Healthy Soils – Part 2: Soil Preservation, Restoration, and Maintenance Practices for Sustainable Landscapes

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With slides from
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Urban Tree + Soils

Based on Healthy Soils Part 1 and Healthy Soils Part 2 by James Urban and David McDonald from ASLA conference Phoenix 9/6/2012, and Soil Improvement for Stormwater, Erosion, & Landscape Success by David McDonald from WSU Low Impact Development course 4/11/2012

www.SoilsforSalmon.org
www.BuildingSoil.org
BMP T5.13 “Post-Construction Soil Quality and Depth”

- Retain native soil and duff wherever possible
- All areas cleared and graded require 8 inch soil depth:
  - Organic matter content \( \geq 10\% \) dry weight (5\% for turf)
  - Use native topsoil, amend existing soil with compost, or import topsoil blend
  - Subsoil scarified 4 inches below 8-inch topsoil layer
  - Protect amended soil from compaction
  - Mulch after planting
  - Maintenance practices to replenish organic content
Guidelines Manual for Implementing BMP T5.13

- Manual developed regionally with experts
- 10% O.M. for landscape beds; 5% for turf
- Develop a “Soil Management Plan” for each site
- **Four options for soil management (can use 1 or more / site):**
  1) Retain undisturbed native soil & vegetation, protect from compaction
  2) Amend existing soil in place with compost
  3) Stockpile topsoil prior to grading, and reuse on site (amend if needed)
  4) Import topsoil meeting organic matter content requirements

- Choose pre-approved or custom calculated amendment rates
- Simple field inspection and verification procedures
- Includes model specs written in CSI and APWA formats
- Available [www.soilsforsalmon.org](http://www.soilsforsalmon.org) or [www.buildingsoil.org](http://www.buildingsoil.org)
Preservation, Restoration, and Maintenance of Healthy Soil

- Preserve Existing Soil
- Reuse Existing Soil
- Modify Existing and Imported Soil

Soil Management Plans

Maintaining Healthy Soils

THE SUSTAINABLE SITES INITIATIVE

GUIDELINES AND PERFORMANCE BENCHMARKS

SITES Benchmarks for sustainability
Designing to Modify Past and Future Soil Disturbance

**Grading**
- Structure
  - Clumps / clods
  - Ped

**Compaction**
- Density
  - Weight / volume
  - Pore space

**Soil mixing**
- Texture
  - Sand / silt
  - Clay

**Reduced Soil Biology**
- Nutrients
  - N P K +
- Salts
- Fertilizer

**Limited air and water movement**
- Water / Drainage
  - Too much / too little

**Acidity**
- Lower organic matter
- pH
  - Higher pH

**Organic matter**
- Carbon

**Soil Disturbance**
- Designing
- To modify
- Past and future
Grading and compaction impacts

- Planting into heavily compacted subsoil
- Thin layer of topsoil
- Deep cut slope
Topsoil over smooth compacted layers causes drainage and root growth problems.

Better: Scarified subsoils

Subsoiling (ripping)
Loss of organic matter

- Plan to preserve existing soil & vegetation where possible
- Minimize grading, cut and fill
- Minimize traffic off road bases
- Even a low-organic subsoil can be substantially restored by amending 10-25% (by volume) with mature, stable compost.
Chemical changes

- pH (sometimes due to compacted, anaerobic conditions)
- Nutrient deficiencies (loss of topsoil)
- Toxins: oil, metals, chemicals

Compost amendment tends to correct all of these

Visually examine and smell, then test for suspected deficiencies, toxins, & pH

Chose well-adapted plants, tolerant of your soil conditions (pH etc.)
Preserve Existing Soil
Protect soil & vegetation during construction

• Fence *vegetation & soil protection zones*
• Inform all contractors & subs: no stockpiles etc.
• If temporary vehicle access required, place steel plates over 6” coarse wood chip.
Reducing soil disturbance

Reduce, simplify paved footprint
Consolidate the planted spaces
Decide early which trees to preserve/protect, or remove
Balance/reduce cut and fill
Control the grading plan

