2E-5 Soil Quality Restoration

BENEFITS

Low = <30%   Medium = 30-65%   High = 65-100%

	Low	Med	High
Suspended Solids	■	■	■
Nitrogen	■	■	■
Phosphorous	■	■	■
Metals	■	■	■
Bacteriological	■	■	■
Hydrocarbons	■	■	■

Description: Healthy soils have tremendous capacity for infiltrating and storing water. Healthy soils also have active microbial life that will breakdown and utilize many pollutants moving in urban non-point runoff. Soil quality restoration helps urban landscapes absorb, infiltrate and purify runoff. Directing stormwater flows onto landscapes with good soil quality reduces the volume of runoff that is generated. Soil quality restoration involves a combination of steps. Reducing compaction, increasing pore space, improving organic matter content, and re-establishment of soil dwelling populations (microbes, worms, insects, etc) are the main components of soil quality restoration. Soil quality restoration is most beneficial to soils that have been altered and compacted through recent land-disturbing activities on construction sites, but almost any urban landscape can benefit from soil quality restoration techniques.

Typical uses:
- Included in the final grading and stabilization of construction sites.
- Incorporated into lawn care management practices on established landscapes.

Advantages/benefits:
- Reduces stormwater runoff volume.
- Protects water quality by infiltrating and processing pollutants moving in stormwater runoff.
- Reduces the need for irrigation by increasing water holding capacity and water availability.
- Usually reduces the need for fertilizers and pesticides.

Disadvantages/limitations:
- Access to soil restoration services may be limited.
- Access to compost may be limited.
- May increase landscaping costs initially.

Maintenance requirements:
- After restoration practices, the key need is to maintain and increase organic matter content.
- Annual applications of compost amendments is recommended (but not required).
- Do not remove lawn clippings; leave to decompose and maintain organic matter content.
- Minimize pesticide use to maintain healthy populations of earthworms, soil dwelling insects, and soil microbes.
- Native landscaping will maintain and enhance soil quality restoration over time.

A. Description

Soil quality is best maintained by minimizing land-disturbing activities. Design new developments to fit the existing topography to the greatest extent possible. Use a "building envelope" to confine grading activities, construction traffic, stockpiling of materials, and other construction activities within a cordoned-off area.

Where land-disturbing activities can't be avoided, perform soil quality restoration as part of the final landscaping. Soil quality restoration generally must be on a lot-by-lot basis in residential developments. Residential development featuring single-family dwellings typically provides 50% to 70% green space, making the soil profile a potential water management and water storage resource. Typically, urban soil gets compacted and altered during construction. Even though urban green space is covered with vegetation, they may actually have post-development curve numbers of up to 90. Consequently, urban green space is typically "hydrologically dysfunction," meaning these landscapes can not absorb and infiltrate water.

On commercial or other ultra-urban development (i.e., lake shore development, condo or townhouse complexes with limited green space), try to maintain 20% to 30% green space. Locate this green space strategically so that impervious surface runoff can be directed to it in a sheet flow, if possible. With 20% green space and good soil quality to a depth of 1.5 feet, the WQv of runoff generated from an 80% impervious development can be infiltrated and stored. If 30% green space can be maintained, the WQv from the 70% impervious surface can be managed by good soil quality to a depth of 1 foot. Good soil quality is defined as having at least 40% pore space, at least 5% organic matter content, and a healthy population of soil microbes and other species of soil dwellers.

If only 10% of a development site can be maintained as green space, install bioretention cells to manage the WQv from the 90% impervious surface.

B. Stormwater management suitability

Soil quality restoration is applicable on all developable sites. Reducing compaction, increasing soil permeability, and improving the soils quality by increasing organic content will enhance and maintain infiltration and healthy vegetation. This non-structural practice will improve water quality and will improve infiltration. Some reduction in runoff volume will be achieved through increased infiltration.

C. Pollutant removal capabilities

Good soil quality will generally provide for the capture of most of the major pollutants of concern, and would be comparable to a bioretention cell for pollutant removal. Hydrocarbons, bacteria, phosphorous, sediment, metals, etc, are generally captured in the top part of the profile when runoff is infiltrated. A healthy microbial population will break down and utilize many of the pollutants. A pollutant such as nitrogen moving in solution could move past the root zone of turf landscapes with high percolation rates. Incorporating strategic native landscaping along with soil quality restoration is recommended for increased evapotranspiration and more nutrient uptake.

D. Application and feasibility

Some component of soil quality restoration is applicable to almost all Iowa soils. Conditions such as extended periods of high water table could render soil quality restoration not feasible. However, such sites would typically not be developed.

The model to be emulated with soil quality restoration (and other infiltration-based stormwater management practices) is the quality of soil that developed under the native prairie ecosystems that existed across Iowa before European settlement. Most of the prairie soils of Iowa originally had at least 45% pore space, and a minimum of 8-10% organic matter content. Altered and compacted soils have higher bulk density and lower porosity. When soils are compacted the area available for water storage in the soil profile is reduced.

