1.4 Soil Restoration

Description

Soil restoration reestablishes pervious area within a development where the soil has been disturbed by clearing, grading, excavation, equipment traffic, or other construction activity. The low potential for stormwater runoff normally associated with developed pervious area as well as its ability to assimilate pollutants in stormwater are the product of healthy soil that both supports and is supported by thriving vegetation. When soil is graded, compacted, or both during construction it loses many of the hydrologic characteristics of pervious area, including ability to support self-sustaining grass lawn and landscaping.

Soil restoration supports the revegetation of developed pervious area and its return to good hydrologic condition by putting in place the components that rebuild soil structure and associated properties. Collectively these properties are termed soil tilth. The soil tilth building process will continue over many years of restorative root activity. This chapter details two levels of soil restoration:

Topsoil replacement – reconstruction of the shallow (12-inch) rooting zone by replacing topsoil removed from the site prior to construction, and

Topsoil replacement with subsoil decompaction – redevelopment of the full soil profile (>24 inches) by alleviating compaction within subsoil prior to replacing topsoil.

The Objective of Soil Restoration: Soil Tilth

Tilth refers to a soil's suitability to support plant growth, or more specifically to support root growth. Topsoil with good tilth is often said to be loose, friable, and well granulated. These soils are composed of small crumbs or aggregates of silt and clay particles. Larger clumps may form from the smaller crumbs. Various size pores form between the various size soil aggregates to create vital pathways for roots, water, and air. Micropores retain water for plant use, while larger pores drain excess water. This porosity extends into the subsoil structure, although more blocky than crumb-like, to allow deep roots to access moisture during droughts.

Plant root growth, earthworms, and other soil biota naturally build stable aggregated soil structure while contributing organic matter to the soil. Organic matter gives strength to aggregated soil by bonding the aggregates together, retains moisture, and enriches the soil with nutrients. Aggregate soil structure formed by tillage without the support of organic matter is unstable and may collapse with saturation.

In addition to providing a healthy rooting environment for good plant cover, soil with stable aggregated structure and good organic matter content, in other words good soil tilth, also abstracts rainwater through storage and infiltration. Natural pervious areas of woods, brush, meadow, or pasture credited with a low runoff potential comprise undisturbed soil and healthy vegetation. This may not be the case for developed pervious areas that have been subject to construction disturbance. Land grading and equipment operation apply loads that destroy tilth by compressing soil into a dense, massive structure with little or no pore space, often deep into the subsoil, and usually after organic rich topsoil has been scraped off. With the at-grade soil lacking the structure for root growth and rainwater infiltration, grass and plants will be unable to restore deep soil tilth through vigorous root growth and decay. Lawn and landscaping will instead rely on a thin layer of sod soil or plant root balls supplemented with costly fertilization and irrigation to survive, producing more runoff and surface ponding than the designer planned or landowner expected.

The objective of soil restoration is not to alter the land's soil type but to initiate the physical conditions that re-establish the interdependent relationship between the in-situ soil, vegetation, and hydrology or more simply, to build soil tilth.

Planning and Feasibility

Soil Resource Management Planning

Healthy soil is a finite resource and therefore has quantifiable value. Good management of on-site soil resources maximizes that value but requires planning. Some projects may warrant a separate plan addressing soil resources while the Stormwater Pollution Prevention Plan (SWP3) will work for many, but in all cases it must be integrated into construction plans and documents. The following steps outline the keys to making the best use of on-site soil resources and maximizing their value.

(1) Inventory the soil resources of a site prior to design. Conduct field studies (soil borings, soil test pits, and percolation tests) in addition to reviewing soil survey publications to determine soil characteristics that may guide design decisions, including how stormwater management will be approached.

(2) Plan a site layout and set a limit of disturbance (LOD) that preserves high-quality soil in place as much as possible. Identify and specify measures to protect preserved soil in the construction plans.

(3) Specify topsoil removal where construction documents address clearing and grading. Include the depth of topsoil to be removed, a location to stockpiling topsoil, and temporary stabilization measures for stockpiles.