Shallow subsoils (B horizon soils) better than deeper C horizon soils
Contractor laydown/staging in areas that will be disturbed or paved
Fence off areas of good topsoil that don’t have to be to be graded
Restoring Top Soil and Sub Soil in Place
Restoring soil in place

- Place sub-drainage if req’d
- Range of equipment for different-sized sites
- If compacted, rip (scarify) to 12-18” depth before or while amending
- 2-4” compost mixed into upper 8-12” of soil
**English Double Spading**

Topsoil from first row

1. **MECHANICAL COMPACTION REDUCTION METHODS**

Add compost

2. Turn Subsoil

3. Remove topsoil

4. Respread compost

Soil moisture is critical Not to wet or dry

**Machine “Double Spading”**

Step one

compost

Step two

compost

Step 3

Respread topsoil
Subsoiling large site

Subsoiling small site

Trenches filled with compost

SUBSOILING (RIPPING)
Modify Existing and Imported Soil
Defining usable soils

While some of these soils may look terrible they may be just fine after de-compaction and the addition of compost.
Textural limitations

Fine grained soil: Will drain very slowly if over-compacted and/or heavily graded. May become anaerobic.

Coarse grained soils: May “self” compact or are easily compacted. May be too dry.

General ranges of textural limitations

<table>
<thead>
<tr>
<th></th>
<th>Un-screened</th>
<th>Screened</th>
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<tbody>
<tr>
<td>Clay/Silt combine</td>
<td>20-60%</td>
<td>15-45%</td>
</tr>
<tr>
<td>Sand</td>
<td>40-80%</td>
<td>55-85%</td>
</tr>
<tr>
<td>Gravel</td>
<td>10% max</td>
<td>8% max</td>
</tr>
</tbody>
</table>

Organic Matter % dry weight

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Topsoil as harvested</td>
<td>2.5% min</td>
</tr>
<tr>
<td>Subsoil</td>
<td>No practical limitation assuming that compost will be added to increase the OM</td>
</tr>
</tbody>
</table>
Soil harvesting, storage, & re-installation

- Harvest at start of grading
- Store covered with breathable fabric, coarse wood chips, or sterile annual grass to prevent erosion and weeds
- Amend with compost just before re-spreading
- Rip in first lift to avoid sharp soil interfaces (which can limit air and water movement)
- Don’t work soil when saturated
Soil removal / replacement

Soil removal and ped retention

Use big loaders and excavators

Remove soil in big scoops to preserve clumps. Do not screen. Preserve peds!
Soil screening machines......

......produces soil with few soil peds

Maintain more macro pore space with soil ped retention
Soil Installation

Working with soils with retained peds

Constantly loosen soil while installing to avoid buildup of deep compaction. Back drag over loader tracks each time.

Require all equipment to have teeth on bucket to scarify soil.

Require low ground pressure equipment (4 psi preferred - 5 psi max)

Teeth on loader bucket
Soil Installation

**Traditional soil delivery**

Requires more mounding to accommodate settlement.

**Alternative soil delivery**

Lift 1 becomes overly compacted.

Lift 1, Lift 2, Lift 3.
Soil Installation

A/O horizon with added compost tilled into upper soil layer

Added soil to accommodate settlement

Specified soil layer

Specified soil depth

Surface preparation prior to planting

Anticipated settlement

Sand Lawn soils 5% of soil depth
Soil/sand/compost soil mix 10% of soil depth
Loam soil w/ pedds and small amounts of compost 10-15% of soil depth
Change specs to allow a combined rocks, roots, sticks, debris up to 5% or maybe even 10%.

Eliminate “free of’ from your spec.

*Light screening through 2 or 3 inch mesh may be needed on soil with large amounts of debris.*

*Control construction debris and trash by approval of soil source not by screening.*
Amending soil (existing, stockpiled, or imported soil)
Amending soils on site

- Place sub-drainage if req’d
- Range of equipment for different-sized sites
- If compacted, rip (scarify) to 12-18” depth before or while amending
- 2-3” compost mixed into upper 8-12” of soil
Clearing up the confusion about “% Organic Matter”

**Soil Organic Matter** = long term accumulation of living soil organisms and dead organic material in the soil. In natural soils organic matter is completely integrated into smallest soil particles.