A healthy soil profile with 45% pore space should typically be able to infiltrate anywhere from 0.6 inches to 2 inches of water per hour into the soil profile. The water-holding capacity of most prairie soils should be around 0.2 inches of water per inch of soil profile. Therefore, a soil with 45% porosity should be able to store at least 2.4 inches of rainfall in the first foot of soil profile. This amount of storage capacity is approximately 160% of the water quality volume that SUDAS recommends we design our stormwater management systems to treat for water quality protection.

Pore space volume and size of pores will typically decrease as you move down in a soil profile, but most upland soils will still maintain the ability to store anywhere from 0.15 to 0.2 inches of water per inch of soil profile. Therefore, a healthy 3-foot soil profile has the potential capacity to store 5.4 to 7.2 inches of rain. The intensity of rainfall and the infiltration rates of a soil would determine how much rain can actually be infiltrated and stored before runoff is generated. The potential infiltration and storage capacity of healthy soils makes an infiltration-based and groundwater driven hydrology seem quite feasible, which was the case back when the prairies and other native ecosystems were intact. If we can mimic this type of a hydrology for 90% or more of rainfall events in Iowa, the potential for water quality enhancement and stabilization of stream flows seems quite feasible, as well.

The 8-10% organic matter content of the prairie soils added to the feasibility of historic landscapes being able to absorb and infiltrate most rainfall events. Today, Iowa soils typically have 2-4% organic matter content, and often less on altered construction sites where topsoil has been stripped and exported off-site. Consequently, modern soils have probably lost 60-80% of their ability to absorb, infiltrate, and store rainfall. Therefore, our modern landscapes initiate runoff sooner and shed more total runoff. Consequently, we have a flashier hydrology and more runoff events that transport pollutants to surface waters. Infiltrated rain on the historic landscape moved slowly through the soil matrix to emerge down-gradient as cool, clean groundwater discharge that fed and maintained stable, clean flows in streams and rivers, and clean, stable levels of water in lakes and wetlands. The goal of soil quality restoration (and the other infiltration-based stormwater management practices) is to make our modern urban landscapes mimic the hydrologic functionality of our historic landscapes, at least for the water quality volume (1.25 inches of rain or less).

E. Planning and design criteria

A soil management plan (SMP) should be created for each new development. Soil management plans are needed to treat landscapes as mass grading is completed and infrastructure is installed. A second SMP will usually be needed for individual lots unless land-disturbing activity and traffic are confined within a building envelope.

Soil management plans will typically involve a seven-step process:

- Determine soil conditions (pre- and post-construction).
- Identify areas where soils and vegetation will not be disturbed.
- Determine areas where topsoil will be stripped and stockpiled.
- Determine tillage needs to address compaction.
- Determine the porosity and organic matter content needed to manage the WQv.
- Quantify compost amendments needs and specify methods of amending.
- Specify methods for establishing vegetative cover (i.e. sodding, seeding rates).
- Specify erosion control components needed until vegetation is well established.

First and foremost, existing soil quality should be protected. By minimizing land-disturbing activities, soil profiles are left intact and compaction does not occur. Compaction, which increases bulk density and reduces pore space, is a primary culprit in the creation of hydrologically-dysfunctional landscapes. Never compact, place fill, or perform deep till under the drip line of trees to be saved.

Stripping and removing topsoil is another key aspect of post-construction soil quality problems. Topsoil contains the organic matter that is the key to soils being able to absorb water. High organic matter gives soils the ability to absorb water like a sponge. Low organic matter content means soils will be able to absorb less rainfall before runoff is generated. Topsoil should be stripped, stockpiled and returned as part of final grading. Topsoil will typically need to be amended with compost to achieve the desired organic matter content of 5-10%.

Healthy topsoil also harbors microbes that breakdown many of the pollutants transported by stormwater runoff. Replacing topsoil in post-construction and supplementing it with compost to achieve a healthy population of soil microbes is a necessary component of soil quality restoration. If topsoil is not available, compost can be substituted at the rate of 1 inch of compost for 3 inches of topsoil (see compost blanket standards in Chapter 7).

Where land-disturbing activities can not be avoided, deep tillage should be performed as part of the final grading. Tillage should be done to a depth specified in the soil management plan. Tillage should be specified to ensure that landscapes have at least enough porosity to absorb the WQv. Generally, the depth of tillage needed will relate to the amount of green space on a site. Rules of thumb for tillage depth are:

- 70% green space: 6-inch depth of tillage
- 50% green space: 8-inch depth of tillage
- 30% green space: 12-inch depth of tillage
- 20% green space: 18-inch depth of tillage

If compost-amended topsoil will be spread after tillage, depth of tillage may be reduced by the amount of topsoil to be placed; but compacted soils should always be tilled to a minimum depth of 4 inches before the addition of topsoil. Apply at least 1 inch of coarse compost (3/4” to 1 inch) and incorporate with deep tillage to help prevent re-consolidation of tilled soil. Do not re-compact the site while top dressing or placing a compost blanket. Use low ground-contact pressure equipment for the spreading of topsoil and/or compost.