(4) Specify measures to limit compaction during construction. This will result in less effort and cost to restore soil function. Limit grading and earthmoving operations to low soil moisture conditions; moisture lubricates soil particles such that compaction increases as soil approaches field capacity. Require traffic control measures to limit soil compaction from equipment movement to locations that will eventually be paved and may benefit from compaction.

(5) In the grading and landscaping plans, specify restoration methods described in this chapter for disturbed soil. Include instructions to quickly establish a permanent vegetative cover. Require a temporary vegetative cover where necessary.

(6) Specify and quantify the materials (for example, compost) necessary to complete the work and incorporate them into the overall materials list and bid documents for cost planning.

Soil Preservation

Stable aggregated soil forms over hundreds or thousands of years through weathering, freeze-thaw cycles, and the action of plant roots and other organisms that simply cannot be replicated by restoration work. Preserving soil in place by protecting it from construction disturbance preserves the extensive hydrologic function (for example, retention and infiltration of rainwater for ground water recharge and stream base flow) that naturally built soil provides, which will often result in better overall site drainage.

Preserve soil by clearly showing the LOD both in the construction documents and physically at the site. Specify highly visible LOD barriers and signs be in place prior to site clearing and throughout construction. Protect the roots of all existing trees or wooded areas to be kept with fence placed a distance equal to 1.5 times the radius of the drip line.

Estimating Runoff from Construction Compacted Soils

Designers must consider the post-construction soil condition of pervious areas to accurately estimate runoff volumes and peak discharge rates to be managed by stormwater infrastructure, including water quality treatment practices. This is particularly important for subdivisions and other developments with a higher proportion of pervious area.

Hydrologic models for estimating runoff assign values to pervious area that may not fully reflect the impact of construction disturbance. For example, composite curve numbers (CN) reported in TR-55 assume urban pervious area is “equivalent to open space in good hydrologic condition” which correlates to “lightly or only occasionally grazed pasture” (USDA, 1986). Studies show this assumption of minor soil disturbance may significantly underpredict runoff volumes and rates from soil subject to construction grading and compaction. Appendix 2.A.5 presents a method to account for construction disturbance by adjusting the Hydrologic Soil Group used to develop the CN.

Similarly, the volumetric runoff coefficient (Rv) equation [Rv = 0.05 x 0.9(i)] used to calculate the water quality volume assigns a minimal runoff coefficient of 0.05 to pervious drainage area. This value also may not fully reflect the negative impact of construction grading and compaction. Table 1.4.1 lists formulas for Rv that better represent graded and/or compacted urban pervious area for designers to consider.

Table 1.4.1 Rv Formula Where Pervious Area is Disturbed Soil (from Battiata)

Hydrologic Soil Group	Rv Formula
A	Rv = 0.15 x 0.9(i)
B	Rv = 0.20 x 0.9(i)
C	Rv = 0.22 x 0.9(i)
D	Rv = 0.25 x 0.9(i)
i equals the impervious ratio or percent impervious divided by 100	

Soil Restoration Timing

The timing of soil restoration is critical to long-term success. Efforts to restore soil structure will be immediately undone if restored soil remains subject to compaction by construction activity or to erosion due to lack of vegetative cover. Plan in a construction schedule to conduct soil restoration work

- after the area will be fully protected from further disturbance throughout construction,
- under soil moisture conditions sufficient to ease tillage, but not excessively wet, and
- when seeding or planting will immediately follow during ideal conditions that ensure rapid establishment (March 15 through June 1 or August 1 through October 15).

Soil restoration in medium or high-density residential developments is best applied to larger contiguous areas along the perimeter or common greenspace that will not be subject to disturbance by later home construction (lot grading, building trades' vehicles and equipment, etc.). Consider reserving a topsoil stockpile for the builder or homeowner to restore soil on individual lots after the home is built.

