 mm size fraction. These proposed limits still reject compost with coarse fragments and those that are overly fine.
- pH: Change to allow 6.0-8.5 to reflect survey results showing that four of six samples had pH greater than 8. Supplier #1 suggested that composts produced from regionally sourced greenwaste would be unlikely to have pH less than 8, but also that regional vegetation is adapted for slightly higher pH than normal.
- Salinity: Change to allow Salinity (mS/cm) < 10 to reflect survey results showing that only one of the six composts met the more stringent County specification. Supplier #1 suggested that compost produced from regionally sourced greenwaste would be unlikely to meet lower limits but also that regional vegetation is adapted to higher values.
- Organic matter: Change to remove upper limit so that new limit is 35-100%. Organic matter content greater than 75% (contained in both existing specifications) is unusual but is not detrimental and should not be the basis for rejecting a compost. A compost below 35% organic matter would still be rejected.
- Solvita Maturity Index: Change to require maturity ≥5.5 to reflect survey results indicating that only half of the samples met the existing City specification of 6. This represents an increase in stability compared to the existing County specifications, but this proposed value should be achievable by most high quality compost producers.
- C:N Ratio: Change to "prefer" 15-40 to reflect survey results showing that only two of six samples met the existing requirements. The upper limit of 40 should be strictly enforced to prevent use of composts that could severely limit plant nitrogen availability. The lower limit of 15 should be considered a goal, however, suppliers may not be able to meet this lower limit without substantial changes to their production methods such as adding higher C:N feedstock materials in with greenwaste.
- Total Heavy Metals: Use existing City requirements which are the same as those included in US EPA Class A standard, 40 CFR Section 503.13 Table 1 for upper limits. Compost survey results indicate that all samples had total metals concentrations well below either the existing City or County specifications suggesting that metals contamination from compost is unlikely.
- Pathogens: Use pathogen limits from the existing City specification requiring that compost passes select pathogen tests for US EPA Class A standard, 40 CFR Section 503.32(a). Compost produced at permitted facilities is routinely tested for pathogens so such data would be readily available for most compost suppliers.

Supplier #1 greenwaste compost:

Supplier #2 compost:

Supplier #3 nitrolized fir shavings:

Supplier #4 manure compost:

Supplier #5 fir shaving compost:

Supplier #6 greenwaste compost:

Figure 3. Photos of compost samples.

Table 5. Analysis results and descriptive information for compost samples presented with pertinent City, County, and proposed updated specifications. Cells shaded gray do not meet the City specification while values in bold and italics do not meet the County specification.

Compost Supplier	**Supplier #1**	**Supplier #2**	**Supplier #3**	**Supplier #4**	**Supplier #5**	**Supplier #6**	**Specifications[1]**		
Description	**Windrow compost**	**Unknown**	**Nitrolized fir shavings**	**Windrow compost**	**Composted wood**	**Windrow compost**	**City**	**County**	**Proposed Updates**
Approximate Pricing (per cubic yard)	$10	Pricing not available	$30	$25	Pricing not available	$10			
Feedstock	Greenwaste	Unknown	fir shavings	***Horse bedding / manure***	fir shavings	Greenwaste		No biosolids or manure	Allow manure but not biosolids
CalRecycle Permitted?	Yes	***Unknown***	***No***	Yes	***No***	Yes		Permitted	Permitted
USCC STA Certified?[2]	No	Unknown	No	No	No	Yes	Certified		Prefer Certified
Physical									
Bulk Density (dry lbs/cubic yard)	***734***	***824***	589	***841***	423	***727***		400-600	
Moisture Content (%)[3]	36	34	48	***24***	42	35	25-55	30-60	25-60
1/2" (% passing)[4]	100	100	100	100	100	100		97-100	97-100
6.3 mm (% passing)[4]	95	96	92	100	99	94	40-95		
2 mm (% passing)[4]	60	80	76	86	83	76	40-90		40-90
Other									
pH	***8.25***	***8.16***	***8.03***	***8.02***	7.21	7.72	6.0-7.5	6.0-8.0	6.0-8.5
Salinity (mS/cm)	***4.20***	***7.51***	***9.91***	***6.21***	0.88	***9.49***	<10	0.5-3	<10
Sodium Absorption Ratio	8.31	6.21	1.92	14.08	3.08	14.02			

Compost Supplier	**Supplier #1**	**Supplier #2**	**Supplier #3**	**Supplier #4**	**Supplier #5**	**Supplier #6**	**Specifications[1]**		
Description	**Windrow compost**	**Unknown**	**Nitrolized fir shavings**	**Windrow compost**	**Composted wood**	**Windrow compost**	**City**	**County**	**Proposed Updates**
Seedling Germination (%)	70	50	80	80	70	40			
Organic Matter (%)[5]	36.8	37.7	65.0	***21.2***	***80.9***	51.9	35-75	35-75	35-100
Solvita Maturity Index	5.5	5.5	5	7	6	6	6	5	≥5.5
Nutrients[6]									
Total Organic Carbon (%)	19.4	20.7	29.9	9.3	33.7	25.8			
Total Nitrogen (%)	1.30	1.56	1.67	0.56	0.52	1.98			
C:N Ratio	***14.9***	***13.2***	17.9	16.6	***64.2***	***13.0***	15-40	15-25	Prefer > 15 Not to exceed 40
Ammonia (ppm)	7.74	14.4	567	8.13	18.8	61.8			
Nitrate (ppm)	7.96	45.5	6.82	65.5	2.24	15.7			
Available Phosphorus (mg/kg)	606	411	635	503	106	377			
Soluble Phosphorus (ppm)	5.29	2.83	7.29	7.92	1.94	19.5			
Potential Plant Toxins[7]									
Boron (ppm)	0.41	0.86	0.75	0.79	0.72	0.76			
Chloride (ppm)	1,029	1,672	326	1,780	122	2,453			
Sulfate (ppm)	65.2	143	1,522	93.2	24.5	86.5			
Total Heavy Metals[8]									
Arsenic (mg/kg)	3.40	3.88	6.84	3.28	1.68	3.91	<75	<20	<75

