BMP 6.7.3: Soil Amendment & Restoration

Soil amendment and restoration is the process of improving disturbed soils and low organic soils by restoring soil porosity and/or adding a soil amendment, such as compost, for the purpose of reestablishing the soil's long-term capacity for infiltration and pollution removal.

Key Design Elements

- Existing soil conditions should be evaluated before forming a restoration strategy.
- Physical loosening of the soil, often called subsoiling, or tilling, can treat compaction.
- The combination of subsoiling and soil amendment is often the more effective strategy.
- Compost amendments increase water retention.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Medium
Water Quality: Medium

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

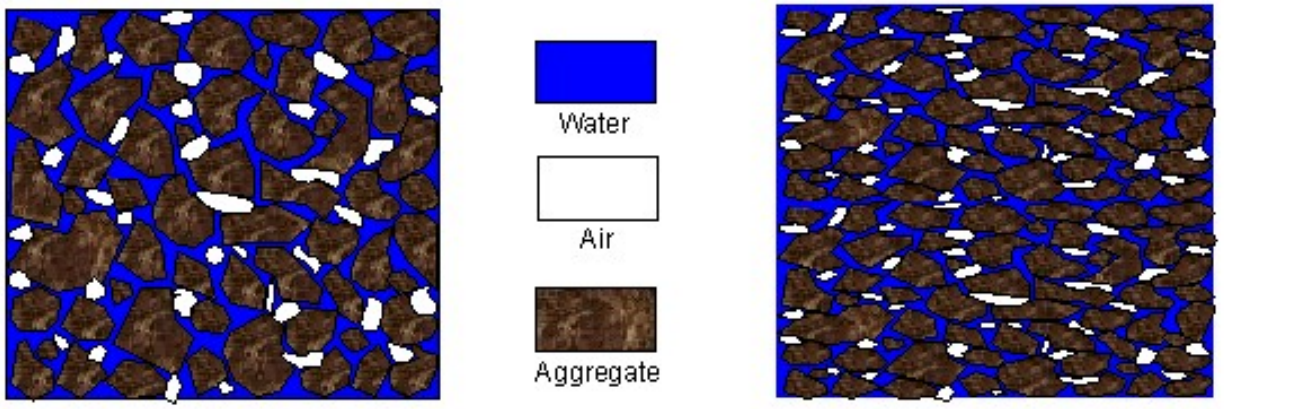
Problem Description

Animals, farm equipment, trucks, construction equipment, cars, and people cause compaction. Wet soil compacts easier than dry soil. Natural compaction occurs due to special chemical or physical properties, and these occurrences are called “hard pans”. A typical soil after compaction has strength of about 6,000 kPa, while studies have shown that root growth is not possible beyond 3,000 kPa.

Different Types of Compaction

1) Minor Compaction – surface compaction within 8-12” due to contact pressure, axle load > 10 tons can compact through root zone, up to 1’ deep

2) Major Compaction – deep compaction, contact pressure and total load, axle load > 20 tons can compact up to 2’ deep (usually large areas compacted to increase strength for paving and foundation with overlap to “lawn” areas)



good physical condition

poor physical condition (compacted)

In general, compaction problems occur when airspace drops to 10-15% of total soil volume. Compaction affects the infiltrating and water quality capacity of soils. When soils are compacted, the soil particles are pressed together, reducing the pore space necessary to move air and water throughout the soil. This decrease in porosity causes an increase in bulk density (weight of solids per unit volume of soil). The greater the bulk density, the lower the infiltration and therefore the larger volume of runoff.

Different types of soils have bulk density levels at which compaction starts to limit root growth. When root growth is limited, the uptake of water and nutrients by vegetation is reduced.

Soil organisms are also affected by compaction; biological activity is greatly reduced, decreasing their ability to intake and release nutrients.

The best soil restoration is the complete revegetation of woodlands, as “A mature forest can absorb as much as 14 times more water than an equivalent area of grass.” (DNREC and Brandywine Conservancy, 1997) (See Structural BMP 6.7.2 Landscape Restoration and use in combination with this BMP)

Soil Restoration Methodology

Soil restoration is a technique that can be used to restore and enhance compacted soils or soils low in organic content by physical treatment and/or mixture with additives such as compost. Soil restoration has been shown to alter soil properties known to affect water relations of soils, including water holding capacity, porosity, bulk density and structure. Two methods have been shown to restore some of the characteristics of soils that are damaged by compaction; tilling and addition of amendments such as compost or other materials.

