California Integrated Waste Management Board

June 2007

Contractor's Report

To The Board

Compost Use for Landscape and Environmental Enhancement

Produced Under Contract by:

The Regents of the University of California

California Environmental Protection Agency

For additional copies of this publication, contact:

Integrated Waste Management Board
Public Affairs Office, Publications Clearinghouse (MS–6)
1001 I Street
P.O. Box 4025
Sacramento, CA 95812-4025
www.ciwmb.ca.gov/Publications/
1-800-CA-WASTE (California only) or (916) 341-6306

Publication #442-07-002

Copies of this document originally provided by CIWMB were printed on recycled paper containing 100 percent postconsumer fiber.

Prepared as part of contract number IWM 04073 ($105,000, includes other services).

Table of Contents

Acknowledgments

This report was prepared under contract by The University of California Regents. The author expresses appreciation to the many compost and mulch producers, erosion control specialists, and others that provided assistance and made this project possible. In addition, authors of this manual wish to express appreciation to the US Environmental Protection Agency for the original authorship of large portions of the section on specific uses of compost filter socks, which may be accessed in its entirety at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index. Also, the author expresses appreciation to Filtrexx International, Inc. for photographs on pages 29-39.

Principal Researchers/Authors

Janet Hartin, Environmental Horticulturist
University of California Cooperative Extension

David Crohn, Associate Professor
University of California, Riverside

Contributors

Dan Noble, Executive Director
Association of Compost Producers

Bill Baker, Principal
William Baker and Associates

Greg Balzer, Senior Landscape Architect
California Department of Transportation

Rod Tyler & Britt Faucette, PhD.
Filtrexx International, Inc. www.filtrexx.com

Project Manager

Brian Larimore
California Integrated Waste Management Board

Editor

Yating Campbell
California Integrated Waste Management Board

Executive Summary

A major focus of the California Integrated Waste Management Board (CIWMB) is the sustainable and cost-effective use of millions of tons of compostable organic materials, which comprise approximately 30% of landfill deposits. Recently, CIWMB began a partnership with the California Department of Transportation (Caltrans) to build additional markets to divert an even greater volume of organic resources. Caltrans manages more than 45,000 miles of California's highway and freeway lanes and is a large user of compost statewide in design and maintenance projects. The Composting Council Research and Education Foundation and United States Composting Council estimate that there is a potential market for between 3,350,000 and 6,725,000 cubic yards of compost on Caltrans maintained roadways.

CIWMB and Caltrans have recently studied the role of using various mulch, compost and co-compost materials for erosion control for re-vegetation of potentially erodable roadsides. Delving into the benefits of using compost for erosion control is nothing new to CIWMB. Over the past several years, CIWMB has funded several projects involving mulch applications to prevent and reduce hillside erosion in crops ranging from vineyards to lemon orchards. In 2005, CIWMB and the Association of Compost Producers (ACP) unveiled a demonstration project in Pasadena that showcases the beneficial use of organic products for weed and erosion control using filter socks on a freeway hillside.

Caltrans has been instrumental in funding several other research projects, as well. A Caltrans/UC Davis literature review and research study determined that various types of compost made from municipal yard trimmings and other organic materials make excellent soil amendments for roadside erosion control. The study documented that composts vary considerably in physical and chemical characteristics. More research is needed to explore the vast potential that exists in establishing plant growth with compost on bare erosion-prone soils.

Other examples of successful Caltrans research projects include the *District 7 Erosion Control Pilot Study* (ECPS) that evaluated alternative soil stabilization methods designed to minimize the erosion and transport of sediment from Caltrans rights-of-way to storm drain inlets; the *Vegetation Establishment and Maintenance Study* undertaken to determine the effectiveness of various planting techniques to provide immediate soil surface stability and long-term erosion control utilizing native vegetation; the *Soil Stabilization for Temporary Slopes Field Guide* which provides information to construction staff on the selection of appropriate erosion products and techniques for soil stabilization for temporary slopes at construction sites; the *Historical Vegetation Review and Analysis of Hydroseeding Limitations* project which analyzed over 55 sites in California for erosion control product effectiveness and failures to reduce sediment in stormwater; several *Temporary* and *Permanent Soil Stabilization Pilot Studies*; the *Hydraulic Application Study* which performed laboratory testing to assess the performance of seven hydraulically-applied erosion control products; and, the *Erosion New Technology Review Project* which identified 40 practices and approximately 200 products for potential use and possible field and/or laboratory pilots.

Compost Use for Landscape and Environmental Enhancement is an important component of a comprehensive partnering effort funded by CIWMB**.** It is the intent of its authors and publishers to offer timely, objective, and user-friendly content on: soils; composts and composting; compost uses and specifications; and, cultural inputs for successful landscape plant establishment to the following public and private professionals:

Caltrans *personnel* (as guidance specifying compost use for landscape and environmental applications, particularly regarding stormwater management and erosion control).

Caltrans *landscape and erosion control contractors* (as a personnel training resource and office and field guide regarding the successful use of compost).

Compost *producers, marketers and users* (as an office and field guide to assist in both personnel training and the appropriate application of compost).

Feedback to strengthen and/or clarify topics and concern discussed in this manual by our readership is invited and welcomed. Please direct comments and suggestions to:

Brian Larimore, CIWMB, blarimor@ciwmb.ca.gov, (916) 341-6579

In addition to this manual, other project goals undertaken by the CIWMB/Caltrans project were to develop compost specifications and a compost use index system for use by Caltrans and associated contractors installing and maintaining landscapes and managing stormwater and erosion control roadside projects. Caltrans specifications for composts and compost uses are described in the Appendix to this document.

1. OVERVIEW OF THE MANUAL

1.1 Purpose

Compost Use for Landscape and Environmental Enhancement is intended to provide objective information regarding compost use in landscape plantings and environmental applications to public and private decision makers, purchasers, installers, and other interested parties. Guidance for distinguishing quality compost is included, along with parameters for matching compost products with various uses. Until a few years ago, compost customers could expect little technical guidance from experts beyond the warning, "buyer beware." Fortunately, due to major advances in compost technology and standardization by research scientists and engineers that are currently being implemented by the compost industry, consistently higher quality composts for a wide range of applications are available.

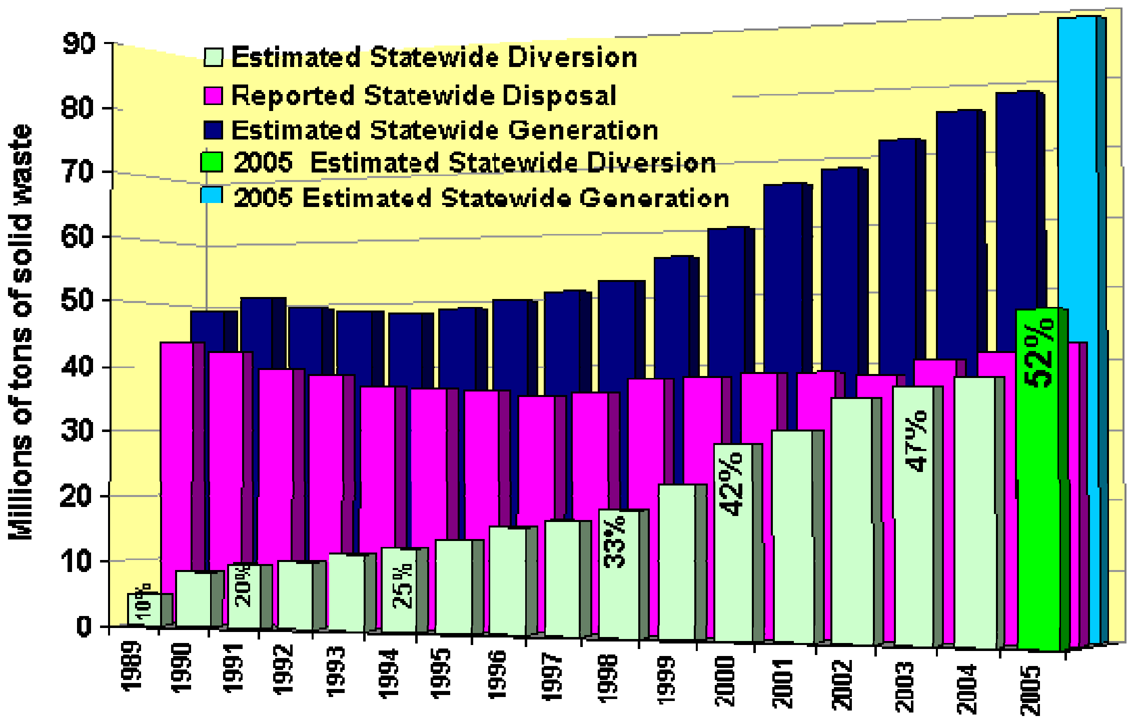
1.2 Introduction

Composting can be traced at least as far back as Marcus Cato, a farmer and statesman from Rome, Italy, who lived over 2,200 years ago. He reported the virtues of compost for enhancing agricultural productivity, stating that all food and animal wastes should be composted and returned to the soil. In the United States, George Washington was an avid composter who designed a building specifically for that purpose on his farm in Mount Vernon, Virginia. By the 19th century, composting was commonly practiced to restore organic matter to soils.

Today, Americans generate more than 240 million tons of trash (municipal solid waste) each year, or 4.5 pounds per person on a daily basis. Of this amount, 72 million tons (31%) is recycled, a number that has been rising steadily as communities work to conserve landfill space. Since 1990, the number of licensed composting facilities operating in the United States today has tripled to over 3,000. Commercial composting processes 17 million tons of yard and food wastes and is responsible for a quarter of the recycling that occurs annually in the United States, as reported in 2005 by the United States Environmental Protection Agency.

Californians generate over 43 million tons of municipal solid waste each year or 6.4 pounds per person per day. Of this amount, 60 percent is collected from businesses and 40 percent from residences. The *California Integrated Waste Management Act* (resulting from Assembly Bill 939, Sher, California Integrated Waste Management Act of 1989) mandates a 25% diversion of organic waste from landfills by cities and counties by 1995 through source reduction, recycling, and composting activities and a 50% diversion by 2000 (based on 1990 levels). Due largely to this legislation, diversion rates have increased dramatically from 11% to 50% between 1989 and 2006.

Table 1. Annual California Waste Disposal, Diversion and Generation



(Source: California Integrated Waste Management Board)

Leaves and grass contribute approximately 1.7 million tons of material each year, or 4.2% of the overall California municipal waste stream. Prunings, trimmings, branches, and stumps contribute more than a million additional tons, so that almost 7 % of the waste stream consists of compostable organic residues derived from landscapes. Composting also provides a means to recycle millions of tons of crop residues, stable bedding materials, manures, food wastes, and other organic materials in a sustainable and environmentally beneficial manner.

Besides conserving landfill space, composting benefits the environment. Composts used as soil amendments add valuable organic matter to the planting bed, and can significantly improve plant growth and development, particularly in depleted or damaged soils. Compost use can also improve water quality. Healthy plant coverage is a critical 'Best Management Practice' for controlling stormwater runoff and reducing soil erosion.

1.3 Important Definitions

Compost is an organic soil conditioner created by decomposing organic matter under controlled conditions until it is stabile enough to improve soils without harming plants or transmitting disease.

Composting is the process of rapidly decomposing organic matter using aerobic (oxygen-using) microorganisms at high temperatures (the active phase) followed by a more gradual decomposition of any remaining by-products at more moderate temperatures (the curing phase).

Organic matter describes the remains of plants, animals, and microbes, as well as humus. It is primarily composed of carbon, oxygen, hydrogen and nitrogen. Examples include:

- Landscape, garden, and agricultural plant remains (herbaceous and woody plants)
- Biosolids (biologically digested and processed human wastewater solids)
- Food scraps (mainly from restaurants and food processing plants)
- Manures (from dairy cows, beef feedlots, chickens, pigs, and horses)

Fertilizer is a single or blended substance containing one or more recognized plant nutrient(s) used to improve plant growth, development and/or yield. Fertilizers alone do not improve the structure of a soil as composts can.

Humus is the relatively stable reservoir of organic matter that remains in a soil after more decomposable plant and animal residues are broken down. Humus usually has a dark color.

Mulch is a protective covering that is spread on the soil surface around plants to reduce evaporation losses, soil erosion, and weed growth, to buffer soil temperatures, and to protect tree trunks from physical injury from lawn mowers and weed whips. Mulches can be organic (leaves, plant trimmings and prunings, peat, wood chips, etc.) or inorganic (plastic sheeting, tire chips, gravel, etc.)

Soil amendments are incorporated into the soil to improve soil physical and chemical properties. They can improve aeration, water penetration, and drainage in heavy soils. In sandy soils, they often enhance the soil water and nutrient holding capacity as well as biological diversity.

Composts are frequently used as mulches and as soil amendments. Note that composts are materials defined by the way they are manufactured and by their physical, chemical, and biological properties. Mulches and soil amendments are defined by their use or purpose. Other materials can also serve as mulches and soil amendments. For example, chipped prunings are often used as uncomposted mulches.

2. Soils Overview

A general understanding of soil formation, chemistry, structure, and textural categories provides important background information helpful for understanding the role that compost can play in improving soils. Indeed, understanding the makeup and function of soil is an important first step in identifying ways in which compost use can improve its physical, chemical, and biological properties, resulting in healthy plant growth, reduced erosion, and water quality protection.

Soils form very slowly over time as a result of the weathering of geological rock formations, and, to a lesser extent, from organic matter originating from plant, animal, and microorganism remains. An inch of soil may take hundreds or thousands of years to develop. A soil that started forming when Leonardo da Vinci finished painting the Mona Lisa and 17 years before Magellan and his crew circumnavigated the earth would be considered brand new today! It is important to understand that less than 5% of the earth's surface can support permanent crops. As populations grow, competition stiffens for dwindling soil reserves. Soil is a precious yet limited resource that can be improved, conserved, and increased through the proper use of compost. The same principles that govern the role of soils in crop production apply to plants that beautify our landscapes and protect soils from eroding onto roads and into nearby washes and streams.