Compost Supplier	Supplier #1	Supplier #2	Supplier #3	Supplier #4	Supplier #5	Supplier #6	Specifications[1]		
Description	Windrow compost	Unknown	Nitrolized fir shavings	Windrow compost	Composted wood	Windrow compost	City	County	Proposed Updates
Cadmium (mg/kg)	0.85	0.98	1.35	0.46	0.41	0.80	<85	<10	<85
Chromium (mg/kg)	17.8	13.0	25.9	15.8	9.41	18.1	<4300	<600	<4300
Copper (mg/kg)	45.0	45.6	125	20.2	16.8	41.7	<840	<750	<840
Lead (mg/kg)	18.8	26.4	14.6	4.51	5.49	14.1	<57	<150	<57
Mercury (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<75	<8	<75
Nickel (mg/kg)	9.97	8.28	10.1	3.07	3.52	5.11	<420	<210	<420
Selenium (mg/kg)	0.94	1.00	7.38	0.59	1.25	1.36	<100	<18	<100
Zinc (mg/kg)	102	146	247	43.3	31.8	99.0	<7500	<1400	<7500

[1] Specification cells without values indicate that no requirements are included in the existing specification.
[2] US Composting Council Standard of Testing Assurance program requires certified producers to submit samples for analysis periodically for a suite of analyses and to provide those results free of charge when requested.
[3] Moisture content data are percent mass of sample as-is before drying.
[4] Percent passing data are on a dry weight basis
[5] Organic matter data are on a dry weight basis calculated from total organic carbon results assuming 1.9 g organic matter per gram organic carbon.
[6] Data reported in % are on a dry weight basis. Data reported in ppm represent concentrations in saturated extract water. Available phosphorus results are presented in mg of P in weak acid extraction per kg of soil sample.
[7] Results for potential plant toxins are concentrations in saturated extract water.
[8] Data for total heavy metals are mg of heavy metal per kg of soil after full sample digestion in a strong acid.

Pre-blended BSM

Eight pre-blended BSM samples were submitted by five of the six suppliers in the survey. Suppliers were instructed to submit only those BSM blends that are typically supplied for BMPs in the City and the County. Photos of each BSM are presented in Figure 4.

Descriptive information and analytical results for pre-blended BSM are presented in Table 6 along with applicable specifications and proposed unified limits. Three samples were blended to the County specification, one was made to the City specification, and four were made to neither specification even though suppliers were provided with both specifications in advance of in-person sampling. Overall, BSM samples were highly variable. In part, this may be due to the fact that different samples were prepared to meet different specifications. However, none of the eight samples met all the requirements for either of the existing specification.

The proposed unified specifications for BSM contain several changes to ensure that quality BSM is accepted while rejecting lower quality material.

- BSM Material Proportions: Change to be permissive of topsoil. This would include 60-80% sand, up to 20% topsoil, and 20% compost. Topsoil would be recommended in systems not utilizing outlet control to help avoid excessive permeability, and would be not be recommended in BMPs that do utilize outlet control as a means of slowing flow.
- Gravel: Limit total gravel content to less than 25% to prevent overly coarse mixtures. Two of the eight BSM samples had gravel in excess of this proposed upper limit.
- Textural Class Fractions: Remove textural limits for sand and silt, but require clay < 5%. Clay content has a major control on BSM hydraulics, so it should be limited.
- Percolation Rate: Change to allow 8-24”/hour for media controlled BMPs and 15-80”/hour for outlet controlled BMPs. The broader limit for media controlled BMPs reflects the fact that typical laboratory percolation rate tests can yield somewhat variable results even for the same samples. This range will still likely result in BSM with more than adequate flow rates that would likely diminish somewhat over time with sediment accumulation. In outlet controlled BMPs, high percolation rates do not pose a problem because the control of flowrate is via the outlet control rather than the media.
- pH: Change to allow a range from 6.0-8.5 to reflect survey results showing that six of eight BSM samples were above, or nearly above, pH 8. Given that regional vegetation is adapted to somewhat higher pH values these levels likely pose no threat to plant health.

