# 700
# Soil and Soil Amendments

## General

With increased focus on stormwater in Washington and new understanding of the role of soils in the mitigation of water quality and quantity, engineered soil and soil amendments have become an important stormwater Best Management Practice (BMP). Topsoil is a biologically active system of minerals, organic matter, air, water, and microorganisms that can take thousands of years to develop. Topsoil nourishes and provides structural support for plant roots and absorbs and cleans water. This chapter focuses on for the use of soil and compost for roadside projects.

Much of the roadside environment is reduced to subsoil at the surface following a typical roadway construction project. Subsoil has little or no organic matter, few pore spaces, and few microorganisms. While the mineral component of soil provides structural support for roads and bridges, climax vegetation cannot grow in this environment, thus we see nitrogen fixing pioneer species like red alder, and exotic plants including Scotch broom and Himalaya blackberry, colonizing construction sites. The resulting community of native and exotic, invasive plants can require costly maintenance and time consuming management. The job of reconstructing a functioning soil community is difficult and costly, and might not be achievable in some areas.

It is necessary to have healthy soil to revegetate a site. Revegetation is necessary to provide slope stabilization, erosion control, biofiltration and infiltration for water quality, screening, local climate modification, habitat, and so forth. Revegetation might also be necessary to meet permit or environmental requirements. As a result, healthy topsoil is an important component of a construction project.

Plant life and water absorption capability require similar soil conditions: loose, friable soil with the right balance of organic matter, microorganisms, and minerals. In contrast, roadway construction requires highly compacted soils with low organic matter content for stability. WSDOT requires that soils for road foundations are compacted to 95% density. Plants require that soils have a density of less than 80%. This density complication poses a challenge in all phases of roadside revegetation management.

## References

*Highway Runoff Manual* M 31-16

Revisions to Highway Runoff Manual: http://wwwi.wsdot.wa.gov/eesc/environmental/Stormwater/HRMRevision.htm

*Construction Manual* M 41-01

*Design Manual* M 22-01

*Roadside Classification Plan* M 25-31

*Standard Specifications for Road, Bridge and Municipal Construction* M 41-10

## Resources

The region's Landscape Architect

The region's Environmental Office

Headquarters Maintenance & Operations Program (HQ M&OP) Materials Lab

HQ Design Office Roadside and Site Development Unit

## Definitions

***biosolids*** Treated wastewater residuals or solids used as a soil amendment.

***clay*** Mineral soil particles with a diameter of less than 0.002 millimeter. A fine-grained soil that has a high plasticity index in relation to liquid limits.[1]

***climax vegetation*** Relatively stable vegetation in equilibrium with its environment and with good reproduction of the dominant plants.[2]

***compost*** Stable, mature, decomposed organic solid waste that is the result of the accelerated, aerobic biodegradation and stabilization under controlled conditions. The result has a uniform, dark, soil-like appearance.

***humus*** Decomposed organic matter that remains once visible plant structure can no longer be determined.

***leaching*** The removal of materials ($CaCO_3$, $MgCO_3$, and other more soluble materials) in solution from the soil.

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[1] Donahue, Roy L., John C. Shickluna, and Lynn S. Robertson, *Soils: An Introduction to Soils and Plant Growth*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1971, p. 509.
[2] Ibid, p. 510.

***loam*** A soil texture class that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.[3]

***microorganisms*** Forms of life that are either too small to be seen with the unaided eye, or are barely discernible.[4]

***mottling*** Soils irregularly marked with spots of color. The presence of orange mottling usually indicates soils that have been though periods of saturation interspersed with periods where the soil had dried out.

***pioneer species*** Fast growing plants that are quick to establish on poor soils. Nodules on their roots fix nitrogen giving them a competitive edge in disturbed soil environments.

***pore space*** Total space not occupied by soil particles in a bulk volume of soil, commonly expressed as a percentage.[5]

***ripping*** Deep scarification using specialized equipment, usually done on compacted soils to increase pore space and improve soil structure for plant growth and infiltration of surface water.

***sand*** A mineral soil particle between 0.05 and 2.0 mm in diameter. A soil textural class.[6]

***silt*** A mineral soil separate consisting of particles of 0.002 and 0.05 mm in diameter. A soil textural class.[7]

***soil*** The unconsolidated mineral and organic matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro and microorganisms, and topography, all acting over a period of time and producing a product – soil – that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.[8]

***soil horizons*** Layers of soil approximately parallel to the land's surface and differing from underlying or overlying layers in physical, chemical, and biological properties or characteristics, such as color, structure, texture, consistency, amount of organic matter, and degree of acidity or alkalinity.[9]. The "O Horizon" is the organic layer. The "A Horizon" is a mineral layer forming at or adjacent to the surface, in which humus is accumulated. The "B Horizon" is a mineral layer comprised of fine grained soils that have been leached.