High quality soils possess:

> *Good Physical Properties*: Soil is composed of sand, silt, and clay (singly or in any combination), organic matter and aggregates (associations of smaller particles) of various sizes; and, pore space containing both water and air. Soil structure refers to the nature of the arrangement of primary particles into naturally formed aggregates. Structures are categorized by descriptive names such as granular, bulky, prismatic, columnar, or massive. Soil structure determines the size and continuity of spaces between soil particles which influences permeability and aeration. A sandy soil may lack structure all together, with individual sand grains behaving independently. A compacted clay soil may also be structureless due to the clumping together of particles into massive chunks. Binding clay and/or sand together with organic matter into aggregates is an effective way to add granular structure to soils.
>
> *Adequate Nutrients*: High quality soils contain adequate levels of nitrogen, phosphorus, potassium, and other nutrients required by plants for proper growth and development. Necessary nutrients are often augmented through the application of organic and inorganic fertilizers.
>
> *Healthy Biota*: Soils contain many types of beneficial microorganisms that initiate important chemical transformations. These microorganisms also play active roles in soil fertility. Soil microbes are largely responsible for the decomposition of soil organic matter and nutrient cycling. Mycorrhizae (symbiotic relationships between microorganisms and roots of higher plants) are also important in increasing the availability of mineral nutrients (particularly phosphorus) to plants. Larger organisms, such as earthworms, aid in building soils, as well.

Five major factors are responsible for soil formation:

- Time
- Climate
- Parent material
- Organisms
- Topography

Because soil is a complex mixture of inorganic material (rocks and dust), organic material (plant and animal matter in various states of decomposition) and living organisms, it is a dynamic system that changes in myriad ways over vastly different time scales:

- Rapid changes over minutes or hours may include mechanical cultivation or turning; tunneling by earthworms and other soil fauna, daily changes in temperature, moisture changes from rain, irrigation, or evapotranspiration, and air exchange with the atmosphere.
- Changes over weeks or months may include the breakdown of plant material into soil organic matter, chemical composition and fertility, organisms, and compaction. When plant materials are introduced into the soil, bacteria, fungi, and insects can rapidly decompose the sugars, fats, waxes, and proteins that they contain. Other plant materials, such as cellulose and lignin, are broken down more slowly. Nutrients in the plant materials, such as nitrogen, then cycle through the bodies of the soil organism or are released into the soil where they are available for use by plants growing in the soil.
- Changes over years or decades may include the breakdown of organic matter into humus, pH, color, particle size, and the formation of stable soil aggregates.
- Changes over hundreds to thousands of years may include the breakdown of rocks by weathering, leaching of mineral nutrients from the soil, particle size distribution changes, and the formation of new horizons.

The layers found in soils are called horizons. A cross-section of soil that includes all of its horizons is referred to as a soil profile. The nature and thickness of the soil horizons within a profile reflect the history of the soil. In soil science, letters are often used to identify different horizons according to a strict taxonomy. As soils develop, parent material (usually rock) weathers into smaller and smaller sizes. Organic matter develops within the surface horizons as a result of plant colonization and turnover. The process of soil formation is often slow, requiring many thousands of years. In landscaped areas, erosion and construction activity can destroy soils very rapidly unless care is taken to protect them. Compost can be used both to protect threatened soils and to restore damaged ones.

3. COMPOST AND COMPOSTING

Composts improve soils and promote plant health, particularly in poor quality, problem or damaged soils commonly encountered in landscapes. Within and on the soil, compost is used to:

- Improve soil tilth and structure
- Improve the water holding capacity of sandy soils
- Improve drainage in heavy soils
- Improve soil nutrient holding capacity
- Prevent or decrease erosion
- Improve soil aeration
- Decrease the need for chemical fertilizers
- Remediate chemically damaged soils
- Replenish trace and macronutrient stores
- Increase the activity and diversity of soil microorganisms
- Reduce the incidence or severity of certain soil-borne diseases
- Filter storm water runoff

Composting on an organic farm

3.1 Creating Compost

Compost is generated when organic matter is consumed and decomposed by microorganisms under favorable environmental conditions. Key management factors for the compost process include maintaining a good nutrient balance, correct moisture content and temperatures, and adequate aeration. Composting is a managed process for accelerating the creation of compost while improving it characteristics.

Nutrient balance: The most important nutrient balance concern when generating compost is the ratio of carbon to nitrogen (C:N) in the decomposing mixture. Bacteria, actinomycetes, and fungi use available carbon for energy they require to grow and reproduce and nitrogen to build protein and genetic material. Initially the C:N ratio in the pile might be around 30 to1. As the microbes consume carbon, they convert it to carbon dioxide gas, which is lost. This causes the C:N ratio to fall as the compost process progresses. By the time the compost is ready to use, its C:N ratio will have decreased considerably, typically to between 10 and 20 to1. Phosphorus and other nutrients are also required by compost microbes but are usually available in adequate amounts in composts with the correct C:N ratio.

Moisture: The moisture content of compost should ideally be about 60% after mixing. Microbes need water to live and grow, but too much will block the supply of fresh air which contains the oxygen that they also need. A general rule of thumb is that a handful of compost should feel moist and hold together without dripping. Depending on the components of the mixture, the initial moisture content can range from 55-70%. However, as the moisture content increases above 70%, oxygen movement is inhibited, leading to low oxygen (anaerobic conditions). Under these conditions, microbes become less efficient, the compost loses heat energy, and chemical pathways are altered, leading to the production of odors. Under dry conditions the microbes lose habitat and the rate of decomposition decreases rapidly. While composting actually generates moisture, a significant amount is usually removed by air flowing through the compost pile. Therefore, moisture often must be added during composting to support an active process.

Temperature: The temperature increases that occur during the composting process result from the breakdown of organic material by bacteria, actinomycetes, fungi, and protozoa. Compost piles can reach 150 °F in less than 2 days. Applying heat to compost from an external source is not necessary since heat is generated from within the compost pile.

As microorganisms decompose (oxidize) the available organic matter, heat is generated and released into the compost. Much of the generated heat is retained in the pile because compost is an excellent insulator and can result in rapid temperature increases. In composting, as in the decomposition of any complex substance, the breakdown is a dynamic process accomplished by a succession of microorganisms reaching peak populations when conditions are optimum for their activity. There are thousands of types of microorganisms involved in the composting process. They are generally classified into 2 categories based on temperatures favoring their metabolism and growth: mesophiles (68-113 °F) and thermophiles (113-150 °F). As temperatures increase, the efficiencies of the microbes increase exponentially until around 150 °F. At that point, the composting rate drops rapidly, becoming negligible above 160 °F, since such high temperatures kill the microbes in the pile.

The majority of compost formation should occur when temperatures are in the thermophilic (100-150 °F) range. At these temperatures the rate of organic matter decomposition is maximized and indicator species of pathogens are reduced to non-detectable levels. The Environmental Protection Agency has found that decomposing organic matter exposed to 131 °F for 3 days is enough to eliminate parasites, fecal matter, and plant pathogens. This temperature will also inactivate most weed seeds. Turning the pile regularly to allow cooler surface zones to mix with hot center areas is recommended to maintain 131°F. Aerated static piles require decomposing organic matter piles to be held at 131°F for 3 consecutive days while windrows are required to be turned 5 times and held at 131°F for 3 consecutive days between turnings.

Aeration: A fresh supply of air is vital for composting. Proper aeration is needed to control the environment required for biological processes to thrive with optimum efficiency. A number of controllable factors are involved. If compost particle sizes are too fine, air will not be able to enter and diffuse within the pile, a condition leading to odors and to the development of phytotoxic contaminants. Some compost operations, called *turned windrow systems*, physically turn the compost to promote aeration. Turning the pile restores the pore spaces in the material so that cooler fresh air can enter the sides of the pile to replace the hot carbon dioxide and water vapor escaping from the top. In another common approach, called *static pile systems*, air is physically forced into - or drawn out of - the pile. While static pile systems do not need to be turned, it is important to note that the energy required to supply the compost with air is greater than the energy required to operate turned windrow systems.

Particle size. Bulking agents are typically wood, straw, or similar materials added to the compost mixture to increase porosity and improve aeration. Because smaller particles provide greater surface area to microbes than larger ones, they decompose more rapidly than bulking agents. When ready, composts are typically screened to separate large and small particles. The coarser fractions, or *overs*, are often sold as surface mulches while the *fines* are marketed for use as soil amendments. Larger bulking agent particles are usually screened out of the material along with the *overs*.

When compost preparation is correct, the active phase will start immediately and thermophilic conditions will be reached as microbes consume readily available carbon and nitrogen-containing compounds. After several days or weeks (based on the quantity and sizes of the feedstock), the temperature will drop and the mesophiles will take over, consuming lignin and other hard to decompose organic materials. Materials are typically repiled for this curing phase. Compost is considered finished, stable, and mature when:

- Its core temperature stabilizes and the material does not reheat or generate excess carbon dioxide when stirred or rewetted
- It is dark brown or black with no recognizable feedstocks or inert materials
- It has an earthy smell

Mixing feedstock prior to composting

on an organic farm

Feedstock are materials used to manufacture the compost product. Compost can be derived from a number of feedstock materials including woody (trees, shrubs) and herbaceous (turfgrass and small flowering plants) greenwaste, crop residues, biosolids (sewage sludge), wood by-products, animal manures, biodegradable packing and building materials, and food scraps. Feedstock materials, even within a particular type, can vary significantly depending on the conditions under which they were collected and processed. The composting process dramatically changes the properties of these feedstock materials, resulting in greater uniformity and consistency.

The following lists some general observations about the influence of feedstock on composts. Keep in mind that, although feedstock contributes to properties of the final material, other factors such as materials handling, processing times, and blending ratios are also of high importance. The decision about what material to select should, therefore, be made based at least as much on measurable parameters as on the compost ingredients themselves. Information should be provided by the vendor on the properties of the final compost product. Among the more frequently encountered feedstock material are:

Greenwaste: Greenwaste is typically derived from tree and shrub prunings and grass clippings originating from residential, commercial and public settings. Other products, such as ground Christmas trees, may be included on a seasonal basis. It is important to know what source products are included and the consistency of the end product.

Biosolids: Biosolids composts are usually generated by combining digested sewage sludge (the solid byproduct of municipal wastewater treatment) with an organic bulking agent such as greenwaste or wood residuals. Biosolids themselves are high in nitrogen and fine in texture. The composition of the compost produced usually depends on the type and rate of bulking agent used, but can also be affected by the method used to stabilize the biosolids. Salinity varies, with much of the soluble salt content derived from soluble nitrogen. Under California law, the presence of heavy metals is regulated in commercial compost regardless of the feedstock used to generate the material. Compost derived from biosolids is typically monitored more frequently than compost from other sources. The presence of pathogen indicator organisms in compost produced with biosolids is also monitored. Organic content varies.

Manures: Animal manures are nutrient rich. Manures may be composted alone or mixed with bulking agents. The properties of manures are more variable than biosolids since the circumstances under which they accumulate before collection differs from farm to farm. Composts tend to be more uniform, less odorous, and are more stable than unprocessed manures.

Stable Bedding: Many compost producers use stable bedding derived from wood shavings (with or without straw) as a feedstock and bulking agent. The stable sweepings include manure and urine. Salinity varies.

Wood By-Products: Many wood-based by-products of the lumber industry are not, by definition, classified as compost since they are often not thoroughly composted. Traditional amendments are redwood and fir sawdust and fir, pine, and redwood bark (these tree species are relatively resistant to decomposition). All require the addition of nitrogen in order to counteract the nitrogen they extract. Unless they are well composted, wood or shavings derived from pine or hardwood make inferior soil amendments due to rapid decomposition and the potential for nitrogen immobilization.

Other Organic Materials: Composts derived from rice hulls, mushroom-growing media, coconut fiber, cotton gin trash, municipal solid waste, and grape pomace are also available. Their use and effectiveness vary based on the type of material and the production method used.

3.2 Compost Quality, Testing, and Use Standards

Suggested end uses for composts vary based on their specific physical, biological, and chemical qualities. There are many different ways to use compost to improve plant growth and development. Since compost feedstock and preparation methods differ, selecting the right product for a particular application is crucial to the long-range success of the planting. For example, just as a road racing performance bicycle is a poor choice for tackling a mountain trail, composted 2”+ woodchips are not a good choice for topdressing turf. Instead, a mountain bike is a recommended for the trail use, and screened biosolids-greenwaste co-compost is a much better choice for the turf site.

Some characteristics of acceptable quality compost can be evaluated by a user with little or no special equipment. As mentioned previously, mature compost is dark, smells earthy and ‘organic’, and has a humus-like texture. Stable compost will not reheat appreciably or have an unpleasant odor when mixed with water. Compost with a putrid odor is not completely cured. However, the human nose and rapid field tests, while certainly useful, have limited accuracy and cannot detect many of the parameters that are important for distinguishing compost suitability for various uses.

Fortunately, standards are becoming available to designate acceptable uses for various composts. In 2000, the U.S. Composting Council coordinated the development of industry standards for compost testing and information disclosure called the Seal of Testing Assurance (STA), and since 2006, a compost classification system referred to as the Compost Use Index, has been under development by the Association of Compost Producers and the University of California Cooperative Extension. To ensure that the right product is selected for the intended purpose, national and California compost industry organizations recommend that all composts being used for large-scale projects be tested and deemed acceptable under the STA (please refer to the *U.S. Composting Council Quality Assurance* section below for more information on the STA program).

Selecting the right compost for the right job is essential. Compost that performs well for one purpose may be highly unacceptable for another. Compost should be obtained from a reputable source that guarantees high quality and provides STA data on the product’s origin, processing, and characteristics. Due to the diverse nature of feedstock, composting processes, and maturation standards, compost quality can vary significantly. Follow the guidelines listed in Section 4 to ensure that the chosen compost is appropriate for the job at hand. Reputable compost operators will always provide a physical and chemical analysis of the product purchased. Experts can differ in their opinions as to appropriate ranges for particular properties. The following ranges are consistent with the experience of the authors.

Carbon-to-nitrogen (C:N) ratio: Nitrogen release rates from composts are difficult to predict with accuracy, but the C:N ratio is a good starting place. Composts that are derived primarily from wood by-products tend to have high C:N ratios unless additional nitrogen is added during the composting process. Compost manufactured from biosolids and manures generally have low C:N ratios since these materials are nitrogen rich. At high C:N ratios (approximately 30:1 or greater) nitrogen may temporarily be tied up (immobilized) by microbes during the decomposition process. Because this deprives plants of needed nitrogen, additional fertilizer is required. Products with C:N ratios below around 15:1 are likely to supply at least some soil nitrogen. It is important to understand that immobilization is a temporary phenomenon, and that immobilized nitrogen will eventually be released in plant-available forms.

Contaminants: Compost materials used for landscape application should be free of measurable levels of inert contaminants such as glass, metal and plastic. Contaminants should compose less than 1% of the weight of the compost and should not be detectible with the naked eye.

Maturity and stability: Maturity refers to how free the compost is of organic phytotoxic substances that can adversely affect seed germination and plant growth. Stability describes the amount of decomposition activity in a compost. Stable compost is well decomposed, consumes little oxygen and generates little carbon dioxide or heat. Unstable compost heats up significantly if rewetted and stirred. Physical characteristics that reflect mature compost are a dark brown or black color and a soil-like, pleasant smell. Products with putrid odors are likely immature and should be avoided.