“% Soil Organic Matter Content” reported in a lab soil tests is by loss-on-ignition method. Just measures **Carbon % by dry weight**

**Compost and other organic amendments** = material in process from raw dead matter into a more stable form.

Most composts and plant materials are 40-70% organic content by the loss-on-ignition test method.

Organic amendments float in-between clumps of soil. As compost decomposes it feeds soil life, and some is turned by those organisms into long term soil organic matter.
Compost is **added** (amended) into the soil by moist volume. The resulting soil is **tested** by dry weight loss-on-ignition.

Adding 10% compost to a soil does not increase the Soil Organic Matter by 10%. It will raise the **tested SOM** by only 1-3% (depending on the organic content of the compost, and its dry density relative to heavier soil’s density).

% (volume) compost added to mineral soil or soil mix  |  % (dry weight loss-on-ignition) rise in tested Soil Organic Matter
---|---
for trees 10-15%  →  1-3%
for lawns 15-25%  →  3-8%
% (volume) compost added to sand for bioretention soil mix (for stormwater swales)  |  30-40%  →  10%

*Use less compost in clay/fine-textured soils*
Add Compost: Most of it in the top layer of the soil profile – *mimic natural profile!*
Plants and decaying organic matter in soil must respire (bring in oxygen expire carbon)

- Too much compost too deep in the soil profile promotes anaerobic conditions
- Plants will die more quickly with too much water than too little !!!!!
- Add most compost to upper 8-12” of soil
- Rip a little compost into deeper soil when subsoiling – just enough to restart soil biology
Wrong! Hard features on amended soil. 30% compost in landscape soil mix. Soil settlement after 3-4 years.

Right! Hard features based on subsoil. 20% compost into reused soil, with final lift added to meet grades after settling.

Over 15% compost in soil mix increases soil settling.
- Base hard features on subsoil, not amended soil.
- Allow for settling by slightly mounding amended soil, or spreading 1-2 topsoil to meet finish grades.
How can trees grow well when completely covered with paving?

Exudates feed soil life to create soil organic matter. Plants are net contributors to soil organic matter through leaf fall, root shedding, and exudates. This helps maintain healthy OM levels after installation.
How to Select Compost

Know your supplier!

Field tests:
- earthy smell - not sour, stinky, or ammonia
- brown to black color
- uniform particle range
- stable temperature (does not get very hot if re-wetted)
- not powdery or soaking wet

Soil/compost lab test info:
- Nutrients
- Salinity
- pH
- % organic content (OM)

Mfr.-supplied info:
- State permitted composting facility
- Meets US Compost Council (STA) “Seal of Testing Assurance”
- TMECC lab test methods, specs:
  - C:N ratio
  - Weed-seed trials
  - Nutrients, salinity, contaminants
  - Size: “screen”, % fines

Stability /Maturity:
- use Solvita test on-site (> 6)
- rely on mfr’s TMECC tests: CO² evolution and seedling growth
Carbon to Nitrogen ratio of composts

- For turf & most landscapes
  C:N ratio of 20:1 to 25:1 - good nutrient availability for first year of growth (no other fertilizer needed)

- For native plants and trees
  C:N ratio of 30:1 to 35:1, and coarser (1” minus screen)
  - less Nitrogen better for woody natives, discourages weeds
  - for streamside, unlikely to leach nitrogen

Compost feedstocks for tree soil amendment

- Generally, yard waste &/or bark compost
  - Higher carbon, lower nitrogen
  - Maturity / stability very important

- Possibly biosolids, manure fully composted with wood
  - Watch the nutrients, C:N, stability/maturity – caution!
Compost Based Erosion Control BMPs