- Sodium Absorption Ratio (SAR): Change from SAR less than 3.0 to SAR less than 8.0 to reflect media survey results and the fact that regional vegetation is adapted to higher than normal SAR.
- Cation Exchange Capacity: Change to require CEC greater than 10 meq/100g to ensure sufficient nutrient holding capacity. Samples made according proposed BSM material proportions would almost always meet this requirement by virtue of topsoil and compost components. If a BSM does not meet this limit it would likely not provide the intended benefits of BSM.
- Organic matter content: Use existing County specification range of 2-5%. BSM made according to proposed material proportions would almost always meet this requirement.
- C:N Ratio: Change to require C:N ratio of 12-40. This range of C:N ratio should somewhat limit the potential for nitrogen leaching while also ensuring that mixtures do not excessively limit plant available nitrogen. A goals of at least 15 will be stated as "preferred."
- Available Nutrients: Remove all requirements for available nutrients contained in the County specification. Survey results showed that every sample was non-compliant with a minimum of three available nutrient limits. Such limits are included to ensure that BSM is suitable for plant growth while not contributing excessively to leaching potential. However, BSM made according to proposed material proportion with 20% compost and up to 20% topsoil is unlikely to be deficient in nutrients. Additionally, stormwater runoff contains substantial nutrient loads, some of which are retained in BSM.

  Utilize different metrics to evaluate overall leaching potential. For nitrogen, proposed C:N ratio limits (12 to 40), along with mandatory use of internal water storage, should limit the potential for excessive nitrogen leaching while also preventing extremely low plant available nitrogen. For phosphorus, future consideration should be given to whether a limit should be developed for phosphorus saturation index (PSI). PSI is the ratio of extractable phosphorus to the sum of extractable iron and aluminum. Iron and aluminum exert a major influence of the solubility and plant availability of phosphorus, and PSI has been shown to have a strong correlation with phosphorus leaching in BSM mesocosm studies. Water soluble phosphorus in survey samples (see Table 6) was better correlated to PSI ($r^2 = 0.896$) than to available phosphorus ($r^2 = 0.715$) suggesting that PSI could be used as a metric to limit phosphorus leaching. Available iron and aluminum are already included in testing requirements, so calculating PSI would not require additional testing. Additional surveys or testing should be completed before PSI is included as a specification requirement.

In areas with specific water quality concerns, additional pollutant leaching tests should still be required, although some changes are proposed to the existing City requirements (discussed below).

- Potential Plant Toxins: Remove requirements for boron and increase upper allowable limit for chloride from 150 ppm to 800 ppm. Survey results indicate that boron is unlikely to be a concern in BSM so the requirement is likely unnecessary. Regional vegetation is adapted to higher chloride levels and much will likely wash out with initial rainwater flushing, which is low in dissolved solids.
- Chemical limits when pollutants are identified as a receiving water impairment:
    - Nitrate: remove soluble nitrate limits and replace with tighter BSM requirements and required BMP design features. Where nitrogen limits apply, BSM should have a C:N ratio of 12-40 (15 to 40 preferred) and should have either an internal water storage zone (if BMPs are lined) or a partial retention storage zone beneath BSM to enhance infiltration.
    - Copper: Change to allow saturated extract copper less than 0.04 ppm instead of the existing limit of 0.025 ppm. This limit is still likely protective of receiving waters.

Supplier #1 Bio 50:

Supplier #1 Bio 65:

Supplier #1 Bio 70:

Supplier #2 bioretention mix:

Figure 4. Photos of BSM samples (part 1 of 2)

Supplier #3 bioretention mix:

Supplier #4 bioretention mix:

Supplier #4 bioretention with compost:

Supplier #5 bioretention:

Figure 4. Photos of BSM sample (part 2 of 2).

Table 6. Analysis results and descriptive information for pre-blended BSM samples presented with pertinent City, County, and proposed updated specifications. Cells shaded gray do not meet the City specification while values in bold and italics do not meet the County specification.

BSM Supplier	**Supplier #1**			**Supplier #2**	**Supplier #3**	**Supplier #4**		**Supplier #5**	**Specifications[1]**		
Product Name	**Bio 50**	**Bio 65**	**Bio 70**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix with Compost**	**Bioswale Mix**	**City**	**County**	**Proposed Updates**
Approximate Pricing (per cubic yard)	$32	$32	$32	NS	$45	$28	$33	NS	NA		
BSM Proportions[2]											
Sand (%)	***50***	65	***70***	***64***	65	***NS***	***NS***	***60***	70-85	65	60-80
Topsoil (%)	***25***	20	***0***	***16***	20	***NS***	***NS***	***0***	None	20	Up to 20
Compost (%)	***25***	15	***30***	***20***	15	***0***	***NS***	***40***	15-30	15	20
Physical											
Gravel (%)[3]	11	11	22	29	17	46	66	10			<25
Non-Gravel	89	89	78	71	83	54	34	90			
Non-Gravel fractions											
Sand (%)[3]	***80***	***84***	89	***83***	***82***	86	86	88		85-90	
Silt (%)[3]	***13***	***12***	9	***12***	***14***	8	8	8		<10	
Clay (%)[3]	***7***	5	3	4	4	***6***	***6***	4		<5	<5
Percolation Rate (in/hr)[4]	11.8	10.6	65.3	14.5	6.1	90.2	56.5	33.4	8-20	>5	8-24 media controlled; 15-80 outlet controlled
Other											
pH	7.87	7.98	7.90	***8.04***	7.68	***8.52***	***8.01***	7.99	6.0-7.5	6.0-8.0	6.0-8.5