Moisture content: The moisture content of delivered compost should range between 40-55%. Moisture increases the bulk density of the product and often its transportation cost. Compost that is too dry is dusty and difficult to work with while compost that is too wet is heavy and can be hard to apply evenly.

Nutrient content: Composts are not normally considered fertilizers because their nutrient content is often lower than conventional fertilizer and is highly dependent on the rate of compost applied as well as the rate of their nutrient release. Because feedstock nutrient concentrations and moisture contents vary (even in high quality compost) nutrient contents cannot be guaranteed with the same precision as fertilizers. Composts derived from manures or biosolids often have higher levels of nitrogen and other nutrients than other composts.

Organic matter content: High quality organic soil amendments usually contains at least 40% organic matter. Concentrations as low as 25% are often adequate for mulches. Soil and silica typically make up the remainder of the compost dry matter. In general, a relatively high organic matter content is preferred for soil amendments and mulches. A moderate amount of inorganic content is desirable as foundation material for compost blankets, filter berms, and similar installations.

Particle size distribution: Particle size distribution (gradation) is determined by passing the compost through a set of sieves and determining respective weight fractions retained on each sieve size. Different distributions serve different purposes. For example, at least 90% of a compost to be used as a turf or landscape soil amendment should pass through a 5/8 inch screen. Composts with larger particles, conversely, serve as excellent mulches.

pH: The pH scale describes the acidity or alkalinity of the soil, ranging from 0-14. A reading of 7 is neutral. The most useful composts have a pH between 6 and 8. Often, a low pH suggests the presence of organic acids and other harmful compounds due to incomplete curing. Most California soils are somewhat alkaline (pH above 7)) and may benefit from low pH compost amendments as long as phytotoxicity is not an issue. When a compost is used as a soil amendment, it is generally desirable to have the final soil/compost mixture fall between pH 6.5-7.5.

Phytotoxicity: Mature plants are less likely to succumb to phytotoxicity than young ones. The threat of phytotoxicity is also reduced when compost is allowed to mature in the soil for several weeks before planting. The compost maturity test measures phytotoxicity. Phytotoxicity suggests that the compost was poorly manufactured. It is rare for commercial products marketed by reputable composters to be phytotoxic.

Soluble salts (salinity): Soluble salts are reported as the concentration of soluble ions in solution. Quantities are expressed as *electrical conductivity* (EC), which is measured in units of decisiemens per meter (dS/m) or micromhos per centimeter (mMhos/cm). EC values for soils and composts are not directly comparable. Soil EC is generally measured using a saturated soil extract (ECe) while a 1:5 water dilution and extraction is used to measure compost EC. Direct comparisons of soil and compost EC values underestimate the salinity contribution of the compost. Soluble salt levels in different composts can vary considerably depending on feedstock and processing. While salts can be rinsed from composts, this can create an effluent disposal problem. Many plants are intolerant of high soluble salts; the salinity (ECe) of a soil after it is amended should be less than 2.5 dS/m. It should be kept in mind that soluble nutrients, such as nitrogen, potassium, and calcium, usually account for most of the salinity in composts. If a high nitrogen compost is used, as is common with biosolids or manure composts, a final salinity (ECe) of up to 4.0 dS/m in the amended soil may be acceptable. It is important to note that most plants prefer a soil ECe of less than 1.0 dS/m and that if a higher ECe value is measured by a soil test, the ultimate level can be reduced through leaching (a slow, deep application of water to move excess salts beneath the root zone).

Trace elements/ micronutrients): The presence of trace elements in compost is directly attributable to the origin of the material used in its production. Many trace elements, such as copper, zinc, manganese, iron, boron, molybdenum, and chlorine, are micronutrients required by plants for normal growth. Therefore, composts containing these plant nutrients may prevent micronutrient deficiencies. However, many trace elements (particularly heavy metals) often raise concerns when found in high concentrations. Although municipalities have made excellent progress in excluding heavy metals from wastewater treatment systems, concentrations of certain heavy metals in composts manufactured from biosolids remain regulated by the United States EPA. California law regulates heavy metals in compost from all commercial scale composting sources. Regulated metals include arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Commercial compost producers routinely test for heavy metals as part of their quality control process and reputable compost producers will readily provide these data.

Weeds and disease organisms: Proper composting destroys insects and disease-causing organisms as well as most weed seeds. Compost generated from greenwaste may contain malva, California burclover, certain palms, and other weeds that are heat-tolerant. Commercial compost producers are required to periodically check for the presence of organism such as *Salmonella* and fecal coliforms, which suggest the possibility of disease transmission.

U.S. Composting Council Quality Assurance

During the 1990's, it was common for results of tests conducted to determine the physical, chemical and biological characteristics and properties of a compost to vary among laboratories testing the same product. This discrepancy was often due to a lack of standardized testing procedures used by the various labs, making comparisons frustrating and confusing to end-users.

To remedy this problem, the U.S. Composting Council (USCC) developed, published, and continues to update and maintain a complete nationwide compost testing system for the industry. Composts that have been tested using the approved methods outlined in the Test Methods for the Evaluation of Composting and Compost (TMECC) carry the Seal of Testing Assurance (STA) and can be used with confidence. STA program details are available at the USCC webpage http://www.compostingcouncil.org/section.cfm?id=37. Compost facilities participating in the STA program can be found at http://www.compostingcouncil.org/section.cfm?id=23.

The nationwide testing system is comprised of 3 components:

- TMECC: Test Methods for the Evaluation of Composting and Compost
- STA: Seal of Testing Assurance Program
- CAP: Compost Analysis Proficiency Program

TMECC: The TMECC manual contains laboratory techniques for measuring the parameters particularly significant for composts. The TMECC details how composts should be collected and prepared and describes in detail laboratory procedures for measuring compost physical properties (such as bulk density, moisture content, particle size distributions, and dry mass), inorganic chemical properties (such as pH, nitrogen, phosphorous, sodium, and chloride), organic and biological properties (such as organic matter content, maturity, and stability) as well as how to detect and measure synthetic organic compounds and pathogen indicators.

Compost Analysis Proficiency (CAP): CAP is a program for laboratories. All laboratories enrolled in the CAP program analyze compost samples on a routine basis and engage in a carefully monitored laboratory certification process that includes receiving blind samples in triplicate from a certification program manager and sharing test results for both precision (standard deviation around a mean for each compost parameter tested) and accuracy (degree of difference between a given lab's mean compared to the other laboratories for each parameter tested). It is strongly suggested that CAP-approved laboratories be selected. This guarantees that important parameters relating to the specific use of the compost are being tested properly and that the end product is well matched to its intended use. All STA program approved laboratories must be enrolled in the CAP program.

Seal of Testing Assurance (STA): STA is a program to help composters build credibility and a steady clientele. Composters who participate in the STA program collect and submit samples at predetermined intervals for analysis at STA certified laboratories. A battery of TMECC tests are then run on the submitted samples. Purchase of STA certified compost helps ensures that reliable data have been used to describe the material. (STA labs do not recommend particular uses for a given compost.)

ACP Compost Use Index

Compost indexing is a developing field that is based on a combination of objective university research and educational expertise, and encourages field results for a variety of specific uses. The Compost Use Index is designed to direct users to compost materials appropriate for specific purposes. While it has progressed rapidly in the last few years, it is a constantly evolving concept, requiring ongoing integration of soil and plant science; improved technical and production methods; and, the development of communication pathways among vendors, users, and technical experts.

Labeling composts by describing key constituents and characteristics once proved a cumbersome and imprecise process. To clarify and improve its 'user friendliness', CIWMB is collaborating with the University of California and the Association of Compost Producers (ACP) to develop a streamlined system for indexing different types of composts based on their suitability for various potential uses in landscapes, agriculture, horticulture, and the environment.

Compost Indexing

The ACP Compost Index is designed to help compost producers and users quickly identify products that will satisfy their particular needs as well as reduce and/or eliminate occasions of inappropriate use. The ACP Compost Index consists of 2 main elements:

- Product Index
- Best Use Directory

Compost Product Index (CPI): The Compost Product Index identifies important physical, chemical and biological properties that a compost should possess for a specific end use. In ACP

CPI Version 1.0, there are 14 test parameters of compost quality that are measured by certified laboratories to determine a Product Index, based on preferred end-user properties. All compost products to be indexed must be analyzed using the TMECC test method procedures required for STA certification. Results are then used to generate the Product Index for each specific compost product. Products are tested for:

- Total nitrogen
- Carbon to nitrogen (C:N) ratio
- Total phosphorus
- Electrical conductivity (ECe)
- Sodium
- Boron
- Chloride
- Stability
- Particle size
- Maturity (phytotoxicity)
- Bulk density
- Organic matter
- Moisture content
- Safety (pathogens and heavy metals)

The CPI is a 14 digit code that assigns a relative number to each of the 14 parameters and is a “short hand” method for referring to specific compost qualities well-matched for a given specification. Examples of this use can be found in the Caltrans compost specifications documentation found in the appendix of this manual. It is not necessary, nor expected, that the typical compost end-user will be interested in a detailed description of specific criteria used to generate the actual CPI.

Best Use Directory (BUD): The purpose of the Best Use Directory is to interpret the CPI so that users can find an appropriate product for their particular use. When fully implemented, it will use the Compost Product Index (CPI) of a given organic material to automatically generate a list of “best uses” for that product. Alternatively, a customer who has specified an end-use will be able to receive a list of appropriate compost products. The BUD identifies a set of suitable compost applications based on the experience of industry experts such as compost manufacturers, compost product formulators, the academic community, government officials, and compost users. In most cases, a particular compost will be appropriate for a variety of uses, such as application as a landscape mulch around ornamental or fruit trees, and as a “blanket” to protect bare soil from stormwater erosion.

4. Compost Uses And Specifications

The information in this section is intended to provide an overview of best use practices for compost in a wide range of landscape horticultural applications. Due to the unique demands of roadside landscaping, the specifications and recommendations provided in this section may differ from Caltrans specifications (Appendix B).

High quality compost enhances the physical, chemical, and biological properties of a soil. It can successfully be used as a soil amendment, turf topdressing, mulch, erosion control agent, and water quality enhancer. Compost increases the water and nutrient-holding capacity of coarse-textured (sand-based) soils and improves the soil structure, infiltration, and drainage of heavy textured (clay-based) soils. It can also significantly increase the organic material content of a soil as well as its biological activity. Recent research indicates that some composts help suppress certain fungal diseases, as well.

Although, historically, compost has been widely used to improve agronomic soils, it is increasingly used to promote plant health in landscapes and for environmental protection.

In the landscape, composts are used primarily as soil amendments to improve soil tilth and structure, to enhance water and nutrient holding capacities, and to promote water and nutrient infiltration in heavy or compacted soils. Large-particle size compost can also be used successfully as landscape mulches to conserve water, suppress weeds, reduce runoff, and for beautification.

Examples of environmental uses for composts include erosion control along roads and highways, slope stabilization, and stormwater remediation to protect surface water from runoff. Soil remediation applications include physical, chemical, and biological improvement of soils damaged by mining, construction, poor landscaping practices, weathering, or erosion.

COMPOST USE CAN…

- Improve soil tilth and structure
- Improve the water holding capacity of sandy soils
- Improve drainage in heavy soils
- Improve soil nutrient holding capacity
- Prevent or decrease erosion
- Improve soil aeration
- Decrease the need for chemical fertilizers
- Remediate chemically damaged soils
- Replenish trace and macronutrient stores
- Increase the activity and diversity of soil microorganisms
- Reduce the incidence or severity of certain soil-borne diseases
- Reduce pesticide use

The compost industry divides the landscape market into 2 categories based on how compost products are marketed and delivered. The bagged market includes small-scale residential uses while the bulk market refers to larger-scale commercial and public uses.

Bulk: Commercial landscape use. Bulk compost is unpackaged and is usually sold by the cubic yard. Although anyone can purchase bulk compost, it is generally purchased and used by private landscaping companies and public entities. End-use applications vary from planting mixes for growing nursery stock to use as mulches and soil amendments in commercial landscapes and turf installations. Bulk compost is commonly used for park, school, shopping center, business park, and roadside plantings. Compost purchased in bulk is typically less expensive than bagged equivalents.

Bagged: Residential use. Bagged compost is pre-packaged for convenience. It is most familiar to homeowners, since it is readily available at garden and home improvement centers. Although bulk compost is usually much less expensive than bagged compost, vendors often require a minimum purchase volume for bulk sales, and offering bagged products is more practical and convenient for small installations.

4.1 Soil Amendment Uses

The correct use of compost as a soil amendment to improve poor and moderate quality soils can greatly enhance the growth and development of landscape plants and turf. However, it is important to remember that proper site design, plant selection, spacing and planting technique, and maintenance are essential for assuring the health of landscape plants, and that no amount of soil amending will eliminate these requirements.

While compost makes an excellent soil amendment for bedding plant, turf, and small woody plant establishment, it should not be added to holes excavated for the purpose of planting landscape trees. This is because developing tree roots tend to prefer the higher quality amended soil, often leading to a pot-bound plant with a shallow root system. It is better to plant trees in the parent soil that has been removed, loosened, and added back into the hole after the sides and bottom of the hole have been etched and cut into to encourage downward and outward root growth. This will help ensure safe and high quality tree development throughout its lifespan.

For all other herbaceous and woody ornamentals, amending the entire planting site or bed with compost is a beneficial practice, leading to high quality plant establishment, growth, and development. If the whole planting area cannot be amended, minimally each planting hole should be dug at least 3 times the size of the root ball of the plant. Compost can then be incorporated back into the hole after being thoroughly mixed with some of the original soil. This will encourage high quality root growth beyond the constraints of the original container, adding both stability and a greater absorptive rooting area. Do not plant woody plants deeper than the original soil level in the pot they are being transplanted out of; this can lead to crown rot.

Soils containing layers with different soil textures (sand, silt, and clay singularly or in combination) can distribute moisture, nutrients, and oxygen poorly. The layers in these soils should be broken up by rototilling, digging, or ripping prior to planting. Added amendments should be thoroughly and uniformly mixed into the soil to a depth of at least 6 inches for turf and groundcover plantings, 1 foot for small woody plants, and at least 18 inches to 2 feet for large shrubs. Amending only a few inches of soil encourages shallow-rooting and should be avoided.

Amending Soil with Compost to Improve Physical Properties

When applied in adequate concentrations, compost can significantly improve the texture of sand and clay-based soils as well as the overall structure of highly compacted and poorly aerated and drained soils.