Perform deep tillage when soil moisture conditions are optimum. Optimum conditions are when soil moisture content is ~ 40%. Do not use rotary tillage, as this breaks down soil structure, kills worms, and creates small pore spaces that can re-consolidate. Use ripping tillage tools for deep tillage.

Apply compost as specified in the soil management plan to achieve at least 5% organic matter content. Applying some compost before deep tillage is a good way to get some organic matter into the soil profile, but earthworms will move organic matter down into the profile with time. Apply at least a 2-inch compost blanket in conjunction with seeding to provide rapid germination and establishment of vegetative cover. A 2-inch compost blanket will provide erosion control until the site is stabilized by vegetation and will typically achieve at least 5% organic matter content.

Incorporate strategic use of native landscaping and direct impervious surface runoff toward areas with restored soil quality and native landscaping.

F. Design procedures

1. Review grading, landscaping, and soil management plans to ensure soil quality restoration is included as needed.

2. Determine existing soil conditions (bulk density, moisture content, organic matter content).

3. Determine depth and type of tillage needed to achieve 40% minimum pore space to the specified depth.

4. Calculate amount of compost amendment needed

G. Inspection and maintenance requirements

Monitor the site after rainfall events to ensure no erosion is occurring. Monitor weekly and after rains of 0.5 inches until vegetation is well established.

Long-term maintenance involves maintaining organic matter content. Do not remove lawn clippings. Leave clippings on the yard to decompose and recycle nutrients and organic matter. Annual applications of ¼ to ½ inches of compost will maintain or increase organic matter.

If earthworms are not present, inoculate the green space with worms in conjunction with a compost application.

H. Design example

1. **Calculating pore space/available storage in tilled soil profiles.** These calculations assume impervious surfaces will have a runoff coefficient of 1, or 100% runoff onto green space.

    a. **Example 1:**
    1) 30% impervious and 70% green space (6-inch depth of tillage)
    2) One acre = 43,560 sq ft. x 70% green space = 30,492 sq ft of green space
    3) Available storage: 30,492 sq ft x 0.5 ft (6-inch) depth of tillage x 0.4 (40% pore space) = 6,098 cu ft of pore space in 6 inches of tilled soil profile
    4) Required pore space for WQv: (4,538 cu ft – same for all examples). 27,152 gals/ac/1 inch of rain. 27,152 x 1.25 inch (WQv) = 33,940 gals x 0.1337 cu ft per gal = 4,538 cu ft of pore space needed vs. 6,098 cu ft of available pore space.

    b. **Example 2:**
    1) 50% impervious and 50% green space (8” depth of tillage)
    2) One acre = 43,560 sq ft. x 50% green space = 21,780 sq ft of green space
    3) Available storage: 21,780 sq ft x 0.67 ft (8 in) depth of tillage x 0.4 (40% pore space) = 5,837 cu ft of pore space in 8 inches of tilled soil profile.
    4) Required pore space for WQv: 4,538 cu ft needed vs. 5,837 cu ft of available pore space.

c. **Example 3:**
   1) 70% impervious and 30% green space (12-in depth of tillage)
   2) One acre = 43,560 sq ft. x 30% green space = 13, 068 sq ft of green space
   3) Available storage: 13,068 sq ft x 1 ft (12-in) depth of tillage x 0.4 (40% pore space) = 5,227 cu ft of pore space in 12 inches of tilled soil profile.
   4) Required pore space for WQv: 4,538 cu ft needed vs. 5,227 cu ft of available pore space.

d. **Example 4:**
   1) 80% impervious and 20% green space (18-in depth of tillage)
   2) One acre = 43,560 sq ft x 20% green space = 8,712 cu ft of green space
   3) Available storage: 8,712 sq ft x 1.5 ft depth of tillage x 40% pore space = 13,068 cu ft of storage in pore space in 1.5 foot of tilled soil profile.
   4) Required pore space for WQv: 4,538 cu ft needed vs. 5,227 cu ft of available pore space.

2. **Equation for calculating compost application rates.** To achieve a target soil organic matter content, the following equation can be used to calculate compost application rates**:**

$$CR = Dx\frac{[SBD(SOM\% - FOM\%)]}{[SBD(SOM\% - FOM\%) - CBD(COM\% - FOM\%)}$$

where:
CR = Compost application rate (inches)
D = Depth of incorporation (inches)
SBD = Soil bulk density (lb/cubic yard dry weight)
SOM% = Initial soil organic matter (%)
FOM% = Final target soil organic matter (%)
CBD = Compost bulk density (lb/cubic yard dry weight)
COM% = Compost organic matter (%)

Source: Technical Memo for Puget Sound Stormwater BMP Manual
http://www.psat.wa.gov/Programs/LID/PSAT_TechMemo3.pdf.

An additional method to achieve a desired organic matter content of about 10% would be to add 1 part compost to 2 parts topsoil (or 25-35% compost amendment by volume). To achieve 5% organic matter content, add 1 part compost to 5 parts topsoil (or about 15-20% compost amendment by volume). These simplified methods assume compost will have an organic matter content of 40-60%.

An Excel compost amendment rate spreadsheet is available for download at http://www.soilsforsalmon.org/resources.htm.