[3] Ibid, p. 536.
[4] Ibid, p. 538.
[5] Ibid, p. 546.
[6]Donahue, et al., p. 550.
[7] Ibid, p. 552.
[8] Ibid, p. 553.
[9] Ibid, p. 558.

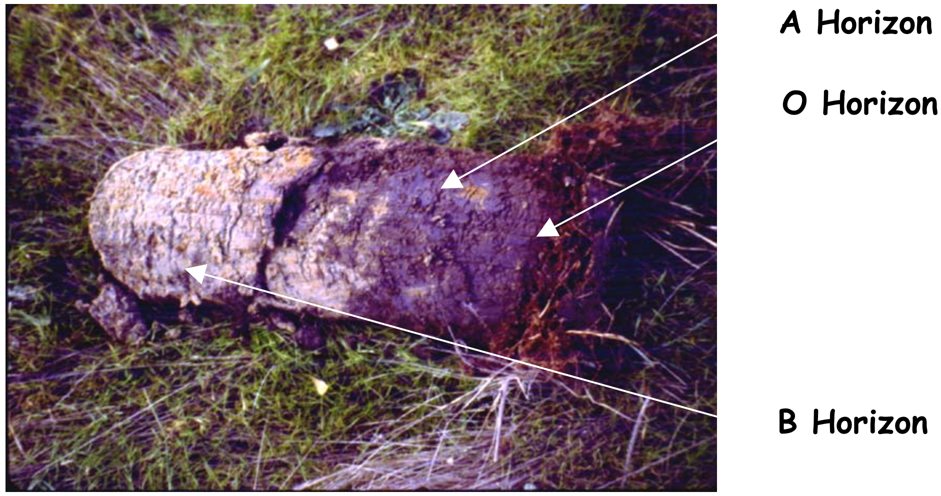


**Figure 700.1 Soil Horizons**

***soil organic matter*** The fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms.[10]

***soil structure*** The combination or arrangement of primary soil particles into secondary particles or units. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades respectively. Examples are: platy, prismatic, columnar, blocky, granular, and crumb.[11]

***subsoil*** The soil layers below the A Horizon that contain little or no organic matter.

***tilth*** The physical condition of soil as related to its ease of tillage, fitness as a seedbed, and ease of seedling emergence and root penetration.[12]

***topsoil*** The original or present, dark-colored (A Horizon), upper soil that ranges from a few millimeters to a meter thick at different locations.[13]

***unsuitable soils*** Generally organic soils that are not appropriate for engineering functions. These soils might be ideal for roadside restoration and revegetation functions.

[10] Ibid, p. 561.
[11] Ibid, p. 561.
[12] Ibid, p. 570.
[13] Ibid, p. 570.

## Structure and Disturbance

The ideal soil for most plants is approximately 50% solid and 50% pore space. The solid component contains minerals and organic matter. Ideally, pore space contains roughly equal parts of air and water. Microorganisms (such as fungi) or invertebrates (such as earthworms) are present in a healthy soil and function to process organic matter, recycle nutrients, and nurture plants.

Any disturbance to the soil alters and influences this complex system. Disturbances include construction, fertilizer and pesticide application, soil compaction from foot traffic and equipment use, and altering hydrological patterns through irrigation, grade changes, and stormwater retention. In other words, any management activity on the roadside is a potential disturbance to the soil system. In areas where plant cover is desirable, roadside management activities are selected and timed to minimize harmful disturbances to the soil, and are focused on long-term soil health.

Soil preservation and preparation are necessary to support goals of the *Roadside Classification Plan* (RCP).

The following table lists recommended practices for dealing with soils along the roadside.

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| During the project definition process, determine how and to what extent soils will be affected. Document in the Design File. |
| Minimize the extent of disturbance activities to minimize impacts to soil outside the project's construction limits. |
| Before beginning any earthwork that includes disruption of the soil, note whether the soils in this area are part of a fill slope comprising the roadway prism. If so, work with the Regional Materials Engineer. |
| Mitigate construction-related soil compaction in vegetation restoration areas. |
| Stockpile and reuse native soils where practical. |
| Minimize erosion potential and weed species invasion by establishing a healthy plant cover. |
| Maintain roadside management zones 2 and 3 to stabilize and improve soil tilth and fertility. |

**Figure 700.2 Summary of Recommended Practices**

## Soil Amendments

The decision to use a soil amendment depends upon the existing soil and the desired outcome. Some soil amendments might encourage unwanted exotic vegetation, while the combination of other soil amendments with native soils might favor native vegetation. Check with the region Landscape Architecture Office or the HQ Design Office Roadside & Site Development Unit for recommendations.