BSM Supplier	**Supplier #1**			**Supplier #2**	**Supplier #3**	**Supplier #4**		**Supplier #5**	**Specifications[1]**		
Product Name	**Bio 50**	**Bio 65**	**Bio 70**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix with Compost**	**Bioswale Mix**	**City**	**County**	**Proposed Updates**
Salinity (mS/cm)	***3.37***	2.91	2.29	2.72	1.36	0.85	3.00	1.33	<3	0.5-3	0.5-3
Sodium Absorption Ratio	***6.1***	***5.3***	***4.7***	***3.2***	2.1	***8.5***	***8.3***	***4.2***	<3.0	<3.0	<8.0
Cation Exchange Capacity (meq/100g)[5]	32.7	29.1	22.7	27.6	15.9	8.1	27.2	12.1		>5	>10
Organic Matter (%)[6]	4.45	2.58	4.33	2.59	2.20	***0.23***	2.12	4.56		2-5	2-5
Carbon and Nitrogen[7]											
Total Organic Carbon (%)	2.2	1.3	2.2	1.3	1.1	0.1	1.1	2.3			
Total Nitrogen (%)	0.16	0.09	0.17	0.11	0.11	0.02	0.05	0.05			
C:N Ratio	14.2	14.6	12.4	11.4	10.1	***6.2***	***22.2***	***49.8***		10-20	12-40 (15-40 preferred)
Ammonia (ppm)	2.1	1.8	1.9	2.1	1.8	1.0	1.2	7.0			
Nitrate (ppm)	9	6	5	21	8	6	8	5			
Available Nutrients[8]											
Phosphorus (mg/kg)	***50.0***	***25.7***	***69.5***	***49.5***	10.2	3.10	***34.0***	10.2		<15	Remove
P Saturation Index	3.6	1.5	5.9	1.7	0.4	0.6	2.4	0.5			Future Consideration
Potassium (mg/kg)	***409***	152	***405***	***379***	***26.6***	***39.7***	***296***	***97.4***		100-200	Remove
Iron (mg/kg)	***13.9***	***16.9***	***11.8***	28.8	24.5	***5.28***	***14.3***	***21.5***		24-35	Remove
Manganese (mg/kg)	***17.6***	***8.86***	***11.2***	***10.8***	5.02	0.61	3.57	***6.81***		0.6-6	Remove
Zinc (mg/kg)	4.65	3.24	3.31	7.45	1.42	***0.18***	1.33	1.24		1-8	Remove

BSM Supplier	**Supplier #1**			**Supplier #2**	**Supplier #3**	**Supplier #4**		**Supplier #5**	**Specifications[1]**		
Product Name	**Bio 50**	**Bio 65**	**Bio 70**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix**	**Bioswale Mix with Compost**	**Bioswale Mix**	**City**	**County**	**Proposed Updates**
Copper (mg/kg)	1.08	0.75	0.47	1.40	0.47	***0.30***	0.42	0.52		0.3-5	Remove
Magnesium (mg/kg)	***164***	149	***172***	***180***	***310***	***193***	***209***	102		50-150	Remove
Sodium (mg/kg)	***211***	***180***	***186***	***140***	93.4	***170***	***275***	***127***		0-100	Remove
Sulfur (mg/kg)	41.0	70.2	36.1	45.0	74.9	***14.7***	26.7	30.7		25-500	Remove
Molybdenum (mg/kg)	***0.08***	***0.05***	***0.05***	***0.10***	***0.06***	***0.04***	***0.06***	***0.07***		0.1-2	Remove
Aluminum (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	0.19	<0.1	<0.1		<3	Remove
Potential Plant Toxins[9]											
Boron (ppm)	0.39	0.26	0.37	0.51	0.12	0.21	0.30	0.35		<2.5	
Chloride (ppm)	***855***	***570***	***382***	***581***	83	120	***854***	***244***	<150	<150	<800
Sulfate (ppm)	88.2	140	46.4	97	182	40.8	48.0	48.7			
Water Quality-Related Limits where Receiving Waters are Impaired[9,10]											
Phosphorus (ppm)	1.35	0.86	2.68	0.94	0.89	0.32	1.33	0.67	<1		<1
Nitrate (ppm)	9.29	5.62	4.53	21.3	8.36	6.11	8.47	5.45	<3		Replace with other provisions
Copper (ppm)	0.03	0.02	0.03	0.03	0.04	<0.01	0.02	<0.01	<0.025		<0.04
Zinc (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1		<0.1
Lead (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.025		<0.025
Arsenic (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02		<0.02
Cadmium (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01

BSM Supplier	Supplier #1			Supplier #2	Supplier #3	Supplier #4		Supplier #5	Specifications[1]		
Product Name	Bio 50	Bio 65	Bio 70	Bioswale Mix	Bioswale Mix	Bioswale Mix	Bioswale Mix with Compost	Bioswale Mix	City	County	Proposed Updates
Mercury (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
Selenium (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.33	<0.01	<0.01		<0.01

[1] Specification cells without values indicate that no requirements are included in the existing specification.
[2] BSM proportion values are a volume basis as reported by media suppliers.
[3] Textural class data are presented on a dry weight basis according to the customary system with gravel presented as the percent of the total sample mass and sand, silt, and clay presented as the percent of the non-gravel sample mass.
[4] Percolation rate data are for the Wallace Laboratories in-house method according to USDA Handbook 60
[5] Cation exchange capacity data are for the sum of cations method. This method can overestimate actual CEC in soils with free calcium.
[6] Organic matter data are on a dry weight basis calculated from total organic carbon results assuming 1.9 g organic matter per gram organic carbon.
[7] Units for carbon and nitrogen are consistent with testing methods. Data reported in % are on a dry weight basis. Data reported in ppm represent concentrations in saturated extract water.
[8] Results for available nutrients are mg of nutrients in extraction per kg soil sample using a weak acid extraction
[9] Data for potential plant toxins and conditions water quality are concentrations in saturated extract water.
[10] Condition water quality standards apply for projects within the City only when applicable water quality concerns are identified.