Improvements in soil structure occur in two ways. First, the compost itself contains particles that improve soil tilth and porosity. To result in immediate improvements, approximately 30% of the final soil volume should be amended with high quality compost. A clay-based soil amended in this way will lead to more productive and healthy plant growth for less cost than amending the same soil with the necessary 45% sand. Second, composts may also be effective at lower application rates, although changes will be gradual, rather than immediate, and repeated applications may be necessary before observable differences are noted. As compost decomposes in soil, it encourages the formation of soil aggregates. These resulting aggregates are composed of parent soil particles and are not merely decomposed compost. Because composts encourage the formation of soil aggregates, they can be particularly useful in restoring a crumb-like structure where construction activities have damaged and altered the natural structure of the soil.

Amending Soil with Compost to Remediate Chemical Problems

Most ornamentals prefer and grow optimally in soils with a pH range from 5.5 to 8.0, with soils near 7 (neutral) being optimal. Many California soils are alkaline. A neutral-pH compost applied in sufficient volume to a slightly to moderately alkaline soil can reduce the pH and promote healthy plant growth. When soil pH is extremely high and/or the pH of the compost is also alkaline, however, the addition of elemental sulfur, iron sulfate, or ammonium sulfate may be necessary to neutralize the pH. It is important to note that results of remediation might not be seen for several months to a year after application.

Twelve to 20 lbs. of sulfur per 1,000 square foot of soil can reduce pH from 8.0 to 6.5. Multiple applications of no more than 5 pounds of sulfur per 1,000 square foot of soil are recommended to avoid plant injury. The sulfur should be incorporated to a depth of at least 8 inches for maximum benefit. Although rarely necessary in California, the pH of an acid soil may be raised by the addition of lime (calcium carbonate).

Soils with poor structure and infiltration rates due to high concentrations of sodium can be improved by applying gypsum (calcium sulfate). During this process, the calcium in the gypsum replaces the sodium. The displaced sodium readily dissolves in the soil water and can be removed by saturating the soil so that the sodium is rinsed, or *leached*, below the root zone. Applications of about 20 pounds per 1,000 square foot of soil followed by repeated leaching (saturation of the soil to below the root zone followed by drainage) can appreciably reduce sodium concentrations and improve infiltration rates. Repeated leaching over several months may be required.

Gypsum use only improves soils damaged by sodium. Unlike compost, gypsum does not alter pH appreciably. Nor will it improve water infiltration and structural components of soils suffering from problems other than high sodium. During the incorporation of gypsum, soils are loosened and aerated; the resulting improvement in drainage is often mistaken for a gypsum-induced benefit even though the gypsum itself had no effect.

The absorption of high levels of certain soluble salts found in the rootzone of a plant can significantly reduce growth and development. Leaf scorch and leaf drop are common symptoms. Repeated leaching, as recommended above for sodic soils, is sometimes effective in reducing damage. It is important to irrigate plants thoroughly after fertilizing and to avoid applying more fertilizer than necessary. Frequently, sodic soils (where 15% or more of the cation exchange capacity (CEC) is occupied by exchangeable sodium affecting plant growth) are also high in soluble salts. These soils require a combination of the above treatments. Compost can also improve sodic soils, and composts and gypsum can be used together. Gypsum is a component of drywall and some composters cull this material from construction and demolition wastes for use in their products.

Remember that rates of compost and fertilizer and any necessary pH adjustment are influenced by the plant selected, soil and site characteristics, compost quality and feedstock, and other factors. Before planting it is advisable to have compost, soil, and soil/compost blend tested by an STA certified laboratory. Consider discussing the results and recommendations with a trained professional before proceeding.

Soil Amendments for Annuals, Perennials, and Small Woody Plant Materials

Using compost as a soil amendment in flowerbeds and for the establishment of small woody plants offers many benefits, particularly when the soil quality is poor. Areas where topsoil has been removed due to construction and other practices are particularly conducive to the addition of compost-based soil amendments. When adequate amounts of compost are added in these cases, there can also be significant improvement in the physical structure of the soil, drainage and/or water holding capacity, as well as microbial activity.

Application rates are highly dependent on the characteristics of the original soil as well as those of the compost. Lower application rates are generally acceptable when using compost with a high organic matter content or when soil quality is moderate. Very coarse-textured (sandy) or fine-textured (clay) soils require greater amounts of compost than loam-based soils. For best results, submit compost, soil, and soil/compost blend samples to an STA certified laboratory for expert analysis and recommendations by a trained professional.

Appreciable amounts of compost should not be added to planting sites where salt-sensitive crops (such as geraniums) will be planted or generally when a compost has a high EC unless leaching is possible. The soluble salt concentration of the compost-amended soil should be lower than approximately 1.25 dS in beds where seeds, young seedlings, or salt-sensitive crops will be planted. Plants should be thoroughly irrigated after planting, and if salts are thought to be an issue, any residuals should be leached beneath the rooting area of the soil to prevent future problems. An alkaline compost should be avoided in acid (low pH) requiring plantings.

Recommended rates of compost depend mostly on soil and compost characteristics, and may be further defined by specific requirements of the plants. In general, poor quality soils should be amended with 3 to 6 cubic yards of high quality compost per 1,000 square feet. This equates to a 1-2 inch layer incorporated 4-6 inches deep and 20-30% compost by volume.

Due to potential injury to young seedlings, manures should be limited to approximately 1 cubic yard per 1,000 square feet and biosolids-based composts should also be used sparingly if they are high in ammonium nitrogen. Composts that are well-cured will have less ammonium nitrogen than nitrate nitrogen. Performing germination and growth rate tests before using these composts is highly advisable. The STA maturity test will help indicate the extent to which a material is likely to injure susceptible seedlings.

APPLICATION PROCESS:

Step 1: Evenly apply a 1-2 inch layer of compost (3-6 cubic yards per 1,000 square feet). Application rates will vary depending upon soil conditions, climate, compost characteristics, and desired plant species.

Step 2: Apply the compost by hand; with a hand tool such as a shovel or rake; or, with a tractor, spreader, or compost blower.

Step 3: Incorporate the compost 4-6 inches deep by hand or with a rototiller or other implement evenly throughout the planting site.

Step 4: Smooth the soil surface with a rake or other implement.

Step 5: Plant ornamental herbaceous and small woody plants in the amended soil using recommended procedures. If seeding, gently rake the surface after planting.

Step 6: Water thoroughly but slowly and keep the planting bed evenly moist through the establishment phase. Fertilize only when and if recommended.

*Once the compost is incorporated evenly and before planting, an additional soil test for the possible additions of soil sulfur or gypsum and to assist in the development of an initial fertilizer program is often useful.

SPECIFICATION GUIDELINES FOR COMPOST USE AS A SOIL AMENDMENT:

1. Particle Size Distribution: Minimum of 95% by weight shall pass a 5/8" screen and at least 70% should pass through a 3/8" screen.

Percent Passing	Sieve Designation
95%	5/8" screen
70%	3/8" screen

2. Organic Content: Between 30-65% based on dry weight and determined by the ash method. Composts with low organic matter contents contain high concentrations of silica and other inorganic compounds. These compounds do not add organic matter to the soil.

3. Carbon-to-Nitrogen Ratio: A maximum 20:1 indicates that the material will enrich the soil with plant-available nitrogen forms.

4. pH: 6.0- 8.5 as determined in saturated paste. In alkaline soils (typical of California) soil amendments with lower pH values are preferred and may eliminate the need to adjust soil pH values using sulfur. However, compost with a pH below 6.0 may not be fully mature; a maturity test is very important for these products. Waiting several weeks before planting helps reduce the possibility of phytotoxicity from immature composts. Soils should be kept moist, but not wet, during this period.

5. Soluble Salts: Soluble nutrients typically account for most of the measured salinity and sodium should account for less than 25% of the total. To avoid a leaching requirement, the final blended product (including the addition of compost to a soil) should have an ECe of 2.5 dS/m (mmhos/cm) or less (saturated pasted extract method) Note that some plants will be damaged at an ECe of greater than 1.0 dS/m. (Please refer to Appendix A for a list of different types of plants and their EC tolerances. Also note that composts rich in available nitrogen will often have high ECe values as a result of their enrichment.)

6. Moisture content: 30-60%. A product that is too dry can be dusty when it is applied.

7. Contaminants: Free of distinguishable contaminants such as glass, metal and visible plastic; < 0.5% as a dry weight basis

8. Maturity: Physical characteristics suggestive of maturity include:

   Color: Dark brown to black.

   Odor: Acceptable = none, soil-like, musty or moldy.

   Unacceptable = sour, ammonia or putrid

9. Particle characterization: Identifiable wood pieces may be acceptable for some uses but the balance of material should be soil-like without recognizable grass or leaves.

Table 2. Preferred Compost Characteristics for Soil Amendments

Parameter	Value Range
pH	6.0 - 8.5; Lower values are preferred for alkaline soils, higher values for acid soils.
Moisture Content	30% - 60%
Particle Size	≥ 95% passing through a 5/8" screen, ≥ 70% passing through a 3/8" screen
Stability	≤ 8 mg CO_2/g OM/day (TMECC 05.08-B, "Carbon dioxide evolution rate")
Maturity/Growth	≥ 80 % emergence (TMECC 05-05-A, "Seedling emergence and relative growth")
Soluble Salts	Caltrans specifications permit EC to be as high as 10 dS/m (TMECC 04.10-A 5:1 slurry method), however <2.5 dS/m (mmhos/cm) or less is the preferred ECe (saturated pasted extract method) for the final soil/compost blend (could vary in areas of the country possessing saline soils). If the product is considered to be nitrogen-rich, as are many biosolids and manure-based composts, the final ECe for the soil after incorporation should be <4.0 dS/m
Organic Matter	30% - 65% dry weight basis

Soil Amendment for Turf Establishment

Composts from various feedstock can be used very effective as soil amendments for turf establishment (seed, sod, or sprigs) in both public and private plantings. Soils low in organic matter, nutrient content, or water-holding capacity may greatly benefit from the addition of compost; research results suggest that high quality compost applied at recommended rates can degrade many commonly applied turf pesticides, protecting water quality. High quality compost may also suppress some plant pathogens. For turf areas in playgrounds, parks, and sports fields, compost should be applied at a rate of 3-6 cubic yards per 1,000 square feet (135-270 cubic yards per acre (1-2 inch layer) with a front-end loader or similar equipment. After the compost is spread, it should be evenly incorporated at least 4-6 inches deep.

Lower application rates can be used when composts possessing higher organic matter contents are used or where soil quality is moderate. Excessively coarse-textured (sandy) or fine-textured (clay) soils will require higher application rates. Soil test results are helpful in establishing application rates.

INSTRUCTIONS FOR COMPOST USED AS A SOIL AMENDMENT FOR TURF ESTABLISHMENT

Step 1: Evenly apply a 1-2 inch layer of compost (3-6 cubic yards per 1,000 square feet). Application rates will vary depending upon soil conditions, climate, compost characteristics, and desired plant species.

Step 2: Apply compost with a front-end loader; tractor and grading blade; wheelbarrow and rake; topdressing unit; or, other appropriate equipment

Step 3: Incorporate compost thoroughly and evenly to a depth of 4-6 inches with a rototiller, constituting 20-30% of the final volume. Pre-plant fertilizers and pH and any needed sulfur (for pH reduction) may be applied before compost incorporation, as necessary. The use of stable, nutrient rich compost may reduce or eliminate the need for pre-plant fertilizer.

Step 4: Establish a smooth seedbed by raking or dragging the soil surface and roll if necessary. Rake the soil surface to remove clumps and debris and to smooth the surface.

Step 5: Apply seed using a hydroseeder, culti-pack seeder, or broadcast it on top of the soil surface and use a rake or drag mat to incorporate it.

Turf Topdressing

Topdressing turf with compost at a rate of 1/8 – 1/2 inch (the higher rate is only recommended for cool season grasses such as tall fescue and rye that are maintained at high mowing heights) followed by aeration and dragging will increase the amount of organic matter in the soil over time, aiding plant growth and improving the physical structure of the soil. Topdressing can be applied using a standard spreader

Benefits of topdressing with high quality compost include:

- Improving the water holding capacity of the soil
- Decreasing runoff and deep percolation which can reduce nitrate pollution
- Reducing canopy temperature
- Potentially extending turf color and quality of warm season grasses into the fall and promoting earlier greenup in spring
- Low levels of essential nutrients
- Potential suppression of certain fungal diseases such as dollar spot and rhizoctonia

4.2 Mulch Uses

A properly applied mulch buffers soil temperature, retains moisture, controls weeds, and protects woody trunks from mechanical damage from lawn mowers and weed whips. Many types of coarse composts make excellent mulches for bedding plant and shrub and tree plantings and offer a viable alternative to standard organic products such as fir, pine, shredded hardwood, cypress bark, and pine straw. Composted greenwaste and biosolids-derived composts are often used

successfully as mulches by landscape professionals.

Aesthetic characteristics such as color, texture, and feel are important features of mulch since it is applied above ground and is visible. Consistency in appearance and the lack of recognizable feedstock products and a pleasant smell are also ranked high by end-users.

Coarser-textured compost mulches are often more effective in reducing weed growth and preventing wind erosion than finer products. The use of unstable or raw wood mulches is not recommended because they often compete with plants for nitrogen, stunting growth and causing chlorotic (yellow) foliage.

Table 3. Preferred Compost Characteristics for Unvegetated Mulches

Parameter	Value Range
pH	6.0 - 8.5
Moisture Content	30% - 60%
Particle Size	≥ 99% passing through a 3" screen, ≤ 25% passing through a 3/8" screen.
Stability	Not critical, however, a stable compost (<8 CO_2/g OM/day (TMECC 05.08-B) may settle and lose mass more slowly after it is applied. Compost should be free of objectionable odors.
Maturity/Growth	Not important if not plantings are considered.
Soluble Salts	≤ 10 dS/m (TMECC 04.10-A); lower soluble salt values are preferred.
Physical Contaminants	≤ 1 % with no sharp items (TMECC 02.02-C). Mulches should be inspected at delivery and visually contaminated products should be rejected.
Organic Matter	≥ 30% dry weight basis

Instructions for Compost Used as a Landscape Mulch

Step 1: Evenly apply compost 2-3 inches depth (6-9 cubic yards per 1,000 square feet). In most cases, biosolids-based composts should not be applied deeper than 2 inches, while most greenwaste-based composts can be applied to a depth of 3 inches.

Step 2: Carefully spread compost around the base of plants using a shovel or rake. Reduce the chance of diseases and insects by not placing mulch against tree trunks or plant stems.

Step 3: Use a rake to smooth and even mulch layer.