### Topsoil

*Topsoil* can be an amendment when only subsoil remains on a site. Commercial topsoil generally consists of mineral soils mechanically combined with organic matter. See the *Standard Specifications* Division 9 for working descriptions of topsoil.

Remove, stockpile, and replace existing topsoil when appropriate. Existing topsoil can have necessary nutrients, organic matter, and microorganisms. The use of existing topsoil onsite can reduce the costs of disposing of excess excavated material. An examination of the site with an inventory of existing vegetation is necessary prior to determining when to use existing topsoil. Stockpiling of topsoil might not be advisable when noxious weeds and their seeds are present. Consult the Landscape Architect for assistance.

Imported topsoil can be used to provide a medium for plant growth when native soil has been removed or is highly disturbed.

### Compost

*Compost* is highly decomposed organic matter that is used to add nutrients and improve soil structure for plant growth. Acceptable compost products originate a minimum of 65 percent by volume from recycled plant waste. A maximum of 35 percent by volume of other approved organic waste and/or biosolids may be substituted for recycled plant waste. Compost should have a Carbon to Nitrogen ratio (C:N) of approximately 30:1.

### Bark or Wood Chip Mulch

*Mulch* shall be bark or wood chip fiber as described in the *Standard Specifications* Division 9. Mulch is used on top of soil and around plants to moderate soil temperature, retain soil moisture, provide a base for desirable fungal colonization, and inhibit weed growth.

### Fertilizer

Commercial fertilizers are labeled to document the content's ratio of Nitrogen (N), Phosphorus (P), and Potassium (K) (Usually listed in order: N-P-K). These are the three main elements associated with plant growth and health. Generally, nitrogen encourages green top growth, while phosphorus and potassium encourage root growth. Fertilizer is applied in various combinations (for example, 20-20-20 or 10-15-5), as determined to be necessary by the results of a soil analysis.

### *Mycorrhizae*

Mycorrhizae are a group of fibrous fungi existing naturally in topsoils that engulf soil particles and pore spaces to absorb water and nutrients in solution and transfer this solution to the roots of plants. In effect, they multiply the plants' root systems many times.

Additional benefits from mycorrhizae may include plant species diversity and improved soil structure. The mycorrhizae applied depend on the species of plant. Check with the Horticulturist or Landscape Architect for assistance.

## Structural Soils

The Urban Horticulture Institute at Cornell University has developed a cost effective structural soil mix that can improve the survivability of street trees in urban environments. This mix might be useful in selected WSDOT projects. The mix is:

- 80% angular stones ¾ to 1 ¼ inch in diameter
- 20% topsoil with organic matter content of 10%
- Soil stabilizer per the manufacturer's specifications
- Potable water – enough to cause soil to coat the stones without having water run off

The angular stones form a skeleton that provides the weight-holding capability for the mix. Specialized compaction tests are not needed with this mix. The water storing polymers bind the stones together and stabilize the soil mix. In addition, this structural soil mix leaves a large volume of rooting space that allows the plants to get oxygen and water. See the Regional or HQ Design Office Landscape Architects for more information.

More information can be found at: http://www.urban-forestry.com/citytrees/v36n3a12.html

## Planning

During the planning process designers and engineers are to consider the following:

- Impacts the proposed construction will have on existing soils.
- Treatment needed to provide adequate soils for restoration of roadside character

### *Procedures*

Determine the extent soils will be impacted. This analysis is performed at the earliest phase of the project. This knowledge will be used to complement design and construction. Consider:

- How the proposed project will affect the existing soil.
- Existing soil compaction and compaction ratios resulting from construction activities.
- Measures to mitigate overly compacted soils, such as ripping the soil.
- Expected treatment levels and soil preparation to accomplish those levels; for example, soil amendments and mulch.