One of the options for soil amendment is compost, which has many benefits. It improves the soil structure, creating and enhancing passageways in the soil for air and water that have been lost due to compaction. This recreates a better environment for plant growth. Compost also supplies a slow release of nutrients to plants, specifically nitrogen, phosphorous, potassium, and sulfur. Using compost reuses natural resources, reducing waste and cost.

Soil amendment with compost has been shown to increase nutrients in the soil, such as phosphorus and nitrogen, which provides plants with needed nutrients, reducing or eliminating the need for fertilization. This increase in nutrients results in an aesthetic benefit as turf grass and other plantings establish and proliferate more quickly, with less maintenance requirements. Soil amendment with compost increases water holding and retention capacity, improves infiltration, reduces surface runoff, increases soil fertility, and enhances vegetative growth. Compost also increases pollutant-binding properties of the soil properties, which improves the quality of the water passing through the soil mantle and into the groundwater.

The second method is tilling, which involves the digging, scraping, mixing, and ripping of soil with the intent of circulating air into the soil mantle in various layers. Compaction down to 20 inches often requires ripping for soil restoration. Tilling exposes compacted soil devoid of oxygen to air and recreates temporary air space.

Bulk density field tests may be used to determine the compaction level of soils.

Soil Texture	Ideal Bulk densities	Bulk densities that may afffect root growth	Bulk densities that restrict root growth
	g/cm3	g/cm3	g/cm3
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Slilt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47
Source: Protecting Urban Soil Quality, USDA-NRCS			

Variations

- Soil amendment media can include compost, sand, and manufactured microbial solutions.
- Seed can be included in the soil amendment to save application time.

Applications

- **New Development (Residential, Commercial, Industrial)** – new lawns can be amended with compost and not heavily compacted before planting, to increase the porosity of the soils.

- **Urban Retrofits** - Tilling of soils that have been compacted before it is converted into meadow, lawn, or a stormwater facility is recommended.

- **Detention Basin Retrofits** – The inside face of detention basins is usually heavily compacted, and tilling the soil mantle on surfaces beyond the constructed embankment will encourage infiltration to take place. Tilling may be necessary to establish better vegetative cover.

- **Landscape Maintenance** – compost can substitute for dwindling supplies of native topsoil in urban areas.

- **Golf Courses** – Using compost as part of the landscaping upkeep on the greens has been shown to alleviate soil compaction, erosion, and turf disease problems.

Design Considerations

1. Treating Compaction by **Soil Restoration**
   a) Soil amendment media usually consists of compost, but can include mulch, manures, sand, and manufactured microbial solutions.
   b) Compost should be added at a rate of 2:1 (soil:compost). If a proprietary product is used, the manufacturer's instructions should be followed in terms of mixing and application rate.
   c) Soil restoration should not be used on slopes greater than 30%. In these areas, deep-rooted vegetation can be used to increase stability.
   d) Soil restoration should not take place within the drip line of a tree to avoid damaging the root system.
   e) On-site soils with an organic content of at least 5 percent can be properly stockpiled (to maintain organic content) and reused.
   f) Procedure: rototill, or rip the subgrade, remove rocks, distribute the compost, spread the nutrients, rototill again.
   g) Add 6 inches compost / amendment and till up to 8 inches for minor compaction.
   h) Add 10 inches compost / amendment and till up to 20 inches for major compaction.

2. Treating Compaction by **Ripping / Subsoiling / Tilling / Scarification**
   a) Subsoiling is only effective when performed on dry soils.
   b) Ripping, subsoiling, or scarification of the subsoil should be performed where subsoil has become compacted by equipment operation, dried out and crusted, or where necessary to obliterate erosion rills.
   c) Ripping (Subsoiling) should be performed using a solid-shank ripper and to a depth of 20 inches, (8 inches for minor compaction).

d) Should be performed before compost is placed and after any excavation is completed.
e) Subsoiling should not be performed within the drip line of any existing trees, over underground utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design.

Subsoiling should not be performed with common tillage tools such as a disk or chisel plow because they are too shallow and can compact the soil just beneath the tillage depth.