Step 4: For singular trees and shrubs, mulch should be applied several inches away from tree trunks outward to the dripline and never touch the tree. A soil berm may be formed around the trunk before mulching to hold water.

Step 5: Once applied, the mulch may need to be watered to help keep it in place. To improve weed control, plastic mulches, landscape fabric, newspaper, or herbicides may be applied prior to mulching.

4.3 Environmental Uses

The use of compost as a soil amendment and mulch for effective erosion and sediment control has been documented through research, field trials, and multiple applications in a variety of construction sites nationwide. Based upon these results, these products have been approved for inclusion as 'Best Management Practices' for Stormwater Pollution Prevention Plan construction permits by federal, state and local regulatory agencies.

Effectiveness of compost in controlling erosion (Adjacent slopes in Temecula, CA)

Since 1996, Caltrans has been developing and implementing Best Management Practices as it implements its Statewide Stormwater Management Plan (SWMP). This plan, which satisfies federal surface water quality protection requirements involves continual development of conservation technologies along with regular training sessions for agency technical support staff in each of the twelve Caltrans districts. Erosion and sediment control are key objectives of the SWMP. Recently, Caltrans has been using compost successfully to vegetate erosion-prone slopes. Plants grown on these restored soils help to hold the soil in place so that it is not lost to area water bodies. Compost applied to the soil surface has also been shown to filter pollutants such as the hydrocarbons and metals that wash from road surfaces.

Compost used as a soil amendment can improve soil structure, reduce compaction, and increase water infiltration, thereby decreasing soil erosion and runoff of both soluble and particulate materials. When incorporated into soils, compost increases soil nutrient holding capacity, reduces the amount of commercial fertilizers needed, and can bind heavy metals and degrade volatile organic compounds and complex organics. Use of compost to prevent and/or decrease erosive forces is instrumental in preventing water quality degradation, as well. Compost can also be used at the surface of the soil as a mulch to both hold it in place and protect water quality. In cases where immediate planting is not feasible or possible, compost can ward off erosion while vegetation is being established by forming a protective layer or sediment filter.

Water pollution can severely reduce water quality, rendering lakes, rivers, and other waterways unsafe for drinking and recreational activities. Authorized under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program regulates point sources, such as pipes or manmade ditches, which potentially discharge pollutants into waters. While private residences connected to municipal systems or using septic systems are not required to hold NPDES permits, industrial, municipal, and other entities responsible for discharge release into surface waters are.

Mechanics of Erosion

Erosion is the detachment and movement of soil by moving water, wind or ice. Splash erosion occurs when rain or irrigation spray dislodges and detaches soil particles from unprotected sites. If irrigation or rain falls at a rate greater than the infiltration rate of the soil, the water is not absorbed and the dislodged soil particles erode away. Erosion is greatly intensified in urban areas as a result of human activity such as construction and grading.

Erosion proceeds through several predictable stages. Most water erosion occurs in one of two ways. Sheet or “inter-rill” erosion occurs when raindrops strike the soil, bouncing loose particles that are then rinsed away with draining rainwater. Inter-rill erosion can be reduced by growing plants or placing residues over the soil to absorb the energy of falling raindrops and to reduce slow runoff so that particles that do dislodge have time to resettle. Gully or “rill” erosion occurs when concentrated flows wear a channel into the earth. Over time, the rill gradually becomes longer, deeper and wider as saturated soil from its upslope inlet and walls is eventually carried away by water rushing along its bottom. Unchecked, growing gullies can quickly undermine the foundations of buildings and roads. Rills also channel sediments from inter-rill erosion into protected surface waters such as streams, rivers, and oceans. Rill erosion can be prevented by dispersing surface flows so that they do not concentrate and by slowing flows so that there is less energy available to further enlarge the channel.

Irrigation and rainwater applied to weakly structured soils with low organic matter can lead to surface crusting that can impede water absorption. This increases runoff, and can lead to drought-stricken plants, water waste, and rill erosion. Serious erosion may occur if the problem is not corrected.

Splash erosion, Photo: USDA NRCS

Consequences of Erosion

Erosion not only reduces soil productivity but may also result in reduced water quality once sediments are carried from the site and enter surface waters. The US Environmental Protection Agency (EPA) considers sediment contamination of surface waters the greatest threat to our nation's water resources. Eroded sediment that is transported to once clean waterways often carries fertilizers, pesticides and other contaminants that attach to soil particles. Sediment-infested water can result in reduced aquatic organism populations, and in water treatment and irrigation system maintenance requirements. In addition, it can lead to decreased recreational, economic (fishing and boating), and aesthetic qualities.

Construction projects often cause significant erosion and sedimentation of surface waters. Operations that remove soil are particularly conducive to erosion. Construction projects often fail to establish vegetation quickly enough to protect the soil from erosive forces. Sites where preexisting topsoil has been totally removed are particularly prone to rapid, heavy erosion. In addition, heavy machinery and steady traffic can lead to compacted soil, creating a layer of hardpan that repels water, increases runoff, and prevents and/or reduces plant growth.

Erosion Control

Controlling erosion is necessary to meet National Pollutant Discharge Elimination System (NPDES) and other regulatory requirements. Due to the complexity of related issues and laws, many government agencies contract consultants or hire full time storm water compliance officers to ensure that effective sediment control technology is employed. Even well-designed and installed projects require regular inspection and maintenance to prevent water quality degradation. Employing 'Best Management Practices' that prevent erosion from occurring is the least costly and most efficient way to reduce sediment and nutrient losses and to avoid disputes regarding compliance with government codes. To this end, timely construction scheduling and minimizing the amount of exposed soil during construction are crucial. Preserving natural vegetation and stabilizing exposed soils are extremely important. Additional methods for erosion prevention include: applications of organic mulches; hydroseeding; drill seeding; use of erosion control blankets; use of turf-reinforced mats (TRM); biofiltration swales and strips; and, compost blankets, compost filter berms, and filter socks.

Compost Structures for Controlling Erosion

Compost Blankets, Filter Berms, and Filter Socks

There are 3 recommended methods for using compost to prevent and/or reduce erosion: compost blankets, compost filter berms, and filter socks. Compost blankets are mulches applied to the soil surface to protect and preserve it. Compost filter berms are permeable barriers that filter (rather than divert) water that has been polluted with sediment. Depending on local circumstances, compost blankets, filter berms, and filter socks may or may not be vegetated.

The slope of the site, amount of potential rainfall and/or irrigation, site activity, and type and timing of the vegetation to be established are all important considerations when deciding whether to use a compost blanket, filter berm or filter sock. These methods may be, and often are, used together. The usefulness of a particular type of compost will depend on many factors including the feedstock and processes used to make it. Unlike textiles, compost blankets and filter berms have intimate contact with the micro contours of the ground. Filter socks filled with compost, as with other manufactured erosion control products, typically must be staked and/or partially buried in order to prevent runoff water from flowing underneath them and the soil.

Compost Installation Alternatives

Compost Blanket installation

Compost Berm

Compost Filter Sock

Compost blankets:

- Increase water infiltration
- Reduce runoff
- Improve slope stability
- Increase plant growth and soil cover
- Reduce soil loss
- Increase the water holding capacity of soil which reduces runoff
- Buffer soil pH which can increase vegetation establishment and growth
- Prevent and/or reduce soil compaction
- Increase rate of vegetation establishment

Blanket Installation and Result

When used as a filter berm, compost works as a water filter and sediment trap.

Filter berms:

- Reduce sediment losses
- Reduce total losses of fertilizers, chemicals, metals, and other pollutants
- Recycle (by keeping silt fences out of the landfill and using recycled organic materials)
- Save money by avoiding the need to collect and dispose sediment traps

Filter Berm[1]

[1] This is the same filter berm installed in theprevious filter berm picture, 7 months later, after a road and fence installation.

When used in a filter sock, compost works like a contained filter berm, and is a very strong water filter and sediment trap.

Filter socks:

- Reduce sediment losses
- Have the strongest integrity during high runoff flows
- Reduce total losses of fertilizers, chemicals, metals, and other pollutants
- Recycle (by using recycled organic materials on site, after removing the sock)
- Offer size flexibility, including 8”, 12”, 18” and 24” diameters, that accept holding and flow rates greater than silt fence alternatives

Filter Sock

Specifications for compost used in erosion control include particle size, moisture content, organic matter content, pH, and soluble salt content. Application rates will usually be based on the erosion control method chosen and the severity of the slope. Two general classes of compost are typically specified:

- Growth media (vegetated) for compost blankets used as amendments, berms or socks where growth is desired in the and through the compost); and

- Filter media (unvegetated) for compost blankets that are used to capture, retain and filter rainfall runoff water

Table 4. Preferred Characteristics for Compost Blankets, Filter Berms and Filter Socks

Parameter	Compost Blankets		• Compost Filter Berm or Sock	
	Vegetated	Unvegetated	• Filter Berms	• Filter Socks
Particle size (% passing screen)	• 100% passing 3" • ≥ 90% passing 1" • ≥70% passing ¾" • 30-60% passing ¼" • 6" max particle length	• 100% passing 3" • ≥ 90% passing 1" • ≥70% passing ¾" • 30-60% passing ¼" • 6" max particle length	• 100% passing 3" • ≥ 90% passing 1" • ≥70% passing ¾" • 30-60% passing ¼" • 6" max particle length	• 99% passing 2" • 30-50% passing 3/8" • 2" max particle length
Moisture content (wet wt. basis)	Not applicable	Not applicable	30-60%	≤ 60%
Soluble salts (ECe)	< 10 dS/m	< 10 dS/m, less is preferred	≤ 10 dS/m	Not applicable
Organic matter (dry weight basis)	30 – 65%	30 – 65%	30 – 65%	30 – 100%
pH	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
Contaminants (dry weight basis)	≤ 1% with no sharps	≤ 1% with no sharps	≤ 1% with no sharps	≤ 1% with no sharps
Application	¾" - 1" depth	1½ - 2" depth	1 - 1½' high, 2 - 3' wide	Determined by sock dimensions
Stability	$< 8 \frac{\text{mg } CO_2\text{-C}}{\text{g OM-day}}$	$< 8 \frac{\text{mg } CO_2\text{-C}}{\text{G OM-day}}$	$< 8 \frac{\text{mg } CO_2\text{-C}}{\text{g OM-day}}$	Not applicable
Maturity (% emergence)	≥ 80%	≥ 80%	≥ 80%	Not applicable
Fecal coliforms and Salmonella TMECC 07.01-B	Pass	Pass	Pass	Pass

Compost Blankets

Compost blankets are surface applications of high quality compost on areas subject to erosion. They are normally used on slopes where immediate protection is desired and can be vegetated or unvegetated, according to local needs. Compost blankets are recommended for controlling erosion on disturbed areas such as construction sites, roadways, and other disturbed or excavated land areas with slopes of no more than 2:1 (horizontal to vertical distance). Studies at

Iowa State University have shown that compost blankets applied to 3:1 slopes perform very well, even when measured rainfall totaled 2 inches in 30 minutes.

Compost blankets work by:

- Protecting the soil surface from the erosive energy of falling rain
- Absorbing water so that flows are reduced
- Distributing water so that when flow does occur, it is slower and dispersed
- Providing a growth media for plants to further reduce runoff and erosion
- Providing an opportunity for percolation

Suggested application rates range from ½- 4-inches deep, depending on conditions and whether the blankets will be vegetated, but low application rates are very difficult to distribute evenly. A 2 inch application rate is recommended for this reason unless plants will be established before the arrival of seasonal rains. Thicker blankets will also absorb more precipitation than thinner blankets. Coverage at depths of 1 inch or less can be expected to show bare spots quickly unless the ground is seeded and watered promptly. Studies have not shown 4 inch applications to be much more effective than 2 inch applications, but deeper applications provide protection again bare spots occurring due to traffic across the mulch surface and afford additional weed protection. Compost and manure spreaders are effective only on open, gradual slopes, but light composts can be spread on much steeper slopes using blower trucks fitted with flexible hoses. Large particles can clog blower tubes, so care should be taken to choose a suitable compost if this method of installation is selected. Compost can also be spread manually, but this process often proves labor intensive. Creative approaches, such as the use of snow blowers, may also prove feasible.

Before spreading the compost, it is a good idea to disk, harrow, or rototill the area parallel to the slope. This roughens the surface, helping the compost adhere to slopes. It also increases water penetration by creating a transition zone between the compost and the soil surface. Additionally, compost should be maintained at least 3 feet over the shoulder of the slope or into existing vegetation whenever possible to prevent rill formation. It is not necessary to work the compost into the soil. Compost blankets should never be used where runoff water converges to a concentrated flow. Under concentrated flow conditions compost can float and be washed offsite. Compost blankets are for controlling sheet flow and should not be used where rills are apparent without appropriate soil preparation.

Specific Uses for Compost Filter Berms

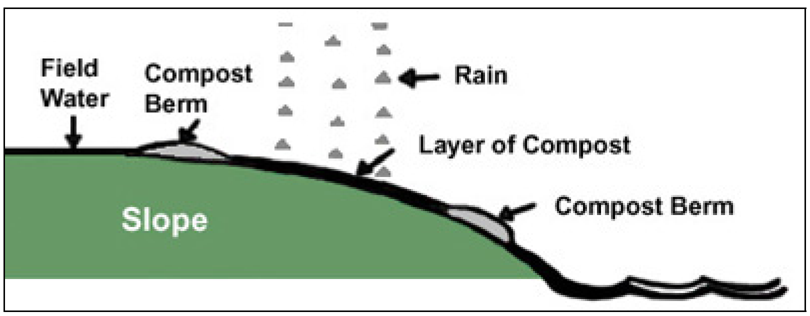
Compost filter berms are raised water barriers used for filtering runoff placed perpendicular to sheet flow. Like compost blankets, berms may or may not be vegetated. They may be placed along the perimeter of a site or at intervals down a slope as a kind of terrace. While compost blankets work by preventing erosion, compost filter berms act by intercepting sediments that have already been displaced. Water initially pools on the upslope side of the berm allowing heavier particles to settle out. As the pooled water gradually flows through the berm, finer sediments and associated pollutants are removed by filtering. To assure proper filtering, having a range of particle sizes present in the compost is important for successful filter berms. Because of this diversity in particle size, compost filter berms transmit water during the filtering process more effectively than other options such as silt fences or hay bales. Particle sizes should include fine (< ¼ inch) and coarse (½ - 1 inch) particles. As with compost blankets, particles as long as 4 inches are acceptable if rapid vegetation establishment is not a primary goal and if sufficient medium and small-sized particles are present to filter runoff. Application and construction of compost berms is easiest using a backhoe, bulldozer, or grading blade. Manual application may be an option in tight or small areas.