Design Criteria - Topsoil Replacement

Topsoil replacement develops a dense vegetative cover with a 12-inch deep rooting zone of loamy topsoil over uncompacted subsoil. Use topsoil replacement on any planned pervious area within a development:

- where strictly surficial compaction has occurred due to light construction disturbance,
- where subsoiling is not possible (for example, small or non-contiguous areas, over buried utilities, shallow bedrock, etc.), and/or
- to construct a post-construction stormwater management practice (for example, grass filter strip, etc.) on graded or disturbed soil.

Replacing topsoil on steep slopes may require measures to prevent slippage and erosion, including a permanent cover of deep-rooted vegetation.

A performance specification may result in adequate topsoil replacement, but the current lack of contractor experience with soil restoration work may merit a prescriptive specification.

Performance Specification

The final soil profile to a depth of 12 inches must have penetration resistance less than 200 psi (1.4 MPa) as measured by a cone penetrometer inserted at 0.8 in/s (2 cm/s) under normal soil moisture. The firmed upper eight inches or deeper must meet the specifications listed in Table 1.4.2 for restored topsoil. Perform at least one soil quality and penetration test per 10,000 square feet of restored soil.

Table 1.4.2 Restored Topsoil Specifications

USDA Soil Texture Classification	Loam, silt loam or sandy loam
Clay Content	less than 25%
Organic Matter Content	greater than 5 percent by weight as determined by loss-on-ignition or equivalent test
pH	6.0 to 8.0, or shall match pH of the subsoil
Dry Bulk Density (Settled)	g/cm^3 (lb/ft^3)
- Silt Loam	1.20 to 1.35 (75.0 – 85.0)
- Loam	1.25 to 1.40 (78.0 – 87.5)
- Sandy Loam	1.30 to 1.45 (81.0 – 90.5)

Construction Sequence for Topsoil Replacement

(1) Prior to grading, remove in-situ topsoil to the depth specified in the construction plans. Avoid over-excavation that mixes heavy subsoil with the excavated topsoil. Reserve the removed topsoil in a stockpile location shown on the construction plans where it will not interfere with construction activity and is distanced from surface waters. Install sediment control measures around the topsoil stockpile and, if construction will extend beyond 21 days, temporarily seed or cover the stockpile.

(2) When the area to be restored can be protected from further disturbance but before replacing the stockpiled topsoil, loosen the at-grade soil to a depth of six inches with at least two perpendicular passes of a chisel plow or ripper attachment. This step is critical. Placing topsoil directly onto smooth graded soil can stratify the soil, creating a perched saturation zone in the topsoil. This condition will stress vegetation and may result in excessive surface ponding. Tillage opens the graded soil so that water will drain through the full soil profile. Additionally, it roughens the at-grade soil to prevent the replaced topsoil from slipping. Locate underground utilities and the root zone of preserved trees prior to tilling.

(3) Spread topsoil to a minimum total depth of six inches over the loose subsoil using lightweight, tracked equipment. To achieve the desired organic matter content, amend the replaced topsoil. Place a one-inch (three cubic yard per 1,000 square feet) layer of compost (see specification) over the topsoil and rototill to a depth of six to eight inches until fully mixed. The final surface may be lightly firmed or leveled as necessary to achieve grade and a proper seed bed. A spading machine (discussed below) may be more effective at loosening and mixing soil in less passes combining steps 2 and 3.

(4) Immediately seed or plant the restored area with vegetation appropriate for its land use, the regional climate, and local site conditions (for example, full or partial sun). Reference chapter 7 for guidance on stabilizing soil with permanent vegetation. Use biodegradable erosion control blankets or mulch to protect the bare soil from erosion and ensure rapid seed germination. A vegetative cover is considered established when both (1) plants can no longer be pulled free from the soil by hand; and (2) 90 percent cover is achieved. Install sediment control measures such as silt fence on the restored area as necessary.