## Design

Activities during the design phase include:

- Soil preservation — plan to stockpile and redistribute existing topsoil within the contract's order of work.
    - Site analysis. Prepare a plant inventory to document predevelopment conditions.
    - Consult with the Landscape Architect prior to considering stockpiling topsoil.
    - Cost savings can be realized by using soils unsuitable for engineering uses (those with high organic content) on roadside projects.
- Determine where to stockpile soil on site.
- Determination of the extent of cut and fill slopes and clearing and grubbing limits.
- Soil analysis (type, compaction, and fertility).
- Specifying topsoil and amendments.
- Matching proposed vegetation with the soil, climate, hydrology,

and anticipated maintenance levels.

The challenge to the roadside designer is to specify the appropriate soil preparation for planting, to prevent soil erosion, and to achieve desired soil structure. Appropriate soil preparation, including possible amendments, is crucial for the success of desirable roadside revegetation.

## *Procedures*

### Site Analysis

- Examine proposed planting areas for any apparent drainage problems. Note any underlying characteristics that might affect drainage (hardpan, compacted subsoil, clay layers, and so forth.). Plan to correct deficiencies or plant appropriate species.
- Analyze soil for susceptibility to erosion from stormwater runoff.
- Determine solar exposure of slopes (slope aspect) and its effect on soil and vegetation.
- Conduct a plant inventory or a germination test to determine seed bank to decide if topsoil stockpiling is practical.

### Soil Testing

Perform a soil test to determine nutrient content and pH of soil.

- Obtain a soil sample bag or a plastic bag capable of holding approximately one quart of soil
- Select a representative area for your sample. If the soil seems to vary in color and composition within the project area, sample those soils also.
- Dig a hole 300 to 460 mm (12 to 18 inches) deep and set the material to the side. Scrape off a small amount of material from the top to the bottom of the side of the hole and place into plastic bag. Do not include any material taken from the hole initially. Refill the hole with the set aside material.
- Locate the test pit on the site map. If more than one sample is taken from the site, number the test pits to correspond with the samples taken.

- Seal the bag tightly and place in a manila envelope and write all the information on the paper surface: your name, date of sampling, site location, and sample identification (such as test pit #1).
- Fill out Soil Test Form and include it with your sample.
- Box or wrap sample for mailing.
- Send the soil sample to a soil chemistry lab listed below.
- Consult with the Landscape Architect for specific amendment recommendations when you get test results, if necessary.

**Soil testing laboratories for soil chemical properties** (call laboratories for forms and pricing information):

**A & L Western Agricultural Laboratories**
10220 SW Nimbus Ave., Bldg K-9
Portland, OR 97223
Phone: 503-968-9225

**Black Laboratories**
503 N. Gardner Rd.
Burlington WA 98233
Phone: 360-757-6112

**Harris Laboratories, Inc.**
621 Rose Street, Box 80837
Lincoln, NE 68501
402-476-2811

**Northwest Agricultural Consultants**
2545 West Falls
Kennewick, WA 99336
Phone: 509-783-7450

**Soil and Plant Laboratory, Inc.**
PO Box 1648
Bellevue, WA 98009-1648
Phone: 425-746-6665

The WSDOT Materials Laboratory does soil testing for engineering properties such as soil strength and gradation. The Regional Materials Engineer can help with soils engineering and related testing.

### Compaction

Appropriate soil treatment is crucial for the success of roadside restoration (including erosion prevention seeding). Analyze the soil for compaction. Pay close attention to areas that have been, or will be, staging areas. These areas will have to be ripped to restore pore spaces between the soil particles. Rip compacted soils, ideally in two directions, to a minimum depth of 460 mm (18 inches) before planting. The roots of most plants are above this depth.

Specify in all contracts that the contractor has the responsibility to restore the soil to a less than 80% density in all staging areas. Higher compaction rates are allowed in areas that are critical for road or structure stability. Include the costs of these procedures as part of the contract. The contract cannot be closed until this step is completed.

Soil compaction can be tested using the bulk density test. Test the soil to a depth of 0.6 m (2 feet). If the density is greater than 80%, take steps to break up the compacted soil. Contact the regional Materials Engineer for assistance.

## *Clearing and Grubbing*

Set clearing and grubbing limits to minimize soil disturbance.

In some areas grubbing is unnecessary. Stumps and root systems may be left in the soil to provide stability. Decomposition of trees varies in time depending upon species and climate. Their decomposition, however, will provide nutrients, organic matter, and habitat for microorganisms.

## *Plans, Specifications, and Estimate (PS&E)*

- Specify soil amendments to achieve revegetation and restoration requirements.
- Specify wide-track construction equipment in contract documents when it is necessary to work in wet soils.
- Where practical, strip topsoil and stockpile for redistribution after completion of rough grading. This is the best source of native seeds but it is also a source of exotic invasive vegetation and noxious weeds. (The plant inventory and germination test performed during the site analysis determine what plants are growing in the soil.)
- Assess the entire project for other places to use removed topsoil. Restoration sites are practical locations to place excess topsoil.

