APPENDIX C
SOIL INFILTRATION AND SOIL AMENDMENTS

INFILTRATION SOIL TESTING PROCEDURE

Test Pit/Boring Procedures

1. One (1) test pit or standard soil boring should be provided for every 1,000 sq ft of the proposed infiltration area.
2. The location of each test pit or standard soil boring should correspond to the location of the proposed infiltration area.
3. Excavate each test pit or penetrate each standard soil boring to a depth at least 2 ft below the bottom of the proposed infiltration area.
4. If the groundwater table is located within 2 ft of the bottom of the proposed facility, determine the depth to the groundwater table immediately upon excavation and again 24 hours after excavation is completed.
5. Determine the Unified Soil Classification System (USCS) texture at the base of the proposed infiltration area to a depth 2 ft below the base. Soil components should be classified and described in general accordance with USCS or modified USCS from ground surface to 2 ft below anticipated design depth.
6. If bedrock is located within 2 ft of the bottom of the proposed infiltration area, determine the depth to the bedrock layer.
7. Test pit/soil boring stakes should be left in the field to identify where soil investigations were performed.
8. A map of the test pit / boring locations and logs shall be provided with stratigraphic classifications (in accordance with USCS) and test results.

Infiltration Testing Procedures

1. One infiltration test should be conducted for every 1,000 sq ft of surface area for the infiltration area.
2. The location of each infiltration test should correspond to the location of the proposed infiltration area.
3. Install a test casing (e.g., a rigid, 4 to 6 inch diameter pipe) to a depth 2 ft below the bottom of the proposed infiltration area.
4. Remove all loose material from the sides of the test casing and any smeared soil material from the bottom of the test casing to provide a natural soil interface into which water may percolate. If desired, a 2-inch layer of coarse sand or fine gravel may be placed at the bottom of the test casing to prevent clogging and scouring of the underlying soils. Fill the test casing with clean water to 2 ft above the top of the soil interface, and allow the underlying soils to presoak for 24 hours.
5. After 24 hours, refill the test casing with another 2 ft of clean water and measure the drop in water level within the test casing after one hour. Repeat the procedure three (3) additional times by filling the test casing with clean water and measuring the drop in water level after one hour. A total of four (4) observations must be completed. The infiltration rate of the underlying soils may be reported either as the average of all four observations or the value of the last observation. The infiltration rate should be reported in terms of inches per hour.

6. Infiltration testing may be performed within an open test pit or a standard soil boring. After infiltration testing is completed, the test casing should be removed and the test pit or soil boring should be backfilled and restored.
7. Together with the map of test pit / boring and infiltration test locations, calculation pages reporting infiltration test measurements and results shall be provided. This information shall include verification that the test holes have been appropriately backfilled. Geotechnical logs, calculations and infiltration test results shall be certified by a qualified registered professional engineer or geologist.

DESIGN CRITERIA FOR AMENDING SOILS WITH COMPOST AND SOIL MIXES

SECTION 1. DESCRIPTION

Soil amendments described herein consist of post-construction restoration. This is a practice applied after construction that consists of deeply tilling compacted soils to restore their porosity by amending them with compost.

These soil amendments can reduce the generation of runoff from compacted urban lawns or other existing lawnscapes, and may also be used to enhance the infiltration characteristics of downspout disconnections, grass channels, and filter strips.

SECTION 2. PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Compost amended soils are suitable as a pervious layer where soils have been or will be compacted by the grading and construction process. This technique can also be used in areas where construction and development have occurred in the past, if infiltration in such areas is low. Soil amendment should be considered when existing soils have low infiltration rates (typically Hydrologic Soil Groups C and D – applicable throughout much of the City of Fayetteville) and when the pervious area will be used to filter runoff (downspout disconnections and grass channels). The area or strip of amended soils should be hydraulically connected to the stormwater conveyance system. In new construction, soil amendment is recommended if mass grading of more than a foot of cut and fill will occur across the site.

Compost amendments are not recommended where:

- Existing soils have high infiltration rates (e.g., HSG A and B), although compost amendments may be needed to restore mass-graded B soils in order to maintain runoff reduction rates.
- The water table or bedrock is located within 1.5 ft of the soil surface.
- Slopes exceed 10% for longer than 25 ft in downslope direction. Compost amendments may be considered for such slopes if permanent erosion control measures are designed and approved by the City Engineer.
- Existing surface soils are saturated or wet for the extent of the wet season.
- They would harm roots of existing trees (keep amendments outside the tree drip line).
- The surface drainage is toward an existing or proposed building foundation.