Berm size and construction varies based on slope gradient and the amount of expected rainfall and other precipitation. Large berms are well suited for long or steep slopes. Compost berms are typically contoured to follow the base of a slope. A second berm may be used on the shoulder contour of steeper slopes for added protection. Berms are typically trapezoidal with a base at least twice the height of the berm with dimensions 1 to 1½ feet high and 2 to 3 feet wide.

Compost berms should be placed loosely on bare soil. Vegetation or compost blankets may be used above the berms, but never beneath them. Filter berms should never be constructed in runoff channels, ditches or gullies subject to concentrated flows capable of floating berm materials out of position. A failed berm is likely to concentrate flows through its ruptures. In sustained and heavy rains ruptures can produce severe rill erosion and, at times, more damage than if the system had not been installed.

Compost filter berms can be planted and seeded at the time of application for permanent vegetation establishment. The roots of developing plants will help to filter runoff and will maintain the physical integrity of the berm. If the berm is not vegetated initially, it can be spread out and planted or seeded at the completion of the project.

Compost Berm Runoff Management System



Specific Uses for Compost Filter Socks

A compost filter sock is a type of contained compost filter berm. Compost filter socks consist of mesh tubes filled with composted material that is placed perpendicular to sheet-flow runoff to control erosion and retain sediment in disturbed areas. The compost filter sock, which is oval to round in cross section, provides a 3-dimensional filter that retains sediment solid phase or adsorbed pollutants, and hydrophobic liquids such as motor oil. Cleansed water is allowed to flow through. The filter sock can be used in place of a traditional sediment and erosion control tool such as a silt fence or straw bale barrier. Composts used in filter socks are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids, and manure.

Compost filter socks are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat stormwater that runs off as sheet flow. Filter socks are flexible and can be filled in place or filled and moved into position, making them especially useful on steep or rocky slopes where installation of other erosion control tools is not feasible. There is greater surface area contact with soil than typical sediment control devices, thereby reducing the potential for runoff to create rills under the device and/or channels carrying unfiltered sediment.

Additionally, they can be laid adjacent to each other, perpendicular to stormwater flow, to reduce flow velocity and soil erosion. Filter socks can also be used on pavement as inlet protection for storm drains and to slow water flow in small ditches. Filter socks used for erosion control are usually 12 inches in diameter, although 8 inch, 18 inch, and 24 inch– diameter socks are used in some applications. The smaller, 8 inch–diameter filter socks are commonly used as stormwater inlet protection.

Compost filter socks can be vegetated or unvegetated. Vegetated filter socks can be left in place to provide long-term filtration of stormwater as a post-construction "Best Management Practice". The vegetation will grow into the slope, further anchoring the filter sock. Unvegetated filter socks are often cut open when the project is completed, and the compost is then applied on-site as a soil amendment or mulch. The mesh sock is then disposed of unless it is biodegradable. Filter sock use is currently under review by Caltrans.

Three advantages the filter sock offers over traditional sediment control tools (such as a silt fence) are:

- Installation does not require disturbing the soil surface, which reduces erosion
- It is easily removed
- The operator must dispose of only a relatively small volume of material (the mesh)

These advantages lead to cost savings, either through reduced labor or disposal costs. The use of compost at the completion of the project provides additional benefits, include the following:

- The compost retains a large volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the filter sock.
- The mix of particle sizes in the compost filter material retains as much or more sediment than traditional perimeter controls, such as silt fences or hay bale barriers, while allowing a larger volume of clear water to pass through. Silt fences often become clogged with sediment and form a dam that retains stormwater, rather than letting the filtered stormwater pass through.
- In addition to retaining sediment, compost can retain pollutants such as heavy metals, nitrogen, phosphorus, oil and grease, fuels, herbicides, pesticides, and other potentially hazardous substances—improving the downstream water quality.
- Nutrients and hydrocarbons adsorbed and/or trapped by the compost filter can be naturally cycled and decomposed through bioremediation by microorganisms commonly found in the compost matrix.

Compost filter socks may be successfully used on construction sites or other disturbed areas where stormwater runoff occurs as sheet flow. A common industry standard pertaining to the use of compost filter devices is that drainage areas do not exceed 0.25 acre per 100 feet of device length and flow does not exceed 1 cubic foot per second. Compost filter socks can be used on steeper slopes with faster flows if they are spaced more closely together, stacked beside and/or on top of each other, made in larger diameters, or used in combination with other stormwater 'Best Management Practices' such as compost blankets.

Design: Filter socks are round to oval in cross section; they are assembled by tying a knot in one end of the mesh sock, filling the sock with the composted material (usually using a pneumatic blower), then knotting the other end once the desired length is reached. A filter sock the length of the slope is normally used to ensure that stormwater does not break through at the intersection of socks placed end-to-end. In cases where this is not possible, the socks are placed end-to-end along a slope and the ends are interlocked. The diameter of the filter sock used will vary depending upon the steepness and length of the slope; example slopes and slope lengths used with different diameter filter socks are presented in the following table:

Table 5. Example Compost Filter Sock Slopes, Slope Lengths, and Sock Diameters

Slope	Slope Length (feet)	Sock Diameter (inches)
<50:1	250	12
50:1–10:1	125	12
10:1–5:1	100	12
3:1–2:1	50	18
>2:1	25	18

Source: Oregon Department of Environmental Quality (ODEQ), 2004

Siting: Although compost filter socks are usually placed along a contour perpendicular to sheet flow, in areas of concentrated flow they are sometimes placed in an inverted V going up the slope to reduce the velocity of water running down the slope. The project engineer may also consider placing compost filter socks at the top and base of the slope or placing a series of filter socks every 15 to 25 feet along the vertical profile of the slope. These slope interruption devices slow down sheet flow on a slope or in a watershed. Larger diameter filter socks are recommended for areas prone to high rainfall or sites with severe grades or long slopes. Coarser compost products are generally used in regions subject to high rainfall and runoff conditions.

Installation: Since no trenching is required, soil is not disturbed upon installation. Once the filter sock is filled and put in place, it should be anchored to the slope. The preferred anchoring method is to drive stakes through the center of the sock at regular intervals; alternatively, stakes can be placed on the downstream side of the sock. The ends of the filter sock should be directed upslope to prevent stormwater from running around the end of the sock. The filter sock may be vegetated by incorporating seed into the compost prior to placement in the filter sock. Since compost filter socks do not have to be trenched into the ground, they can be installed on frozen ground or even cement.

Limitations

Compost filter socks offer a large degree of flexibility for various applications. To ensure optimum performance, heavy vegetation should be cut down or removed, and extremely uneven surfaces should be leveled to ensure that the compost filter sock uniformly contacts the ground surface. Filter socks can be installed perpendicular to the flow in areas where a large volume of stormwater runoff is likely, but should not be installed perpendicular to the flow in perennial waterways and large streams.

Maintenance Considerations

Compost filter socks should be inspected regularly, as well as after each rainfall event, to ensure that they are intact and the area behind the sock is not filled with sediment. If there is excessive ponding behind the filter sock or accumulated sediments reach the top of the sock, an additional sock should be added on top or in front of the existing filter sock in these areas, without disturbing the soil or accumulated sediment. If the filter sock was overtopped during a storm event, the operator should consider installing an additional filter sock on top of the original, placing an additional filter sock further up the slope, or using an additional "Best Management Practice", such as a compost blanket in conjunction with the sock/s.

Effectiveness

A number of studies have reported the effectiveness of compost filter socks in removing settleable solids and total suspended solids from stormwater. These studies suggest that compost filter socks are at least as effective as traditional erosion and sediment control 'Best Management Practices' and often are more effective. Compost filter socks are frequently used in conjunction with compost blankets to form stormwater management systems. Together, these 2 'Best Management Practices' are very effective at retaining a high volume of stormwater, sediment, and other pollutants.

The compost in the filter sock can also improve water quality by absorbing various organic and inorganic contaminants from stormwater, including motor oil. In a recent laboratory study using 13 types of composts in filter socks, half of the socks removed 100 percent of the motor oil introduced into the simulated stormwater (at concentrations of 1,000 – 10,000 milligrams per liter [mg/L]) and the remaining compost filter socks removed over 85% of the motor oil from the stormwater.

Filter socks can be used for many applications that produce superior erosion control results over non-compost based 'Best Management Practices'. These are summarized in the following table:

Filter Sock BMPs for Main Current Erosion Control Practices

Compost Filter Sock BMP	Conventional Alternative/ Application	Product Brief	Example
Silt Socks	Silt Fence Replacement	A 3-dimensional storm water runoff filtration device proven to outperform silt fence in sediment and hydrocarbon removal.	
Inlet Socks	Inlet Protection	Specifically designed to allow storm water to enter inlets quickly, while removing sediment and protecting stormwater inlets from clogging with silt.	
Ditch Check	Straw Bale Replacement	A natural replacement to eliminate formations of gully's in ditches.	
Edge Saver	Streambank Stabilization	One of the only organic products to protect stream edges.	
Filter Rings	Outflow Filtration	To filter outflow run off water. Acts like a constructed swale.	

Channel Socks	Rip Rap Replacement	Replaces rock rip rap to protect soil in channels	

Hydroseeding

Hydroseeding is a process in which seed, water, fiber mulch, and sometimes fertilizer and other soil enhancers or conditioners are blended together in a tank and sprayed onto a prepared seedbed. When performed correctly, hydroseeding offers large erosion control dividends. However, for hydroseeding to be successful, the use of high quality seed and a thorough, even slurry application are paramount.

The importance of contracting with a reputable firm well versed and experienced in proper hydroseeding methods cannot be over emphasized. Unfortunately, there are many examples of poor erosion control outcomes due to the hiring of unqualified low bidders who shortcut necessary procedures such as selecting high quality seed and applying it at recommended rates.

Adequate seedbed preparation prior to hydroseeding is crucial to the success of the project and includes: roughening the area to be seeded with furrows along the contours; rolling using a crimping or punching type roller (or track walking if other methods are not practical). Use of the right equipment and the right balance of slurry ingredients are also important. Applying hydroseeded slurries with blower trucks is becoming more and more standard due to recent objective, research based information on the efficacy of this practice. Unlike other hydroseeding equipment, blower trucks are also equipped to apply wood chips, small gravel or bark mulch for aesthetic enhancement.

While there are many types of native and non-native grass and broadleaf seeds available for hydroseeding, there is a trend toward specifying the use of only native species due to the ability of many to thrive on low maintenance (including infrequent mowing) and on little supplemental water once established. In some cases, specifications call for using only local native seed collected within a few miles of the area to be planted. A key to successful vegetation establishment is selecting climatically adapted species. Many non-native grasses and broadleaves fit this criterion as well as their native counterparts.

Caution should be used when selecting a seed supply source; companies or suppliers with unknown reputations should be avoided. Unscrupulous suppliers may even sell noxious weed seeds that are extremely difficult to kill without creating large bare spots, often leading to erosion. Awareness of which seeds require pretreatment to germinate is also important. To prevent contamination from weed seeds, some specifications require the application of a non-selective herbicide prior to hydroseeding. Some longer term projects also specify that woody species be installed separately with herbaceous grasses and broadleaves hydroseeded around them.

It is often wise to conduct a soil test prior to hydroseeding to determine fertilizer needs. Specification for sites with minimum erosion potential may include recommendations for tackifiers while sites with greater erosion concerns may specify tackifiers, polyfiber mulch, and possibly a bonded fiber matrix (a spray-on blanket to prevent erosion in highly suspect areas).

All hydroseeded areas should be inspected regularly to ensure even application and to assess the need for cultural inputs such as fertilizer and herbicides. Follow-up applications may be required to cover uneven or bare spots.

Drill Seeding

An alternative to hydroseeding on flat or gently rolling areas is drill seeding. A seed drill is a piece of equipment attached to the back of a tractor that creates a furrow, plants seed (between

¼ - ½ inch deep) and fills and closes the furrow. Drill seeding and hydroseeding work well for establishing grasses and small herbaceous plants, although drill seeding is not effective on sloped or steep areas. Because furrows are immediately covered, in windy areas drill seeding may be preferable to hydroseeding due to a reduction in seed loss due to wind and birds.

Table 6. Preferred Compost Characteristics for Drill Seeding

Parameter	Value Range
pH	6.0 - 8.5; Lower values are preferred for alkaline soils, higher values for acid soils.
Moisture Content	30% - 60%
Particle Size	≥ 95% passing through a 5/8" screen, ≥ 70% passing through a 3/8" screen
Stability	≤ 8 mg CO_2/g OM/day (TMECC 05.08-B, "Carbon dioxide evolution rate")
Maturity/Growth	≥ 80 % emergence (TMECC 05-05-A, "Seedling emergence and relative growth")
Soluble Salts	Caltrans specifications permit Ec to be as high as 10 dS/m (TMECC 04.10-A, "5:1 slurry method"), however <2.5 dS/m (mmhos/cm) or less is the preferred ECe (saturated pasted extract method) for the final soil/compost blend (could vary in areas of the country possessing saline soils). If the product is considered to be nitrogen-rich, as are many biosolids and manure-based composts, the final ECe for the soil after incorporation should be <4.0 dS/m.
Organic Matter	30% - 65% dry weight basis
Physical Contaminants	≤ 1 % with no sharp items (TMECC 02.02-C). Compost should be inspected at delivery and visually contaminated products should be rejected.

Biofiltration Swales and Strips

Both biofiltration swales and strips (vegetated filter strips) are effective in removing debris and solid particles but operate by different mechanisms.

Biofiltration swales are shallow, gently sloping vegetated channels that receive directed flow and convey storm water designed for treating stormwater runoff in relatively small (less than 5 acres) sites of impervious surface. Pollutant removal is largely dependent on the length of time that water remains in the swale and the amount of contact between the flow, vegetation and soil surface. Fine, dense grasses generally perform better than other herbaceous plants. Due to climatic preferences of these grasses, biofiltration swales are not suited to continually wet or shaded areas and need to dry out regularly. If they are installed prior to site construction, they must be free of sediment and may need to be reseeded. Adequate upstream erosion control is necessary because they are designed for only modest sediment loads from stable sites. Runoff flows should be diverted around swales until grass is established and irrigation may be necessary.

Biofiltration strips (vegetative filter strip) are designed to direct stormwater runoff as overland sheet flow where vegetation (typically perennial grasses) has been established before leaving a site or entering a storm sewer system. Pollutants suspended in the runoff or attached to suspended soil particles are removed by filtration, absorption, and gravity sedimentation. For successfully functioning, filter strips need a dense stand of grass and assurance that only overland sheet flow crosses the strip to prevent concentrated flows. It is important to note that vegetative filter strips need to be situated between the pavement surface and a surface water collection system, pond, wetland, or river to correctly function.