Alternative BSM Components

Four of the six suppliers indicated that they supply select alternative media components (Table 2) including biochar, coconut coir pith, peat, perlite, pumice, and redwood bark. No samples of alternative media components were collected for analysis. Some of these materials could be useful in further evolution of BSM to reduce the potential export of more challenging pollutants such as nitrogen and phosphorus.

PROPOSED UNIFIED SPECIFICATION

Survey results and recommendations were used to develop a proposed unified specification for BSM and BSM components. Proposed specification requirements are presented in Tables 3 through 6 and discussed in sections above. Given the somewhat limited scope of this project the proposed these specifications represent incremental changes to existing specifications. The proposed specifications are generally somewhat less stringent that the current specifications, while still avoiding significant issues. The primary intent of these proposed updates is to ensure that high quality BSM materials that are available locally can reasonably meet the specification. This is intended to have the side-effect of more carefully screening out lower quality mixes that do not meet these relaxed specifications.

The proposed specifications have been compiled into "Greenbook" format and are presented in Attachment 1. The "Greenbook" is a nationwide engineering and construction reference manual used by many municipalities. The City of San Diego maintains the Sand Diego "Whitebook" which is a regional supplement to the "Greenbook". The "Greenbook" formatted proposed specifications for BSM were prepared to be included in the San Diego Whitebook. Numbering and references in the proposed specifications refer to materials included in the San Diego Whitebook.

SUMMARY AND LIMITATIONS

A total of twenty-three blended BSM, sand, topsoil, and compost samples were sourced from regional material suppliers. The samples were submitted for analysis of parameters required under existing specifications for BSM used by the City and the County. Supplier input, material availability, and analytical results were used to support the development of a proposed unified specification for blended BSM and BSM components. Information was also requested from regional material supplier regarding availability of alternative materials for use in BMPs located in areas with water quality impaired receiving waters.

Recommended updates to existing specification have been identified from this study, and a draft proposed version of a unified specification are included in Attachment A. Changes have been summarized in the sections above.

It should be noted that the recommendations derived from this study do not fully address potential issues of nitrogen and phosphorus leaching. Mixes that contain compost have a significant chance of either short-term and/or sustained issues with N and/or P export. In order to further reduce the chance of pollutant export, a substantially revised mix may be needed. This could include coco coir pith and/or decomposed wood as a substitute for compost. However, the ability for plants to survive in this mix has not been demonstrated in California and needs to be addressed before this mix can receive a full recommendation.

Attachment A

Proposed White Book Specification for Bioretention Soil Media and Aggregate Drainage Layers

Draft for Review

SECTION 803 - BIORETENTION SOIL MEDIA COMPOSITION, TESTING, AND INSTALLATION

803-1 GENERAL.

Bioretention Soil Media (BSM) is intended to filter storm water and support plant growth while minimizing the leaching of potential pollutants. This specification includes requirements that apply to BSM used in stormwater treatment BMPs, including bioretention and biofiltration.

803-2 BLENDED BSM CRITERIA AND TESTING REQUIREMENTS

803-2.1 General. Blended BSM shall consist of 60% to 80% by volume sand, up to 20% by volume topsoil, and up to 20% by volume compost. Sand, Topsoil, and Compost used in BSM shall conform to requirements listed in Sections 803-3, 803-4, and 803-5, respectively. For bioretention/biofiltration with outlet controlled designs, it is likely that topsoil will need to be omitted or reduced to achieve permeability targets.

Alternative mix components and proportions may be utilized, provided that the whole blended mix conforms to whole BSM criteria, detailed in Section 803-2.3 through 803-2.5. Alternative mix designs may include alternative proportions and/or alternative organic amendments. Alternative mixes are subject to approval by the reviewing jurisdiction. Alternative mixes that use an alternative organic component (rather than compost) may be necessary when BMPs are installed in areas with nitrogen or phosphorus impaired receiving waters in order to meet more stringent BSM quality requirements as detailed in Section 803-2.5.

803-2.2 Testing and Submittals. At least 30 days prior to ordering materials, the Contractor shall submit the following to the local jurisdiction reviewer: source/supplier of BSM, location of source/supplier, a physical sample of the BSM, whole BSM test results from a third party independent laboratory, test results for individual component materials as required, and description of proposed methods and schedule for mixing, delivery, and placement of BSM. The test results shall be no older than 120 days and shall accurately represent the materials and feed stocks that are currently available from the supplier.