• EPA-approved BMPs: blankets, berms, and socks
  see www.buildingsoil.org

• “2 for 1” value – use compost for erosion control, then till in at end to restore soil:
  - No disposal costs
  - Faster planting, better growth

• Costs: blankets similar to rolled products, but savings on disposal, plus 2 for 1 benefits

More info at www.BuildingSoil.org
Soil biological additive products

Compost teas – useful in remediation, but just use good compost for soil preparation

Mycorrhizal inoculants – species specific, also in soil from healthy trees

Kelp & other organic additives – match plant nutrient needs – good for micronutrients

Fertilizers – stick with organic sources, match plant needs – compost often supplies most needs for establishment.

*Base fertilization on soil test results!*
Too much Sand?  Too little Sand?
Adding sand to improve drainage

Sand does not mix into surface soil well and is **not advised** unless the soil is a soil mix component and large equipment is used.

Use coarse sand (concrete sand) at quantities where the **medium to coarse sand** in the final mix will exceed 55%. Below that amount you can do more harm than good. Self compacting, and drainage not improved or made worse.
Other soil amendments

Diatomaceous Earth?

Polymer gel?
Soil texture modification

In heavy clay soils:

Gypsum can improve structure which improves drainage

Adding expanded shale (or lava rock) at about 25-30% by volume may increase soil drainage.

Organic matter (compost) opens up micro-structure and improves macro-structure, which improves drainage, aeration, root access, water and nutrient cycling.
What kind of sand?
ASTM C 33 Coarse Concrete Sand – **Not** masonry sand

Fines Modulus Index of between 2.8 and 3.2

River pumped round sand or quarried sharp sand (regional variation)

Calcareous stone vs quartz sand – Can you accept a higher pH?
Soil chemistry & pH modifications

- Match plant selection to site soils, rather than trying to modify chemistry
- Lime as needed for Ca & Mg plant needs
- Sulfur applications only lower pH temporarily

Plant problems? Get a soil test.

Compost buffers pH, acid or alkaline towards optimal 6.3-6.8

Compost increases cation exchange capacity (CEC) = nutrient storage & availability

CATIONS
- calcium
- magnesium
- potassium
- ammonium

ANIONS
- nitrate
- sulfate
- phosphate

\[ \text{CEC} = \text{nutrient storage} \text{ & availability} \]

\[ \text{H}^+ \rightarrow \text{OH}^- \]

\[ \text{decreases pH} \rightarrow \text{increases pH} \]
**pH**

Best option, **pick plants that are pH adaptable.**

pH can be raised easily with lime.

pH can be lowered with sulfur products but.....

Is only temporary and requires continuous re treatment

Long term treatments can create other soil toxicities.
Rationale for less fertilizer for urban trees and landscapes

Not crops – Fruit production or crop yields not required

Sufficient required nutrients available to support plant goals

No yearly harvest/removal of biomass

Slower growth may be a desirable trait

Too much N increases sucking insects and foliar diseases, and annual weeds

Feed the soil, not the plant by mulching and leaving fallen leaves.
Plant problems? Get a soil test.
Soil Toxicity

Explore possible contaminants early in site design
• Involve a local soil expert, and dependable lab
• Know the site’s history
  • Lead, arsenic, chemical, oil tanks, etc.

When to get rid of, cap, or remediate the soil
• Toxic plant nutrients, salts
• Other chemicals toxic to plants
• Chemicals toxic to soil organisms or people

Remediating soil
• Compost amendment reduces heavy metal mobility, toxicity, and breaks down hydrocarbons & most pesticide residues
• Specific microbial remediation for complex chemicals
Soil Management Plans

SECTION 02910
PLANTING SOIL PREPARATION

PART 1 - GENERAL

1.1 SUMMARY
   A. The work in this section includes, but is not limited to, the following:
      1. Mixing and testing of top soil, sand and organic material to create planting mixes.
      2. Installation of planting mix.
      3. Compacting and grading of planting mix.