3. Other methodologies:
   a) Irrigation Management – low rates of water should be applied, as over-irrigation wastes water and may lead to environmental pollution from lawn chemicals, nutrients, and sediment.
   b) Limited mowing – higher grass corresponds to greater evapotranspiration.
   c) Compost can be amended with bulking agents, such as aged crumb rubber from used tires or weed chips. This can be a cost-effective alternative that reuses waste materials.
   d) In areas where compaction is less severe (not as a result of heavy construction equipment), planting with deep-rooted perennials can treat compaction, however restoration takes several years.

Table 2. Mean runoff from unvegetated test plots during a 30 minute high-intensity (~ 4 in/hr) rain storm

	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Geometric mean runoff (mm) during 30-minute rainfall	0.13[a]	<0.01[a]	0.08[a]	26.22[b]	15.54[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

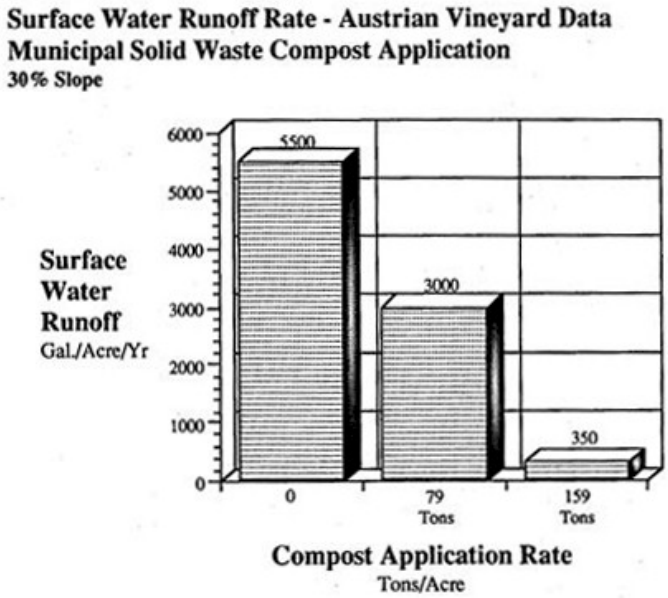
Table 3. Mean time to initiate runoff from unvegetated test plots

	Biosolids	Yard Trimmings	Bio-industrial	Compacted Subsoil	Topsoil
Mean time (min)	31.08[c]	56.92[d]	32.17[c,d]	4.67[a]	7.83[b]

Values with different letters are significantly different statistically ($p<0.05$) from one another.

Detailed Stormwater Functions

Infiltration Area (If needed)
The infiltration area will be the entire area restored, depending on the existing soil conditions, and the restoration effectiveness.



Volume Reduction Calculations
Soil Amendments can reduce the need for irrigation by retaining water and slowly releasing moisture, which encourages deeper rooting. Infiltration is increased; therefore the volume of runoff is decreased.

Compost amended soils can significantly reduce the volume of stormwater runoff. For soils that have either been compost amended according to the recommendations of their BMP, or subject to restoration such that the field measured bulk densities meet the Ideal Bulk Densities of Table 1, the following volume reduction may be applied:

Amended Area (ft^2) x 0.50in x 1/12 = Volume (cf)

Peak Rate Mitigation
See Section 8 for peak rate mitigation.

Water Quality Improvement
See Section 8 for water quality improvement.

Table 4. Adsorbed Mass of Nutrients and Metals in Unvegetated Plot Runoff From 30-Minute, High-Intensity (100-mm/hr.) Rainstorm

	Compost Treatments			Conventional Treatments	
	Biosolids	Yardwaste	Bioindustrial Compost	Compacted Subsoil	Topsoil
Element	Geometric Mean (mg)				
Chromium	0.01[b]	<0.01[a]	<0.01[b]	0.92[c]	0.76[c]
Copper	0.02[b]	<0.01[a]	0.01[b]	1.03[c]	0.66[c]
Nickel	<0.01[b]	<0.01[a]	<0.01[b]	0.96[c]	0.67[c]
Lead	0.01[b]	<0.01[a]	<0.01[b]	1.82[c]	0.95[c]
Zinc	0.10[b]	<0.01[a]	0.03[b]	6.55[c]	3.99[c]
Nitrogen	0.47[b]	<0.01[a]	0.09[a,b]	266.65[c]	211.87[c]
Phosphorus	0.45[b]	<0.01[a]	0.09[a,b]	36.47[c]	29.07[c]
Potassium	0.17[b]	<0.01[a]	0.09[a,b]	103.94[c]	71.57[c]

Means within the same row with different letter designations are significantly different ($p<0.05$).