- The contributing impervious surface area exceeds the surface area of the amended soils.
- Areas of additional jurisdiction apply (i.e., Streamside Protection Area, FEMA Special Flood Hazard Area, USACE Jurisdictional Wetlands Areas)

Compost amendments can be applied to the entire pervious area of a development or be applied only to select areas of the site to enhance the performance of runoff reduction practices. Some common design applications include:

- Reduce runoff from compacted lawns.
- Enhance rooftop disconnections on poor soils by amending the soils and redirecting roof runoff from impervious surfaces to amended soil areas.
- Increase runoff reduction within a grass channel.
- Increase runoff reduction within a vegetated filter strip.
- Increase the runoff reduction function of a tree cluster or reforested area of the site.

SECTION 3. DESIGN CRITERIA

Soil Testing

Soil tests are required during two stages of the compost amendment process. Initial testing is done to ascertain soil properties in proposed amendment areas prior to restoration activities. The initial testing is to obtain samples and determine soil properties to a depth 1 ft below the proposed amendment area. Soil tests should include bulk density, organic content, moisture content, pH, salts, and soil nutrients (NPK). An infiltration test may also be performed. These tests should be conducted every 5000 sq ft, and are used to determine what, if any, further soil amendments are needed and to characterize potential drainage problems.

The second soil test is taken at least one week after the compost has been incorporated into the soils. This soil analysis should be conducted to determine whether any further nutritional requirements, pH adjustment, and organic matter adjustments are necessary for plant growth. This soil analysis should be done in conjunction with the final construction inspection to ensure tilling or subsoiling has achieved design depths and should include the parameters required for initial testing as described herein. If improved infiltration characteristics are included in anticipated runoff reduction, an infiltration test must be performed to confirm improvement. In such cases, antecedent moisture conditions must be documented.

Determining Depth of Compost Incorporation

The depth of compost amendment is based on the relationship of the surface area of the soil amendment to the contributing area of impervious cover that drains to the amended surface area. Table C.1 presents some general guidance derived from soil modeling by Holman-Dodds (2004) that evaluates the required depth to which compost must be incorporated. Some adjustments to the recommended incorporation depth were made to reflect alternative recommendations of Roa Espinosa (2006), Balousek (2003), Chollak and Rosenfeld (1998) and others.

Table C.1. Short-Cut Method to Determine Compost and Incorporation Depths.				
	Contributing Impervious Cover to Soil Amendment Area Ratio [1]			
	IC/SA = 0 [2]	IC/SA = 0.5	IC/SA = 0.75	IC/SA = 1.0 [3]
Compost (in) [4]	2 to 4 [5]	3 to 6 [5]	4 to 8 [5]	6 to 10 [5]
Incorporation Depth (in)	6 to 10 [5]	8 to 12 [5]	15 to 18 [5]	18 to 24 [5]
Incorporation Method	Rototiller	Tiller	Subsoiler	Subsoiler

1. IC = contrib. impervious cover (sq. ft.) and SA = surface area of compost amendment (sq ft).
2. For amendment of compacted lawns that do not receive off-site runoff.
3. In general, IC/SA ratios greater than 1 should be avoided.
4. Average depth of compost added.
5. Lower end for B soils, higher end for C/D soils.

Once the area and depth of the compost amendments are known, the designer can estimate the total amount of compost needed, based on the equation below:

Equation 8.1. Compost Quantity Estimation

$$C = A * D * 0.0031$$

Where:

C = compost needed (cu. yds.)

A = area of soil amended (sq. ft.)

D = depth of compost added (in.)

3.3 Compost Specifications

The basic material specifications for compost amendments are outlined below:

- Compost shall be derived from plant material and provided to meet the minimum following requirements: The compost shall be the result of the biological degradation and transformation of plant-derived materials under conditions that promote anaerobic decomposition. The material shall be well composted, free of viable weed seeds, and stable with regard to oxygen consumption and carbon dioxide generation. The compost shall have a moisture content that has no visible free water or dust produced when handling the material. It shall meet the following criteria, as reported by the U.S. Composting Council STA Compost Technical Data Sheet provided by the vendor:
  - 100% of the material must pass through a half inch screen
  - The pH of the material shall be between 6 and 8
  - Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 1.0% by weight
  - The organic matter content shall be between 35% and 65%
  - Soluble salt content shall be less than 6.0 mmhos/cm
  - Maturity should be greater than 80%
  - Stability shall be 7 or less

- Carbon/nitrogen ratio shall be less than 25:1
- Heavy metals test results within limits of the USEPA 40CFR Part 503, for applicable sources
- The compost must have a dry bulk density ranging from 40 to 50 lbs./cu.ft.

SECTION 4. CONSTRUCTION

Construction Sequence

The construction sequence for compost amendments differs depending whether the practice will be applied to a narrow filter strip, such as in a rooftop disconnection or grass channel or a large area. For larger areas, a typical construction sequence is as follows:

Step 1. Prior to building, the proposed area should be deep tilled to a depth of 2 to 3 ft using a tractor and sub-soiler with two deep shanks (curved metal bars) to create rips perpendicular to the direction of flow. (This step is usually omitted when compost is used for narrower filter strips.)