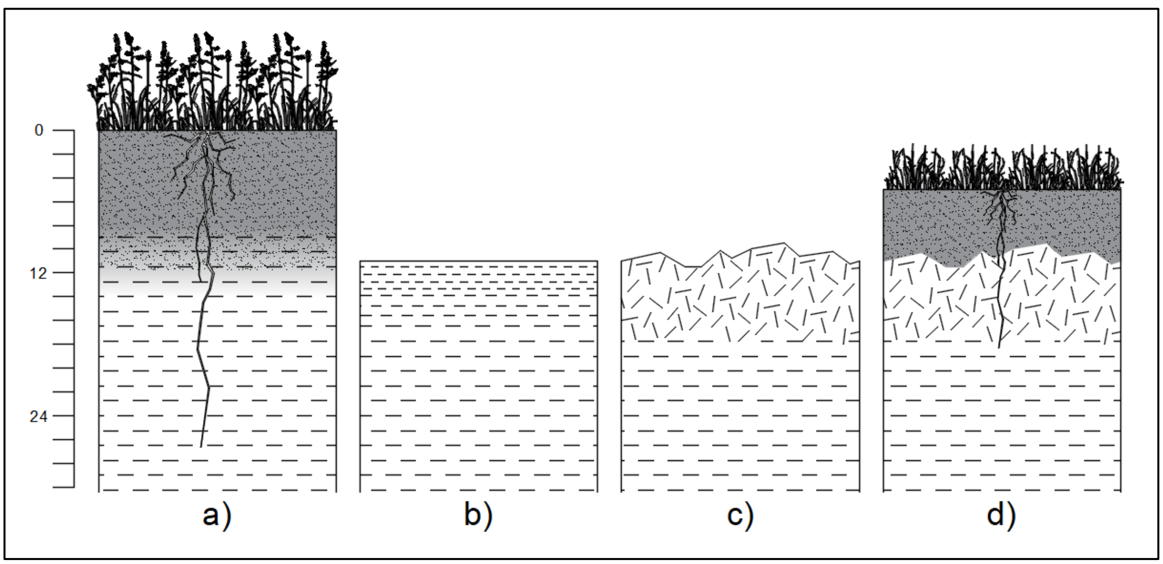

Figure 1.4.1 Illustration of Topsoil Replacement Steps: a) Original Soil Profile; b) Disturbed Subsoil After Removing Topsoil; c) Loosened In-Situ Subsoil; d) Final Grade Achieved with Topsoil Replaced and Stabilized with Grass

Spading Machine

An articulating spading machine may be a more efficient and effective tillage implement for replacing topsoil. Spading machines demand less pulling horsepower than other implements but do require a power take off (PTO) shaft. The action of an appropriately sized spading machine can loosen and mix soil, combining steps 2 and 3 above. A rotary spading machine is not recommended due to potential soil inversion as well as smearing at the plow line.

In-situ Topsoil

Topsoil, the A soil horizon in soil science terms, is the upper layer of loose and crumbly mineral soil where plants concentrate most of their roots. Topsoil is darker than the lower subsoil horizons due to the accumulation of humified organic matter within the mineral soil. All topsoil is not the same. Because topsoil forms from the parent subsoil below, characteristics such as clay content and pH may differ from location to location in the same way soil types and profiles vary. The depth of topsoil can vary from less than four inches in weakly formed or disturbed (farmed) soil to greater than 12 inches in the highest-quality soil.

Soil survey publications offer general guidance on typical topsoil depth by soil type. However, farming practices and other pre-construction disturbance could substantially reduce the depth or alter the quality of topsoil reported. A qualified person should conduct a field assessment to 1) locate high-quality topsoil to preserve in place and 2) decide the depths and areas of in-situ topsoil available to remove and reserve for soil restoration.

Compost Specification

Amending soil with composted organic material improves soil drainage and supplies nutrients for soil organisms and plants until the cycle of growth and decomposition can naturally build soil organic matter.

The term compost is often applied to a range of organic material so it must be specified in detail in the construction plans. **Compost used as a soil amendment shall be very mature and stable.** It shall be well aged, no longer resembling the parent material. Immature compost may contain phytotoxic compounds that inhibit plant growth and may leach nutrients. Compost shall be free of objectionable odors or content. Raw manure shall not be substituted as compost. Table 1.4.3 defines a material specification for compost as a soil amendment. The product shall be certified through the U.S. Composting Council's Seal of Testing Assurance Program and originate from an Ohio EPA Class IV composting facility.