1.2 RELATED DOCUMENTS AND REFERENCES
   A. Related Sections:
      1. Section 02300 EARTHWORK
      2. Section 02625 - PLANTER DRAINAGE
      3. Section 02810 - IRRIGATION SYSTEM
      4. Section 02930 - EXTERIOR PLANTS
      5. Section 02935 - LAWN
   B. References:
      1. The following references and standards are use herein and shall mean:
         b. USDA: United States Department of Agriculture.

22 January 2007

Hartman-Cox Architects
Create A Soil Management Plan (SMP)

- A scale-drawing identifying areas where each treatment (soil protection or restoration) option will be applied.
- A completed SMP form identifying treatment options, amendment products and calculated application rates for each area.
- Identify a Reference Soil as a guide for planned soil restoration.
Developing a Soil Management Plan

step 1: Identify & map
- Healthy soil areas as “vegetation and soil protection zones”
- Disturbed areas needing different soil restoration treatments
Soil Management Plan

step 2: Compute compost amendment or amended topsoil and mulch needed for each area

This form is in the Building Soil Manual at [www.BuildingSoil.org](http://www.BuildingSoil.org) (see pages 8-13)
Protect soil & vegetation during construction

- Fence *vegetation & soil protection zones*
- Inform all contractors & subs: no stockpiles etc.
- If temporary vehicle access required, place steel plates over 6” coarse wood chip.
step 3:
Communicate SMP vegetation and soil protection zones and restoration plans to all contractors and crews.

Soil and tree preservation are similar, but trees sometimes need extra effort.
Soil Management Plans – real world challenges, schedules, and conflicts

On site storage limitations:
- Space / Time and need or other contractor operations.
- Cost vs environmental benefit

Wet periods and overly moist soil:
- Options for overly tight schedule must be in specification
- Require covered storage (breathable fabric not plastic film)

Contractor / owner resistance to new ideas:
- Education
- Pre bid and preconstruction meetings
- Need to do it a few times with better contractors to convince the hold-out contractors

See http://www.buildingsoil.org/tools/When_to_Amend.pdf
Soil Maintenance

Using mulches after planting and for annual maintenance

BENEFITS:

Mulches limit weed growth, and make weeds that sprout easier to pull or cultivate.

Mulches conserve water, moderate soil temperature, and reduce erosion.

Mulches replenish soil organic matter, enhancing soil biodiversity, structure, and nutrient cycling = increased plant vigor.
Mulching

**WHEN**  After planting, and once every year or two:
- Spring or fall on trees and shrubs to prevent weeds.
- Early summer on gardens.  (Let soil warm up.)
- Fall on beds to prevent erosion and compaction.

**WHERE** Whole beds, paths, 3 ft. or larger ring around trees & shrubs in lawns.

**HOW**  Remove weeds & grass before spreading mulch.  Keep mulch away from plant stems.  Use cardboard weed barrier (not fabric) to control aggressive weeds.
Mulching

WHAT

Woody mulches (arborist wood chips, bark) for woody plants (trees & shrubs).

Non woody mulches (compost, leaves, grass clippings, composted manure or biosolids) for non-woody plants (annuals, perennials, berries, roses).

HOW MUCH

Compost, leaves, sawdust, fine bark, grass clippings: 1-2” deep.

Wood chips or coarse bark: 2-4” deep.
Other Soil Maintenance Practices

• Leave plant litter, recycle fall leaves and chipped prunings into mulch on site.

• Base all fertilizer applications on soil tests (every 1-3 years on most sites). Learn about soil testing at www.puyallup.wsu.edu/soilmgmt/Soils.html. See videos and factsheets on “Collecting a soil sample”, “Determining soil texture by hand”, and “Understanding soil test results”.