Test results shall demonstrate conformance to agronomic suitability and hydraulic suitability criteria listed in Sections 803-2.3 and 803-2.4, respectively. BSM for use in BMPs in areas with water quality impairments in receiving waters shall also comply with applicable Chemical Suitability criteria in Section 803-2.5. No delivery, placement, or planting of BSM shall begin until test results confirm the suitability of the BSM. The Contractor shall submit a written request for approval which shall be accompanied by written analysis results from a written report of a testing agency. The testing agency must be registered by the State for agronomic soil evaluation laboratory test fees shall be paid for by the Contractor.

803-2.3 Agronomic Suitability. The BSM shall conform to the requirements herein to support plant growth. BSM which requires amending to comply with the below specifications shall be uniformly blended and tested in its blended state prior to testing and delivery.

a) pH range shall be between 6.0-8.5.
b) Salinity shall be between 0.5 and 3.0 millimho/cm (as measure by electrical conductivity)
c) Sodium absorption ratio (SAR) shall be less than 8.0

d) Chloride shall be less than 800 ppm.
e) Cation exchange capacity shall be greater than 10 meq/100 g.
f) Organic matter shall be between 2 and 5%.
g) Carbon:Nitrogen ratio shall be between 12 and 40 (15 to 40 preferred).

Textural class fraction shall adhere to limits in Table 803-2.1, as determined by ASTM Method D422 or an approved alternative method:

TABLE 803-2.3

Textural Class (ASTM D422)	Size Range	Mass Fraction (percent)
Gravel	Larger than 2 mm	0 to 25 of total sample
Clay	Smaller than 0.005 mm	0 to 5 of non-gravel fraction

Test results shall show the following information:

a) Date of testing
b) Project name, contractor name, and source of materials and supplier name
c) Copies of all testing reports including, at a minimum, analytical results sufficient to confirm compliance with all requirements listed in this section.

803-2.4 Hydraulic Suitability. BSM shall meet the have appropriate hydraulic properties for filtering stormwater. The BSM shall conform to the requirements herein to support plant growth. BSM which requires amending, shall be uniformly blended and tested in its blended state prior to testing and delivery.

803-2.4.1 Testing. The saturated hydraulic conductivity of the whole BSM shall be measured according to the method detailed in the measurement of hydraulic conductivity (USDA Handbook 60, method 34b), commonly available as part of standard agronomic soil evaluation, or ASTM D24234 Permeability of Granular Soils (at approximately 85% relative compaction Standard Proctor, ASTM D698). BSM shall conform to hydraulic criteria associated with the BMP design configuration that best applies to the facility where the BSM will be installed (Section 803-2.4.2 or 803-2.4.3).

803-2.4.2 Systems with Unrestricted Underdrain System (i.e., media control). For systems with underdrains that are not restricted, the BSM shall meet the minimum and maximum measured hydraulic conductivity found in Table 803-2.4 to ensure adequate flow rate through the BMP and longevity of the system but reduce excessive velocities through the media. In all cases, an upturned elbow system on the underdrain, measuring 9 to 12 inches above the invert of the underdrain, should be used to control velocities in the underdrain pipe and reduce potential for solid migration through the system.

803-2.4.3 Systems with Restricted Underdrain System (i.e., outlet control). For systems in which the flow rate of water through the media is controlled via an outlet control device (e.g., orifice or valve) affixed to the outlet of the underdrain system, the hydraulic conductivity of the media should meet the requirements in Table 803-2.4 and the outlet control device should control the flow rate to between 5 and 12 inches per hour. This configuration reduces the sensitivity of system performance to the hydraulic conductivity,

compaction, and clogging of the material, reduces the likelihood of preferential flow through media, and allows more precise design and control of system flow rates. For these reasons, outlet control should be considered the preferred design option.

803-2.4.4 Systems without Underdrains. For systems without underdrains, the BSM shall have a hydraulic conductivity of at least 5 inches per hour, or at least 2 times higher than the design infiltration rate of the underlying soil, whichever is greater.

Table 803-2.4.

	Hydraulic Conductivity Requirements	
Underdrain System	**Minimum (in/hr)**	**Maximum (in/hr)**
Unrestricted (media control)	8	24
Restricted (outlet control) Preferred Design Option.	20	80

803-2.5 Chemical Suitability for Areas Draining to Impaired Receiving Waters.

803-2.5.1 General. The chemical suitability criteria listed in this section do not apply to systems without underdrains, unless groundwater is impaired or susceptible to nutrient contamination. Limits for a given parameter only apply if that parameter is associated with a water quality impairment, priority water quality condition, and/or TMDL in the receiving water. Limits may be waived at the discretion of the reviewing jurisdiction if it is determined by the jurisdiction that it is unreasonable to meet the specification using locally-available materials (available within 100 miles).

803-2.5.2 Testing. Potential for pollutant leaching shall be assessed using either the Saturated Media Extract Method (aka, Saturation Extract) that is commonly performed by agronomic laboratories or the Synthetic Precipitation Leaching Procedure (SPLP) (EPA SW-846, Method 1312). If the saturation extract method is used, samples may be rinsed with up to five pore volumes before collecting extract for analysis.

803-2.5.3 BSM Limits in Areas Draining to Impaired Receiving Waters. The limits in this section are in terms of the concentration of a parameter in water that has been contacted with the BSM.