Table 1.4.3 Material Specification for Organic Compost as a Soil Amendment

Gradation	100% passing ½ inch screen
Organic Matter Content	30 to 65 percent (dry weight basis)
Moisture Content	30 to 60 percent (wet weight basis)
pH	5.5 to 8.5
Maturity	Greater than 80 percent seed emergence and seed vigor relative to positive control or Solvita® Index Value between 7 and 8
Stability	Less than 8 mg CO2-C/g-OM/day
Carbon to Nitrogen Ratio	Less than 25:1
Soluble Salt Content	Less than 10 mmhos/cm
Chemical Contaminants	Meet or exceed US EPA Class A standard, 40 CFR §503.13, Tables 1 and 3 levels
Biological Contaminants (seeds, pathogens)	Meet or exceed US EPA Class A standards, 40 CFR §503.32(a) levels
Physical Contaminants (plastic, concrete, ceramics, metal, and other inert materials)	Less than 1 percent (dry weight basis)

Design Criteria - Topsoil Replacement with Subsoil Decompaction

Compaction associated with construction activity can extend 12 to 24 inches or more below the soil surface. The lack of natural restorative processes (for example, freeze/thaw cycle, root growth) at this depth can result in a permanent loss in hydraulic function that is not easy to restore. Subsoiling (also referred to as ripping or deep tillage) can alleviate deep compaction. Subsoiling in conjunction with topsoil replacement restores hydraulic function to the full soil profile. Use topsoil replacement with subsoil decompaction:

- on graded or compacted pervious areas in the development,
- to redevelop pervious area on soil that previously supported pavement or structures, and/or
- to construct a post-construction stormwater management practice (grass filter strip, etc.) on graded or disturbed soil.

Soil Conditions for Subsoiling

Subsoiling increases rooting depth and soil drainage by applying an upward force that shatters the compacted soil above it. Soil must be dry through the subsoiling depth to ensure the implement fractures the soil rather than compresses it. The travel speed affects the performance and should be evaluated and adjusted as the work proceeds.

Subsoiling Implements

Use a commercially manufactured solid-shank subsoiler with winged tips designed to fracture the soil laterally and vertically to a depth of at least 24 inches. Common tillage tools (disk, chisel plow, etc.) are too short and not built to be pulled through densely compacted soil. Either a heavy-duty, agricultural grade subsoiler with in-line shanks or a multi-shank ripper with winged tips affixed to a large bulldozer is recommended. Agricultural paraplows and V-rippers may be effective if they have sufficient depth. Shank spacing will depend upon the type of implement used but should not exceed one and a half (1.5) times the working depth.

Figure 1.4.2 Shanks on a Subsoiler (from NRCS)

Depth

The subsoiler shanks work by lifting soil and should reach just below the depth of compaction. Subsoil to a minimum depth of 18 inches below the surface. Deeper tillage may be necessary if post-grading field tests (penetrometer or borings) indicate compaction exceeds 18 inches.