• More urban soil remediation & maintenance strategies in Up by Roots by James Urban.
Soil and the Design Process – SITES Benchmarks

*best practices for every project*

**THE SUSTAINABLE SITES INITIATIVE™**

[www.sustainablesites.org](http://www.sustainablesites.org)

SITES™ is a new national rating system for site and landscape development, similar to the LEED™ green building system.
SITES Guidelines = Best soil practices for every project

Site Selection

Prereq’s. 1.1-1.4: Limit Development on Farmland, Protect Floodplain, Wetland and Habitat Functions

Credits 1.5-1.6: Redevelop Degraded Sites, Locate Within Existing Developed Areas

- Protect existing high quality soils
- Select already-impacted sites where possible
- Restore degraded soil and vegetation functions

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Pre-Design Assessment and Planning
Prereq’s 2.1-2.3: Conduct a Pre-Design Site Assessment,
Use an Integrated Design Process,
Designate Vegetation and Soil Protection Zones.

- Visually inspect soil profile (borings)
- Test each different soil area on site
  - bulk density
  - OM
  - pH
  - nutrients
  - CEC
  - salts (EC) in arid zones
- Identify Reference Soils as standards for restoration.
- Involve soil, tree, and plant experts early in design, to identify issues/solutions, and Vegetation and Soil Protection Zones.

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SITES Guidelines = Best soil practices for every project

Site Design – Water

Prereq’s 3.1-3.2: Reduce Irrigation Water Use; Manage Rainfall Onsite

- Preserve and restore soils – the most cost-effective way to reduce irrigation and manage storm water onsite

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Site Design – Soil and Vegetation

Prereq 4.3: Create a Soil Management Plan

Credits 4.4-4.7: Preserve or Restore Existing Healthy Soils and Vegetation

Create a Soil Mgmt. Plan during site design:

- Designate protection (VSPZ) and restoration Zones
- Show soil protection and restoration zones and practices on Soil Mgmt. Plan and in specifications

  - Restore soils compacted, stripped or graded during current project,
  - Look for opportunities to restore previously disturbed soils.
  - Basic restoration is de-compacting (12” min. depth, 18-24 is better) and mixing 10-25% compost by volume into upper 8-12 inches.
  - Minimize grading and soil export/import – just amend site soils with mature compost.
  - Develop soil restoration practices appropriate to the intended vegetation.
  - Provide adequate soil volume strategies for trees

- Plan details and specifications become part of the contract documents

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SITES Guidelines = Best soil practices for every project

Construction
Prereq 7.3 Restore Soils Disturbed by Construction
Credit 7.4 Restore Previously Disturbed Soils
Credit 7.6 Divert reusable vegetation, rocks, and soil from disposal.

Implement your Soil Management Plan:
- Communicate SMP to contractors & subs
- Monitor & enforce Vegetation and Soil Protection Zones, especially tree root zone protections
- Keep construction traffic on road bases: protect site soil
- Manage grading for effective storage and reuse of topsoil
- Consider bringing compost onsite as erosion control cover, then till in per the SMP before planting

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Operations and Maintenance
Prereq 8.1 Plan for Sustainable Site Maintenance
Credit 8.3 Recycle Organic Matter

Create a Landscape Management Plan
• Guides maintenance: IPM, mulching, soil protection and restoration.
• Reuse site organics as mulch, grasscycling or compost, to maintain soil health

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SITES Guidelines = Best soil practices for every project

Education & Performance Monitoring
Prereq 9.1, Credit 9.2
Monitor Site Performance; Develop a Case Study

- Monitor plant health
- Test soils in case of plant problems
- Adaptively manage soil health through mulching, protection from compaction and de-compaction techniques, and organic additions
- Educate maintenance staff, owners & users

www.sustainablesites.org

Up By Roots: Healthy Soils and Trees in the Built Environment
By James Urban, available at Amazon.com

Natural Landscaping: Design, Build, Maintain and other resources at www.buildingsoil.org
Soil Goals and Requirements – *Right plant, right place, right soil!*

**Tree Issues**
- Expected canopy size

**Use Issues**
- Use intensity
- Irrigation or rain harvesting?
- Storm water?
- Lawn?
- Maintenance?
- Food?

**Soil Issues**
- Soil drainage
- Space for roots and trunk flare
- Sufficient soil volume
- Imported soil sources
- Existing soil conditions
- Grading