Step 2. A second deep tilling to a depth of 12 to 18 inches is needed after final grading of individual building lots is complete.

Step 3, if required. Dewater to ensure dry conditions at the site prior to incorporating compost.

Step 4. Using a roto-tiller or similar equipment, incorporate a compost mix meeting the requirements per Section 3 into the soil, at the volumetric rate of 1 part compost to 2 parts soil.

Step 5. The site should be leveled and seeds or sod used to assist in establishing a vigorous grass cover, where individual seedling or container planting is not required. Lime or irrigation may initially be needed to help the grass grow quickly. A general fertilizer such as 13-13-13 would work as a starter and is readily available if needed. Do not add a high nitrogen fertilizer as it can burn seedlings.

Step 6. Employ simple erosion control measures, such as silt fence, to reduce the potential for erosion of and trap sediment from areas receiving compost amendments and exceeding 2500 sq ft in size.

SECTION 5. ENGINEERED SOIL MIXES FOR BIORETENTION

Engineered soils are an option for Bioretention GSP soil media when infiltration rates of the post construction soils do not meet acceptable infiltration rates. As stated in the Bioretention GSP-01 specification, post construction soils should exhibit a minimum infiltration rate of 1 inch/hr in accordance with the infiltration testing procedure in this manual.

Engineered Soil Requirements

Two soil mix designs are provided herein. These soil mixes may be used for soil filter media in bioretention practices. The soil mix design should be selected based upon the desired infiltration characteristics and regional availability of materials. Since the post-construction bioretention feature must provide adequate infiltration capacity, pre- and post-construction infiltration testing of the mix design should be performed

using materials known to be readily available. For economical reasons, on-site soil material should be used provided infiltration characteristics can be met. In this case, additional pre-construction tests should include particle size, or gradation analyses, of these soils in accordance with ASTM D-422, and Atterberg Limits tests on the fines in accordance with ASTM D-4318.

Soil Mix A

For the best infiltration characteristics and longevity (minimal clogging of pore space), a relatively well-graded sand-compost mixture with minimum clay content (to restrict infiltration rates and achieve the desired 24-hour retention time) is recommended, following MPCA (2005):

Concrete Sand (Sand meeting ASTM C-33 gradation): 60%-80%

Compost[1]: 15%-30%

Natural soil material[2]: 5%-10%

1. With a required organics component of the compost ranging from 30%-60%, the proportion of compost should be limited so the total organic content of the resulting soil mix does not exceed 8%, if species from the native vegetation list are used. Where non-natives are specified and approved, higher organic content may be permissible.
2. The total clay content of the resulting soil mix may not exceed 5%. If used, clay must be low plasticity (CL) per Unified Soil Classification System (USCS). If topsoil containing clay is used, post-construction infiltration tests must be performed to ensure adequate infiltration rate.

Soil Mix B

This soil mix allows for incorporation of additional natural soil material with the expectation that existing on-site soil material containing silt and clay will be used where possible. On-site silts and clays of low plasticity (ML and CL) may only be used if infiltration and hydraulic conductivity analyses indicate the design infiltration rate can be achieved. During mix preparation, the on-site soil material must be judiciously combined with the concrete sand to achieve the desired sand and fine ratio, to ensure permeability of the resulting soil mix is not too low. The compost material may be added last. The exact composition of organic matter and soil material will vary depending on the native soils available for use, thus an exact design is difficult to develop without a prior evaluation of available materials. (MWS, 2011). After construction, infiltration tests should be performed (see the recommended ratio per GSP-01) to show that the minimum initial infiltration rate is achieved:

Concrete Sand (Sand meeting ASTM C-33 gradation): 40%-70%

Silt: 0%-40%

Compost[1]: 15%-30%

Clay[2]: 0%-20%

1. With a required organics component of the compost ranging from 30%-60%, the proportion of compost should be limited so the total organic content of the resulting soil mix does not exceed 8%, if species from the native vegetation list are used. Where non-natives are specified and approved, higher organic content may be permissible.

2. The total clay content of the resulting soil mix may not exceed 5%. If used, clay must be low plasticity (CL) per Unified Soil Classification System (USCS). If soil containing clay is used, post-construction infiltration tests must be performed to ensure adequate infiltration rate.

REFERENCES

Minnesota Pollution Control Agency, 2008, *Minnesota Stormwater Manual, Version 2, Chapter 12-6 Bioretention*, St. Paul, MN.

Virginia Department of Conservation and Recreation, 2011, *Virginia DCR Stormwater Design Specification No. 4 Soil Compost Amendment, Version 1.8*, Richmond, VA.