Biostrip, Lake Tahoe Basin, courtesy of Caltrans

Bioswale, courtesy of Caltrans

5. Other Cultural Inputs for Successful Landscape Plant Establishment

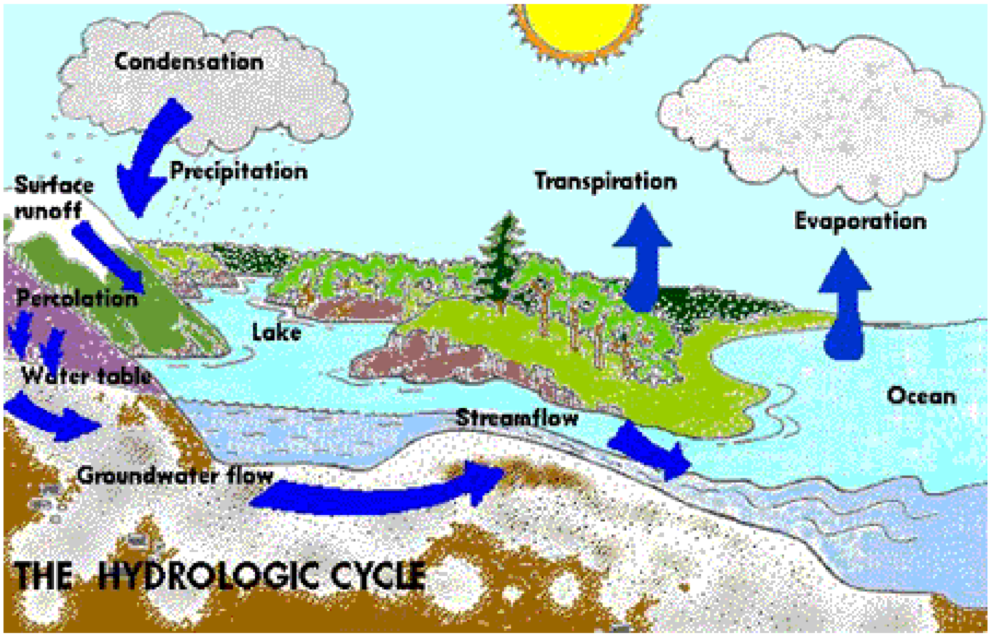
In addition to the virtues of compost use in the landscape, it is essential that other recommended cultural management practices be incorporated to ensure long term health and sustainability of landscape plantings. Following proper horticultural practices can significantly reduce the production of organic materials in landscape plantings. Implementing recommended irrigation, fertilization and other important management practices can also reduce the vegetative growth of turf and woody plants without sacrificing aesthetic appeal or performance. Adopting the techniques described below will enable landscape managers to achieve both goals.

5.1 Irrigation

Water is a valuable limited resource that is essential for life and required by all land plants. It is necessary for photosynthesis and other biochemical processes, cell turgidity and nutrient transport. Due to prolonged droughts, uncertainty of future Colorado River water supplies and state legislation limiting urban landscape water allocations, implementing sound water management practices to ensure the health and vitality of California's landscape and roadway plantings is critical.

The Water Cycle

Understanding the water cycle of plants is useful for developing effective irrigation schedules and for recognizing and correcting signs of drought stress. Water and minerals in the soil enter plants through the root system and are transported to shoots through the xylem (the water-conducting vascular system that extends from the roots to the leaves). Eventually, much of this water is returned to the atmosphere in the form of vapor, a process called transpiration. Water moves through a plant from a gradient of high to low water potential, initiated by leaf transpiration and culminating by water absorption by the roots. In addition to transpiration, water is also evaporated from the soil. The combination of evaporation of water from the soil surface and transpiration from the leaf surface is referred to as evapotranspiration (ET). The driving force behind this water (hydrologic) cycle is the sun.



Plant Water Use

Plants return large amounts of water to the atmosphere through ET. Water lost must be replaced to enable the plant to continue to grow and develop normally. On hot summer days, some trees lose a hundred gallons of water or more through this process. While ET rates vary among plant species, the process itself is driven by environmental factors.

The California Department of Water Resources operates a series of over 100 weather stations strategically placed in various climatic zones throughout California. This network is called the California Irrigation Management Information System (CIMIS). Each weather station estimates reference ET (ETo: the amount of water required over a given period of time by healthy 4-6" tall cool season grass) by an intricate formula that includes temperature, solar radiation, relative humidity and wind speed measurements.

From this information, a further estimate of water use can be made using the formula

ET (plant) = ETo x Kc (crop coefficient)

Crop coefficients vary, normally ranging from about .5 to .8 for most landscape plants and are significantly influenced by microclimate factors such as the density of the planting and shade. ETo is highest in the low elevation desert (averaging over 88 inches annually) and lowest in the San Francisco Bay area (averaging around 25 inches). Water demand in all locations follows a bell-shaped curve peaking during July and minimized during the winter, although coastal climates are more buffered and the curve is flatter with less variance throughout the year.

Drought Resistance and the Use of Native Plants

Due to a desire to conserve urban water, there has been increased interest in the use of drought resistant plants in recent years. Drought resistance reflects the ability of a plant to withstand less than optimal water supplies due to adaptive or avoidant mechanisms. Some plants adapt physiologically by closing stomata (small specialized pores on the leaf surface that regulate water vapor losses) to avoid water loss during high temperatures while others avoid stress by producing deep root systems that can absorb additional water. Still others possess morphological characteristics that prevent water loss, such as leaves that fold when stressed or silver or gray leaves that reflect light to reduce heat. Some plants avoid water stress through the production of thick cuticle layers or waxy leaf surfaces while others have leaves with minimal surface area such as needles. While many native plants possess drought resistant traits and require little supplemental irrigation once established, many mature non-natives thrive on low amounts of water, as well. Both native and introduced plants require water until established.

It is important to note that urban conditions no longer parallel those of decades ago when air pollution, reradiated heat and other detriments were less prevalent. Therefore, the most important consideration when choosing suitable plants is not whether they are native to California, but if they will perform well in a given climate, microclimate, and under the available maintenance level. Some non-natives perform as well or better than natives under adverse urban conditions and should not be ruled out. In addition, diversifying the landscape plant palette with many species can reduce the likelihood of widespread devastation from pathogens and insects that often prove opportunistic in monoculture plantings.

Signs of Drought Stress

Although plants vary in the amount of water they require for optimum growth and development, most exhibit characteristic symptoms when they are in need of water. Because stressed plants require water during the early stages of water deficit to prevent irreversible damage, it is crucial to check them regularly for symptoms of drought, preferably during the afternoon when symptoms are most evident. Common symptoms include: leaf wilt, curled and chlorotic (yellow) leaves that may fold and/or drop, new leaves that are smaller than normal, and dull turf that retains a footprint for a half hour or more.

Physiological wilt can occur on a hot, dry day even when there is adequate soil moisture if roots cannot absorb water fast enough to replace the water lost from leaves. Fortunately, afflicted plants generally recover during the evening when temperatures drop. Adding additional water during the day is not necessary and, in some cases, may prove detrimental by depriving roots of oxygen.

Other causes of symptoms mimicking water stress are vascular fungal diseases such as *Verticillium* spp.and *Fusarium* spp. Checking the level of soil moisture in the root zone of the plant is sometimes necessary to determine the cause of wilt. If soil is moist or the plant does not respond to watering within 24 hours, other causes should be suspected.

Water Infiltration and Movement in Soil

The movement of water into soil is called infiltration. The infiltration rate of a soil is the rate at which the water enters it. Water infiltration is largely determined by soil properties such as organic matter content, structure, and texture. Other factors that influence infiltration are surface cover, slope, and water quality. It is important to note that water movement within a soil also influences this process; water that is not able to move downward (permeate) prevents additional water from entering the soil surface. Soils or soil layers that do not conduct water effectively due to compaction and/or layering may become impermeable.

When the application rate of the irrigation system is greater than the infiltration rate of the soil, runoff occurs, potentially wasting large amounts of water. Conversely, if too much water is applied to a soil that drains freely, such as a sand-based soil, water may be lost below the root zone in a process called deep percolation. In either case, water quality can be impaired.

As discussed in Chapter 2, soil types (textures) largely determine the water holding and drainage capacity of a soil. A sandy soil will hold only about 1/4 to 1/6 as much water as a clay soil, and needs to be irrigated more frequently to prevent water stress. However, clay soils drain slower and are much more likely to become waterlogged and oxygen deprived. It is important to note that a plant growing in a clay soil requires just as much water as it does in a sandy soil.

Estimating Drainage and Depth of Water Penetration

Adequate soil drainage is an essential part of successful landscaping. To test drainage where a tree is desired, it is often useful to dig a 30" vertical hole and fill it with water. Wait 24 hours and fill the hole with water again. At this point, if the water level drops 2 inches or more in 2 hours, drainage is adequate. Once ornamentals are planted it is important to use a soil corer, trowel, or even a long handled screwdriver to determine how deeply water is penetrating and how long the rooting area stays moist.

'Best Management Practices' to reduce water waste and encourage healthy ornamentals

Hydrozone. Place plants with similar water requirements together to allow them to be watered on the same schedule. This allows the correct amount of water to be applied to individual plants at the right time, leading to healthier plants and less water waste.

Apply the right amount of water. In established plantings, over-watering and not allowing soil to dry out adequately between irrigations is often more problematic than under-watering. Clay soils that hold relatively high volumes of water and dry out slowly are particularly prone to over-watering. It is important to reduce the number of minutes programmed into the controller during the fall and winter when ET rates are lowest to reduce water waste and maintain healthy plantings. Even during summer when daily temperatures are high, plants are prone to over-watering. This usually occurs when a sprinkler system is not applying water evenly throughout the designated area, resulting in too much water being applied to portions of the planted area in an attempt to correct brown, drought-stressed areas not receiving enough water. Irrigation systems should be checked regularly for physical and operational problems, and 'can tests' should be conducted at least annually to measure distribution uniformity of applied irrigation water.

Water deeply and infrequently. Allowing soil to dry down adequately between irrigations is an excellent way of preventing disease-forming fungi from damaging plants. Watering plants as deeply as possible enables them to access a large reservoir of available water. While the genetic rooting potential of a plant cannot be altered, watering deeply encourages root systems to reach their maximum potential. Often, the environment is the limiting factor rather than genetics.

Water early in the morning when evaporation rates are lowest. Watering early in the morning before temperatures and wind increase can greatly reduce evaporative water loss. It is important to check irrigation systems regularly for broken components and leaks. In many cases, this requires running each cycle manually since the controller may be set for pre-dawn hours.

*Avoid deep percolation and runoff***.** Deep percolation is most likely to occur in sandy well-drained soils and results in water waste below the root zone of the plant. Applying water slowly and for shorter periods of time can significantly reduce deep percolation in coarse, sandy soils. Since clay soils hold more water than sandier ones and absorb it more slowly, they are more prone to runoff than to deep percolation. To prevent runoff in heavy soils, water should be applied at low rates as long as possible before runoff occurs.

Cycle water. Cycling water in heavy soils, compacted soils. or those on slopes is often useful. This process involves dividing the water that would normally be applied in a single irrigation into 2 or more shorter cycles, applied as closely together as possible when the soil is still moist. Water cycling should not be confused with allowing soil to dry down between 1 and several days between irrigations.

Water cycling can be very beneficial on slopes where the challenge is applying sufficient water to the upper plantings while preventing excess runoff at the base. Although avoiding runoff completely is almost impossible, it can be greatly reduced by cycling water. Water should be applied for 5 to 10 minutes every hour (or until the first sign of runoff), and the cycle repeated as many times as necessary to fill up the soil profile. High output sprinklers that apply water faster than it can be absorbed should be avoided. Sprinkler precipitation rates of over ½ inch per hour often lead to excessive runoff. Drip irrigation of ornamental plantings on slopes is highly recommended and allows water to be placed in the root zone and avoids runoff. Micro- and mini-sprinklers are excellent for this purpose, and apply water at a slower rate than conventional lawn sprinklers.

System maintenance

Irrigation systems should regularly be checked for leaks, broken heads, faulty valves, and other malfunctions. If there are brown spots in a turf or groundcover planting not caused by insects or diseases and a 'can test' indicates that water is not being applied evenly (low distribution uniformity), physical problems with the irrigation system are likely to blame. Common problems that can readily be identified and corrected are: broken sprinklers; unmatched sprinklers; poorly spaced sprinklers; sunken heads; crooked sprinklers; vegetation growing around heads; and, sand or debris plugging sprinklers. Correcting these problems can reduce water waste by 20-50% and greatly improve the health of the planting.

Water Management Strategies for Specific Types of Plants

Annuals and perennials. Newly planted beds of annuals and perennials require a relatively even supply of water until roots are established. Once established, they should be irrigated to a depth of at least 6 inches, allowing soil to dry out some between waterings. Large plantings of bedding annuals are difficult to maintain during a drought and may need to be sacrificed or the planting size reduced to enable watering more valued (and often more expensive) plantings if water restrictions necessitate prioritization.

Landscape trees. Newly planted container trees should be kept adequately moist the first season of establishment. As they mature, deeper and less frequent irrigation is preferred to a depth of 1 to 3 feet to encourage deep root systems and structural strength. Because tree roots spread laterally well beyond the dripline, it is important to irrigate outward as well as downward. The objective is to water slowly, to ensure that moisture extends into and just below the current root zone to encourage deep rooting. Watering mature trees for short periods of time encourages shallow rooting which can lead to water stress. Relying on turf sprinklers to adequately water trees should be avoided. Although trees vary in water demands, in general mature trees benefit from about 10 gallons of water per inch of trunk diameter during each watering during their growing season. It is important to keep tree trunks and foliage dry when watering to avoid diseases caused by water-borne pathogens. Turf and other plants should be kept at least 1 foot away from tree trunks to promote optimum tree growth, reduce competition for water, and avoid water-borne diseases. This also helps prevent tree damage from string weed trimmers (weed whips) and lawn mowers. It is particularly important to assure that trees adjacent to structures receive adequate water since reradiated heat increases water demand. For this reason, trees in large open landscaped areas and parks often require less water than those on the south or west sides of a structure with cement surroundings.

Turf. Cool-season grasses such as tall fescue, annual and perennial ryegrass, bluegrass and bentgrass require about 20 percent more water than warm season grasses such as bermudagrass, zoysiagrass and St. Augustinegrass. Increasing the effectiveness of an irrigation system can reduce water waste by 20-50% or more and improve health and performance of the turf planting. Even a properly designed system needs regular upkeep to water effectively. A common problem of turf sprinklers is uneven water application (poor distribution uniformity) resulting in brown spots. Water is wasted when a large turf area is watered to compensate for a few dry spots within the area caused from poor coverage. A better approach is to troubleshoot the cause of the poor uniformity. A few simple repairs and adjustments can save water, money, and frustration.