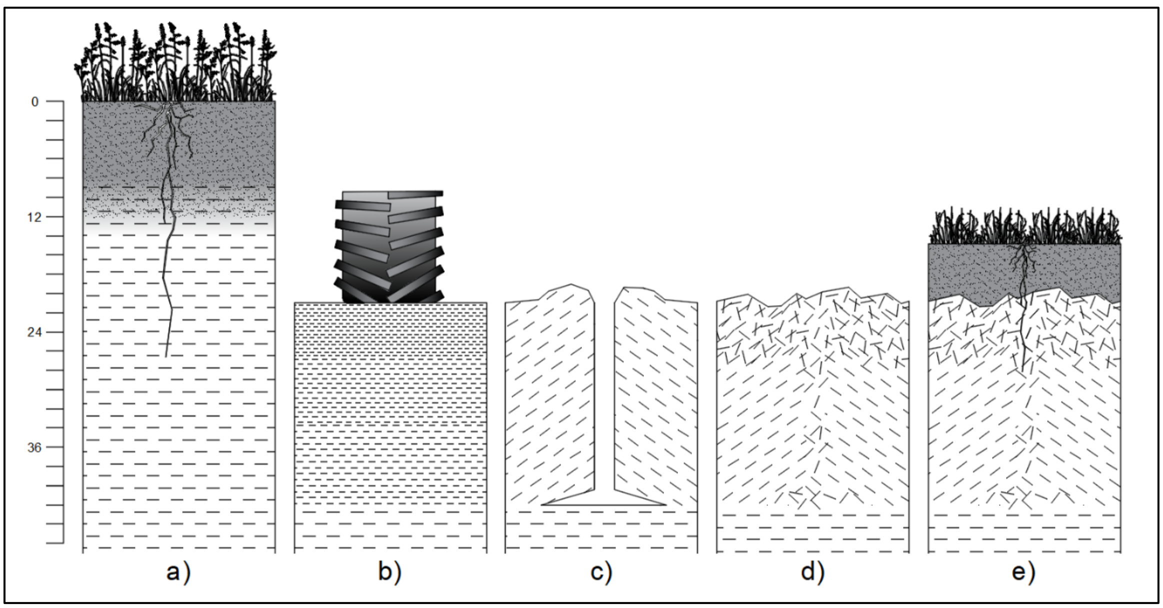

Figure 1.4.3 Illustration of Topsoil Replacement with Subsoil Decompaction Steps: a) Original Soil Profile; b) Compacted Subsoil After Removing Topsoil; c) Decompaction by Subsoiling; d) Loosened In-Situ Subsoil; e) Final Grade Achieved with Topsoil Replaced and Stabilized with Grass

Construction Sequence for Topsoil Replacement with Subsoil Decompaction

Accomplish topsoil replacement with decompaction through the following steps.

(1) Prior to grading, remove in-situ topsoil to the depth specified in the construction plans. Avoid over-excavation that mixes heavy subsoil with the excavated topsoil. Reserve the removed topsoil in a stockpile location shown on the construction plans where it will not interfere with construction activity and is distanced from surface waters. Install sediment control measures around the topsoil stockpile and, if construction will extend beyond

21 days, temporarily seed or cover the stockpile.

(2) When the area to be restored can be protected from further disturbance but before replacing the stockpiled topsoil, shatter the soil to a minimum depth of 18 inches with a subsoiler implement. Form a two-dimensional grid of deep-ripped channels with one of the directions following the contour. For slopes steeper than 4:1, a single subsoiling pass along the contour is recommended. Locate underground utilities and the root zone of preserved trees prior to subsoiling.

(3) Loosen the at-grade soil to a depth of six inches with at least two perpendicular passes of a chisel plow or ripper attachment. This step is critical. Placing topsoil directly onto smooth graded soil can stratify the soil, creating a perched saturation zone in the topsoil. This condition will stress vegetation and may result in excessive surface ponding. Tillage opens the graded soil so that water will drain through the full soil profile. Additionally, it roughens the at-grade soil to prevent the replaced topsoil from slipping.

(4) Spread topsoil to a minimum total depth of six inches over the loose subsoil using lightweight, tracked equipment. To achieve the desired organic matter content, amend the replaced topsoil. Place a one-inch (three cubic yard per 1,000 square feet) layer of compost (see specification) over the topsoil and rototill to a depth of six to eight inches until fully mixed. The final surface may be lightly firmed or leveled as necessary to achieve grade and a proper seed bed. A spading machine may be more effective at loosening and mixing soil in less passes combining steps 3 and 4.

(5) Immediately seed or plant the restored area with vegetation appropriate for its land use, the regional climate, and local site conditions (for example, full or partial sun). Reference chapter 7 for guidance on stabilizing soil with permanent vegetation. Use biodegradable erosion control blankets or mulch to protect the bare soil from erosion and ensure rapid seed germination. A vegetative cover is considered established when both (1) plants can no longer be pulled free from the soil by hand; and (2) 90 percent cover is achieved. Install sediment control measures such as silt fence on the restored area as necessary.

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