Highest Medium Lowest

Construction Sequence

1. All construction should be completed and stabilized before beginning soil restoration.

Maintenance Issues

The soil restoration process may need to be repeated over time, due to compaction by use and/or settling. (For example, playfields or park areas will be compacted by foot traffic.)

Cost Issues

Tilling costs, including scarifying sub-soils, range from $800/ac to $1000/ac.

Compost amending of soil ranges in cost from $860/ac to $1000/ac.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. SCOPE

    a. This specification covers the use of compost for soil amendment and the mechanical restoration of compacted, eroded and non-vegetated soils. Soil amendment and restoration is necessary where existing soil has been deemed unhealthy in order to restore soil structure and function, increase infiltration potential and support healthy vegetative communities.

    b. Soil amendment prevents and controls erosion by enhancing the soil surface to prevent the initial detachment and transport of soil particles.

2. COMPOST MATERIALS

    a. Compost products specified for use in this application are described in Table 1. The product's parameters will vary based on whether vegetation will be established on the treated slope.

    b. Only compost products that meet all applicable state and federal regulations pertaining to its production and distribution may be used in this application. Approved compost products must meet related state and federal chemical contaminant (e.g., heavy metals, pesticides, etc.) and pathogen limit standards pertaining to the feedstocks (source materials) in which it is derived.

    c. Very coarse compost should be avoided for soil amendment as it will make planting and crop establishment more difficult.

d. **Note 1** - Specifying the use of compost products that are certified by the U.S. Composting Council's Seal of Testing (STA) Program (www.compostingcouncil.org) will allow for the acquisition of products that are analyzed on a routine basis, using the specified test methods. STA participants are also required to provide a standard product label to all customers, allowing easy comparison to other products.

3. SUB-SOILING TO RELIEVE COMPACTION

a. Before the time the compost is placed and preferably when excavation is completed, the subsoil shall be in a loose, friable condition to a depth of 20 inches below final topsoil grade and there shall be no erosion rills or washouts in the subsoil surface exceeding 3 inches in depth.

b. To achieve this condition, subsoiling, ripping, or scarification of the subsoil will be required as directed by the owners s representative, wherever the subsoil has been compacted by equipment operation or has become dried out and crusted, and where necessary to obliterate erosion rills. Sub-soiling shall be required to reduce soil compaction in all areas where plant establishment is planned. Sub-soiling shall be performed by the prime or excavating contractor and shall occur before compost placement.

c. Subsoiled areas shall be loosened to less than 1400 kPa (200 psi) to a depth of 20 inches below final topsoil grade. When directed by the owner's representative, the Contractor shall verify that the sub-soiling work conforms to the specified depth.

d. Sub-soiling shall form a two-directional grid. Channels shall be created by a commercially available, multi-shanked, parallelogram implement (solid-shank ripper). The equipment shall be capable of exerting a penetration force necessary for the site. No disc cultivators chisel plows, or spring-loaded equipment will be allowed. The grid channels shall be spaced a minimum of 12 inches to a maximum of 36 inches apart, depending on equipment, site conditions, and the soil management plan. The channel depth shall be a minimum of 20 inches or as specified in the soil management plan. If soils are saturated, the Contractor shall delay operations until the soil will not hold a ball when squeezed. Only one pass shall be performed on erodible slopes greater than 1 vertical to 3 horizontal. When only one pass is used, work should be at right angles to the direction of surface drainage, whenever practical.

e. Exceptions to sub-soiling include areas within the drip line of any existing trees, over utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design (abutments, footings, or in slopes), and on inaccessible slopes, as approved by the owner's representative. In cases where exceptions occur, the Contractor shall observe a minimum setback of 20 feet or as directed by the owner's representative. Archeological clearances may be required in some instances.

4. COMPOST SOIL AMENDMENT QUALITY

a. The final, resulting compost soil amendment must meet all of the mandatory criteria in Table 4.

5. COMPOST SOIL AMENDMENT INSTALLATION

    a. Spread 2-3 inches of approved compost on existing soil. Till added soil into existing soil with a rotary tiller that is set to a depth of 6 inches. Add an additional 4 inches of approved compost to bring the area up to grade.

    b. After permanent planting/seeding, 2-3 inches of compost blanket will be applied to all areas not protected by grass or other plants

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