Table 803-2.5.3

Applicable Pollutant(s)	Saturation Extract or SPLP Criteria
Phosphorus*	< 1 mg/L
Zinc	< 1 mg/L
Copper	< 0.04 mg/L
Lead	< 0.025 mg/L
Arsenic	< 0.02 mg/L
Cadmium	< 0.01 mg/L
Mercury	< 0.01 mg/L
Selenium	< 0.01 mg/L

803-2.5.4 Alternative BSM for Reduced Phosphorus Leaching. In areas with impaired receiving waters, alternative BSM should be considered, especially if receiving waters are phosphorus impaired. BSM with 20% compost may result in phosphorus leaching and soluble phosphorus test results in excess of the 1 mg/L limit presented in Table 803-2.5.3 Alternative organic amendments, such as coco coir pith and/or composted wood products, in place of compost should be considered in these areas. Sand and soil components with higher levels of iron and aluminum should also be considered to limit the solubility of phosphorus.

803-5.5.5. Nitrogen Impaired Receiving Waters. In areas with a downstream water quality impairment or TMDL for nitrogen, a combination of BSM composition and BMP design shall be used to reduce the potential for nitrate leaching from BMPs.

- BSM: The C:N ratio of BSM shall be between 15 and 40 to reduce the potential for nitrate leaching.
- BMP design: BMPs shall be designed to either enhance infiltration into underlying soils or with internal water storage to promote reduction of nitrogen:
    - If a BMP is installed with a liner, the BMP must include an internal saturated zone, consisting of at least an 18-inch thick layer of gravel, to enhance denitrification.
    - If a BMP does not include a liner, it must be installed with a retention zone below the underdrain discharge elevation, consisting of at least an 18-inch thick layer of gravel, to enhance infiltration into underlying soils.

803-3 SAND FOR BSM.

803-3.1 General. Sand used in BSM should preferably be washed prior to delivery. If sand is not washed it must still meet sieve analysis requirements in Table 1.

803-3.2 Gradation Limits. A sieve analysis shall be performed in accordance with California Test 202, ASTM D 422, or approved equivalent method to demonstrate compliance with the gradation limits shown in Table 803-3.2. Fines passing the No. 200 sieve shall be non-plastic.

TABLE 803-3.2

	Percentage Passing Sieve (by weight)	
Sieve Size (ASTM D422)	**Minimum**	**Maximum**
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

803-4 TOPSOIL FOR BSM.

803-4.1 General. Topsoil shall be free of hazardous materials and shall be consistent with a common definition of topsoil. Decomposed granite and derivatives of decomposed granite are not considered to be topsoil for the purpose of this specification.

803-4.2 Textural Class. Topsoil shall be classified as a sandy loam or a loamy sand according to the US Department of Agriculture soil classification system. In addition, a textural class analysis shall be performed in accordance with ASTM D422, or an approved alternative method to demonstrate compliance with the gradation limits in Table 803-4.2.

Table 803-4.2

Textural Class (ASTM D422)	Size Range	Mass Fraction (percent)
Gravel	Larger than 2 mm	0 to 25 of total sample
Clay	Smaller than 0.005 mm	0 to 15 of non-gravel fraction

803-5 COMPOST FOR BSM.

803-5.1 General. Compost shall be produced at a facility inspected and regulated by the local enforcement agency for CalRecycle. Compost should also preferably be certified by the U.S. Composting Council's Seal of Testing Assurance Program (USCC STA) or an approved equivalent program. Compost shall not be produced from biosolids feedstock.

803-5.1.1 Gradation Limits. A sieve analysis shall be performed in accordance with ASTM D 422, or approved equivalent method to demonstrate compliance with the gradation limits show in Table 803-5.1.1.

Table 803-5.1.1

Sieve Size (ASTM D422)	Percent Passing Sieve (by weight)
1/2"	97 to 100
2 mm	40 to 90

803-5.1.2 Material Content. Organic Material Content shall be 35% to 100% by dry weight and moisture shall be 25% to 60% wet weight basis. Physical contaminants (manmade inert materials) shall not exceed 1% by dry weight.

803-5.2 Compost Testing. Compost shall meet the following requirements as demonstrated through standard agronomic testing methods:

a) **Carbon to nitrogen (C:N) ratio.** C:N shall be between 15:1 and 40:1, preferably above 20:1 to reduce the potential for nitrogen leaching/washout.

b) **pH.** pH shall be between 6.0 and 8.5.

c) **Soluble Salt Concentration.** Soluble Salt Concentration shall be less than 10 dS/m. (Method TMECC 4.10-A, USDA and U.S. Composting Council).

d) **Stability.** Carbon Dioxide evolution rate shall be less than 3.0 mg CO2-C per g compost organic matter (OM) per day or less than 6 mg CO2-C per g compost carbon per day, whichever unit is reported. (Method TMECC 5.08-B, USDA and U.S. Composting Council). Alternatively a Solvita rating of 5.5 or higher is acceptable.

803-5.2.1 Pathogens and Pollutant Limits. Select pathogens shall pass US EPA Class A standard, 40 CFR Section 503.32(a). Trace Metals shall pass US EPA Class A standard, 40 CFR Section 503.13, Table 1 for Ceiling Concentrations.

803-6 DELIVERY, STORAGE, HANDLING, AND PAYMENT

803-6.1 General. BSM shall be thoroughly mixed prior to delivery using mechanical mixing methods such as a drum mixer. The Contractor shall protect soils and mixes from absorbing excess water and from erosion at all times.