### *Soil Treatment to Enhance Native Plant Growth*

To encourage native woody plant species, the following technique can be employed. Incorporate 3 inches of Compost Type 2 into the top 12 inches of soil. Place 3 inches of bark or wood chip mulch on the surface. Plant through these layers. This is shown in Figure 700.3.

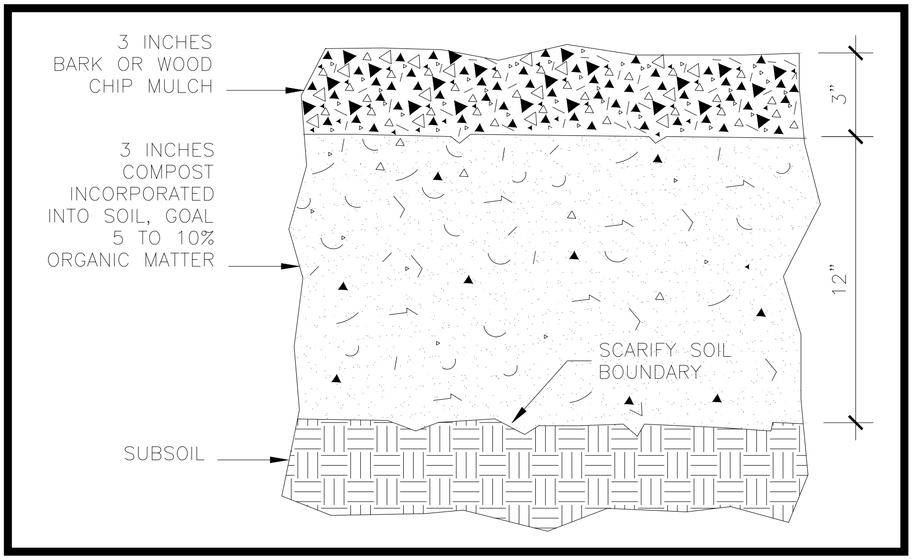


**Figure 700.3 Amendments to encourage native woody plants**

## Construction

The challenge to the Project Manager and the Construction Office is to avoid or minimize damage to the soils resulting from construction activities. Mitigate unavoidable damage to the soil before planting.

### *Procedures*

The following procedures will minimize impacts to topsoil during construction:

- Set limits of work areas for vehicles and equipment to minimize and prevent excessive soil compaction. Use flagging and fencing in conjunction with signs to define work areas.
- Minimize compaction during construction. Avoid heavy machinery use on saturated soil.
- Use wide-track construction equipment.
- Cover staging areas with a 150 mm (6 inch) layer of wood chip mulch to reduce compaction.

- Before specifying or beginning earthwork that includes scarifying the soil, note and document the soils' structural function and performance. This is particularly critical on fill slopes where the soil is compacted to comprise the highway prism.
- Mitigate construction-related soil compaction in vegetation restoration areas by ripping the soil to loosen its structure.
- When stockpiling topsoil, mound soil no higher than 1.3 m (4 feet) high for less than 1 year. Cover to prevent soil erosion and contamination by weeds.
- Use only well composted soil amendments and incorporate them as specified.
- Avoid walking, operating equipment or driving vehicles on planting areas after soil preparation is complete.
- Minimize erosion potential by establishing a healthy plant cover.

## Maintenance

Maintenance activities can greatly affect soil structure in a positive or negative way. A solid plant cover is the best defense against erosion and invasive species. Routine maintenance activities can help build the soil to support vigorous plant growth.

### *Procedures*

- Plants suffer from nutrient deficiencies in the soil. Contact the Landscape Architect for recommendations before amending soil. The Landscape Architect can provide information on appropriate fertilizers or soil amendments.
- Allow organic matter to remain on the ground where it will not jeopardize safety or visual quality. Logs and brushpiles enrich the soil and provide habitat while decomposing. Such decomposition can reduce the need for additional fertilization or soil amendments and reduce maintenance expenditures.
- Fresh wood chips can use up available nitrogen and affect plant growth. To avoid this problem, spread wood chips thinly over a large area or add nitrogen to aid in decomposition.
- Avoid driving vehicles or operating equipment on saturated soil and in vegetated areas.
- Reseed, cover, or mulch bare soils as soon as possible when they have been exposed by maintenance activities or errant vehicles.