803-6.1.1 Delivery. The Contractor shall not deliver or place soils in wet or muddy conditions.

803-6.1.2 Storage. The Contractor shall not store materials unprotected during large rainfall events (>0.25 inches). If water is introduced into the material while it is stockpiled, the Contractor shall allow the material to drain to the acceptance of the reviewing jurisdiction before placement.

803-6.1.3 Handling and Placement. BSM shall be lightly compacted and placed in loose lifts approximately 12 inches (300 mm) to ensure reasonable settlement without excessive compaction. Compaction within the BSM area should not exceed 75 to 85% standard proctor within the BSM. Machinery shall not be used in the bioretention facility to place the BSM. A conveyor or spray system shall be used for media placement in large facilities. Low ground pressure equipment may be authorized for large facilities at the discretion of the reviewing jurisdiction. Placement methods and BSM quantities shall account for approximately 10% loss of volume due to settling. Planting methods and timing shall account for settling of media without exposing plant root systems.

803-6.1.4 Hydraulic Suitability. The reviewing jurisdiction may request up to three double ring infiltrometer tests (ASTM D3385) or approved alternative tests to confirm that the placed material meets applicable hydraulic suitability criteria. In the event that the infiltration rate

of placed material does not meet applicable criteria, the reviewing jurisdiction may require replacement and/or de-compaction of materials.

803-6.2 Quality Control and Acceptance

803-6.2.1 General. Close adherence to the material quality controls herein are necessary in order to support healthy vegetation, minimize pollutant leaching, and assure sufficient permeability to infiltrate/filter runoff during the life of the facility. Amendments may be included to adjust agronomic properties. Acceptance of the material will be based on test results certified to be representative. Test results shall be conducted no more than 120 days prior to delivery of the blended BSM to the project site. For projects installing more than 100 cubic yards of BSM, batch-specific tests of the blended mix shall be provided to the reviewing jurisdiction for every 100 cubic yards of BSM along with a site plan showing the placement locations of each BSM batch within the facility.

803-6.5 Measurement and Payment. Quantities of mixed BSM will be measured as shown in the Bid. The volumetric quantity of mixed BSM to be paid for shall be the volume of BSM placed within the limits of the dimensions shown on the Plans.

803-7 AGGREGATE MATERIALS FOR BIORETENTION AND BIOFILTRATION DRAINAGE LAYERS

803-7.1 General. This section provides material specifications for drainage layers below BSM in bioretention BMPs. This consists of a two-layer filter course placed below the BSM and above an open-graded aggregate stone reservoir.

803-7.2 Rock and Sand Materials for Drainage Layers

803-7.2.1 General. All sand and stone products used in BSM drainage layers shall be clean and thoroughly washed.

803-7.2.2 Filter Course. Graded aggregate choker material is installed as a filter course to separate BSM from the drainage rock reservoir layer. The purpose of this layer is to limit migration of sand or other fines from the BSM. The filter course consists of two layers of choking material increasing in particle size. The top layer (closets to the BSM) of the filter course shall be constructed of thoroughly washed ASTMC33 Choker Sand as detailed in Table 200-1.5.5. The bottom layer of the filter course shall be constructed of thoroughly washed ASTM No. 8 aggregate material conforming to gradation limits contained in Table 200-1.2.1.

803-7.2.3 Open-Graded Aggregate Stone. Open-graded aggregate material is installed below filter course layers to provide additional storm water storage capacity and contain the underdrain pipe(s). This layer shall be constructed of thoroughly washed AASHTO No. 57 open graded aggregate material conforming to gradation limits contained in Table 200-1.2.1.

803-7.3 Layer Thicknesses and Construction.

803-7.3.1 General. Aggregate shall be deposited on underlying layers at a uniform quantity per linear foot (meter), which quantity will provide the required compacted thickness within the tolerances specified herein without resorting to spotting, picking up, or otherwise shifting the aggregate material.

803-7.3.2 Filter Course Layers. Each of the two filter course layers (top layer of ASTM C33 Choker Sand and bottom layer of ASTM No. 8) shall be installed to a thickness of 3 inches (75

mm). Both layers shall be spread in single layers. Marker stakes should be used to ensure uniform lift thickness.

803-7.3.3 Aggregate Drainage and Storage Layer. The thickness of the aggregate drainage and storage layer (AASHTO No. 57) will depend on site specific design and shall be detailed in contract documents.

803-7.3.4 Spreading. Drainage layers shall be as delivered as uniform mixtures and each layer shall be spread in one operation. Segregation within each aggregate layer shall be avoided and the layers shall be free from pockets of coarse or fine material.

803-7.3.5 Compacting. Filter course material and aggregate storage material shall be lightly compacted to approximately 80% standard proctor without the use of vibratory compaction.

803-7.4 Measurement and Payment. Quantities of graded aggregate choker material and open-graded aggregate storage material will be measured as shown in the Bid. The volumetric quantities of graded aggregate choker stone material and open-graded storage material shall be those placed within the limits of the dimensions shown on the Plans. The weight of material to be paid for will be determined by deducting (from the weight of material delivered to the Work) the weight of water in the material (at the time of weighing) in excess of 1% more than the optimum moisture content. No payment will be made for the weight of water deducted as provided in this subsection.