Conducting a 'can test' will determine both sprinkler output (precipitation rate) and distribution uniformity. If more than a 15 to 20% difference among the depths of water in individual cans is found, there are likely some significant problems with the irrigation system that need to be corrected to improve the evenness (uniformity) of the system. After fixing the problems, a second 'can test' should be conducted. Download a free copy of the University of California *Lawn Watering Guide* http://anrcatalog.ucdavis.edu/pdf/8044.pdf (publication #8044) for specific directions on how to conduct the test and how to schedule irrigations based on the climatic zone, species of turf, and precipitation rate of the irrigation system. The number of minutes to irrigate each week (based on monthly historical ETo) is listed for each climatic zone in California. If you are interested in irrigating based on 'real-time' ETo information, you may access the California Irrigation Information System (CIMIS) computerized weather station network (developed by University of California and managed by the CA Department of Water Resources) at http://wwwcimis.water.ca.gov.

Additional Ways to Save Water in Turf

- Water early in the morning to reduce evaporation
- Water turf separately from trees, shrubs, and groundcovers
- *Remove thatch in spring if it is more than 1/2 inch thick. Thatch should not be removed in the heat of the summer*
- Control weeds, which compete for water, light, and nutrients
- Fertilize moderately, applying the low end of recommended rates

- Aerate as necessary to improve water infiltration. Proper aeration requires removal of plugs. Clay soils often require aeration 2 or 3 times a season.

- Maintain the proper mowing height and remove no more than 1/3 of the height of the grass during each mowing.

- Compost

5.2 Plant Nutrition

During photosynthesis, plants use energy from the sun to convert carbon dioxide (CO_2) and water (H_2O) into 'plant food' (sugars and starches). This 'food' is combined with plant nutrients to produce proteins, enzymes, and other life-sustaining elements.

There are 9 essential elements required in relatively large amounts for plant growth that are referred to as macronutrients. They are: nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, carbon, hydrogen, and oxygen. The last three are readily available in air and water. Seven other essential elements required in small amounts by plants (micronutrients) are iron, manganese, zinc, boron, molybdenum, copper, and chlorine.

Nutrient deficiencies are uncommon in established landscape plantings other than palms. In fact, applying high rates of fertilizer may stimulate excessive, undesirable growth. Soils lacking adequate organic matter are very susceptible to nutrient deficiencies. Adding compost to these soils improves both nutrient content and retention, often alleviating the need for commercial fertilizers.

Composts used as soil amendments often contain a rich variety of macro and micronutrients as well as organic matter. While on a per-unit basis most composts do not contain the large quantities of nutrients found in commercial fertilizers, they often meet the nutritional needs of established landscape plantings due to the greater application rate.

The decision to augment the inherent fertility of a landscape soil should be based on how healthy the plants look and results of soil and/or tissue tests performed by a reputable laboratory. Symptoms of nutrient deficiencies include smaller than normal yellowish leaves and stunted shoot growth. Often, these symptoms are the result of other factors, including root or crown diseases resulting from over-watering, insect damage, or environmental problems. Correctly identifying the cause of the symptoms is crucial for optimum plant health and to prevent surface and groundwater pollution from unnecessary fertilizer applications.

Fertilizer applications are sometimes necessary for recently planted non-native landscape plantings and, again, should be based on the results of reputable soil and/or tissue tests (including a pH test). Plantings where compost with adequate nutrients has been added as a soil amendment are less likely to require augmentation. In cases where commercial fertilizer is warranted, application at the correct rate in the root-zone of the plant will likely remedy the problem.

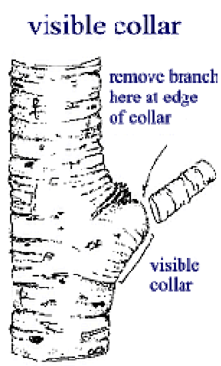
5.3 Pruning and Training Landscape Trees

Recently Planted Trees. Recently planted trees should not be heavily pruned but may require minor corrective pruning. The belief that trees should be pruned when planted to compensate for root loss is misguided. Instead, trees need to retain as much foliage as possible to provide necessary photosynthetic material for optimum shoot and root growth. While broken and damaged branches should be removed at planting, extensive pruning and training should take place over the next few years. Unpruned trees establish faster and develop stronger toot systems than trees pruned heavily at planting. Wound dressings are not recommended.

Young Trees. Training and pruning immature trees is essential for ensuring the development of mature trees with strong structures and desirable forms. Improperly pruned young, developing trees often require extensive corrective pruning in the future that could have been avoided. The International Society of Arboriculture (ISA) has developed pruning standards that lead to the development of healthy, safe, long-lived trees. Use of these standards is also important for reducing unnecessary greenwaste production.

Important 'Best Management Practices' for pruning trees include the following:

- Each cut has the potential to change the growth of the tree
- There should be a purpose for each cut
- Proper technique is essential. Improper or careless pruning can cause damage that extends over the life of the tree. It is important to know where and how to make cuts before beginning the process:



- Trees do no 'heal' the way people do. When a tree is wounded, it must compartmentalize the wound. Therefore, a small cut does less damage than a large cut. Waiting to prune a tree until it is mature can create the need for large cuts that cannot be easily compartmentalized.

Mature Trees. Pruning mature trees is important for functional and aesthetic purposes. Proper pruning based on principles of tree biology can maintain optimum tree health and structure and enhance the aesthetic and economic value of urban landscapes. In most cases, mature trees are pruned for corrective or preventive measures. Legitimate reasons are to remove dead, crowded, or poorly angled limbs; reduce potential hazards; and, to increase light and air penetration. While this type of general pruning can be done any time of year, tree growth is maximized and wound closure occurs most readily if pruning takes place before the spring growth flush. Heavy pruning just after this flush should be avoided to conserve energy and reduce stress. In some cases, the potential occurrence of disease spread certain times of year warrants pruning in a set season.

Routine thinning does not always improve the health of a tree. Removing large amounts of foliage can reduce growth and stored energy reserves, resulting in stressed trees. Pruning cuts should always be made just outside the branch collar; this protects trunk tissue that should not be cut into and needs to remain intact.

Appendix A: Tolerance of Plants to Soil Salinity

Table 1. Tolerance of landscape grass species to soil salinity.*

Botanical name	Common name	Tolerance to soil salinity (**)
Agropyron cristatum (L.) Gaertn.	Fairway Wheatgrass	M
Agropyron elongatum (host) Beauv.	Tall Wheatgrass	T
Agropyron intermedium (Host) Beauv.	Intermediate Wheatgrass	M
Agropyron sibiricum Willd.	Siberian Wheatgrass	M
Agropyron smithii Rydb.	Western Wheatgrass	M
Agropyron trachycaulum (Link) Malte	Slender Wheatgrass	M
Agrostis palustris Hunds.	Creeping Bentgrass	M
Agrostis palustris Hunds.	Creeping Bentgrass (Seaside variety)	M
Agrostis tenuis Sibth.	Colonial Bentgrass	M
Allopecurus pratensis L.	Meadow Foxtail	S
Arrhenatherum elatius Beauv.	Oat Grass	S
Bouteloua gracilis (H.B.K.) Lag.Ex Steud.	Blue Grama	M
Bromus carinatus Hook.et Arm.	California Brome	M
Bromus inermis Leyss.	Bromegrass, smooth	M
Bromus marginatus Nees	Bromegrass, mountain	M

Bromus unioloides Willd.	Rescue Grass	M
Buchloe dactyloides (Nutt.) Engelm.	Buffalograss	M
Chloris gayana Kunth	Rhodes Grass	M
Cynodon dactylon (L.) Pers.	Bermudagrass	T
Dactylis glomerata L.	Orchard Grass	S
Deschampsia caespitosa (L.) Beauv.	California Hairgrass	S
Deschampsia elongata (Hook) Munro ex Benth.	Slender Hairgrass	M
Distichlis spicata L. Greene.	Saltgrass	H
Elymus angustus Trin.	Altai Wildrye	T
Elymus canadensis L.	Canadian Wildrye	T
Elymus glaucus Buckl.	Blue Wildrye	M
Elymus junceus L.	Russian Wildrye	T
Elymus triticoides B uckl.	Beardless Wildrye	T
Eragrostis sp. Beauv.	Love Grass	S
Eremochloa ophiuroides (Munro) Hack.	Centipedegrass	M
Festuca arundinacea Schreb.	Tall Fescue	M
Festuca californica Vasey.	California Fescue	M
Festuca elatior L.	Meadow Fescue	M
Festuca longifolia Thuill.	Hard Fescue	M
Festuca rubra L.	Creeping Fescue	M
Leptochloa fusca (L.) Kunth (syn. Diplachne fusca Beauv.)	Kallargrass	T
Lolium multiflorum Lam.	Annual Ryegrass	S
Lolium perenne L.	Perennial Ryegrass	M
Melica californica Scribn.	California Melic	M
Muhlenbergia rigens Benth.	Deergrass	T
Panicum antidotale Retz.	Panicgrass	M

Paspalum dilatatum Vasey	Dallisgrass	S
Paspalum notatum Flugge.	Bahiagrass	M
Paspalum vaginatum L. (Seashore ecotype)	Seashore Paspalum	T
Phalaris arundinacea L.	Canarygrass	M
Phalaris tuberosa L.	Harding Grass	M
Phleum pretense L.	Timothy	S
Poa annua L.	Annual Bluegrass	S
Poa pratensis L.	Kentucky Bluegrass	S
Poa scabrella (Thurb.) Benth.	Pine Bluegrass	M
Poa trivialis L.	Rough Bluegrass	S
Puccinellia airoides Parl.	Alkaligrass	H
Sorghum sundanense (Piper) Stapf.	Sudangrass	M
Sporobolus airoides Torr.	Alkali Sacaton	H
Stenotaphrum secundatum (Walt) Kuntze.	St. Augustinegrass	M
Zea mays L.	Corn	S
Zoysia japonica Steud.	Zoysiagrass	M

Table 2. Tolerance of landscape tree species to soil salinity.*

Botanical name	Common name	Tolerance to soil salinity (**)
Acer rubrum L.	Red Maple	S
Albizia julibrissin Durazz.	Silk Tree	S
Araucaria heterophylla (Salisb.)	Norfolk Island Pine	T
Averrhoa carambola L.	Carambola, Starfruit	M
Bauhinia purpurea L.	Orchid Tree	M
Callistemon citrinus Curtis.	Lemon Bottlebrush	M
Carya illinoensis Koch.	Pecan	M
Cedrus deodara Don	Deodar Cedar	M

Celtis sinensis Pers.	Chinese Hackberry	S
Citrus limon L.	Lemon	S
Citrus paradisi Macf.	Grapefruit	S
Citrus reticulata Blanco.	Tangerine	S
Citrus sinensis Osbeck.	Orange	S
Coccoloba uvifera L.	Sea Grape	T
Cornus mas L.	Cornelian Cherry	S
Cotoneaster microphyllus Lindl.	Rockspray or Littleleaf Cotoneaster	M
Cupressus sempervirens L.	Italian Cypress	M
Diospyros digyna L.	Black Sapote	M
Diospyros virginiana L.	American Persimmon	S
Eriobotrya japonica Lindl.	Loquat	M
Euryops pectinatus	Golden Marguerite	S
Ficus carica L.	Edible Fig	T
Forsythia x *intermedia* Zabel	Forsythia	T
Fraxinus oxycarpa Bieb. Ex Willd.	Raywood Ash	M
Gingko biloba L.	Ginkgo	S
Grevillea robusta Cunn.	Silk Oak	T
Jacaranda mimosifolia D. Don.	Jacaranda	S
Juniperus silicicola Bail.	Southern Red Cedar	T
Juniperus virginiana L.	Skyrocket Juniper	T
Koelreuteria paniculata Laxm.	Golden Raintree	M
Lagerstoemia indica L.	Crape Myrtle	S
Ligustrum japonicum Thunb.	Japanese Privet	M
Liquidambar styraciflua L.	Sweet Gum	S
Litchi chinensis Sonn.	Lychee	S
Magnolia grandiflora L.	Southern Magnolia	S
Malus sylvestris Mill.	Crabapple	S
Mangifera indica L.	Mango	S
Manilkara zapota	Sapodilla	T
Musa acuminata Colla.	Banana	S

Olea europaea L.	Olive	S
Parthenium argentatum Gray.	Guayule	H
Persea Americana Mil.	Avocado	M
Pinus cembroides Zucc.	Mexican Pinon Pine	T
Pinus clausa Vasey	Sand Pine	T
Pinus elliottii Engelm.	Florida Slash Pine	M
Pinus halapensis Mill.	Aleppo Pine	M
Pinus thunbergii Parl.	Japanese Black Pine	M
Pistachia chinensis Bunge.	Chinese Pistache	S
Platycladus orientalis Franco	Oriental Arborvitae	M
Plumbago auriculata Lam.	Cape Plumbago	M
Plumeria spp. L.	Frangipani	T
Prunus armeniaca L.	Apricot	S
Prunus caroliniana Ait.	Carolina Laurel Cherry	S
Prunus dulcis D.A. Webb.	Almond	S
Prunus persica Batsch	Peach	S
Prunus spinosa L.	Blackthorn	M
Psidium guajava L.	Guava	S
Punica granatum L.	Pomegranate	M
Pyrus communis L.	Pear	L
Pyrus spinosa Forssk.	Almond Leaf Pear	M
Quercus agrifolia Nee	Coast Live Oak	T
Quercus laurifolia Michux	Laurel Oak	S
Quercus suber L.	Cork Oak	M
Quercus virginiana Mill.	Live Oak	T
Sapium sebiferum Roxb.	Chinese Tallow Tree	T
Schefflera actinophylla Harms	Schefflera, Umbrella Tree	M
Sequoia sempervirens Endl. Var: Aptos Blue	Coast Redwood	S
Sequoia sempervirens Endl. Var: Los Altos	Coast Redwood	M

Syzygium jambos Alston	Rose Apple	S
Ulmus parvifolia Drake	Chinese Elm	M
Ulmus parvifolia Jacq.	Chinese Elm	M

Palms

Acoelorrhaphe wrightii Becc.	Paurotis Palm	M
Butia capitata Becc.	Pindo Palm	T
Caryota mitis Lour.	Fishtail Palm	M
Chamaerops humilis L.	Mediterranean Fan Palm	T
Chrysalidocarpus lutescens Wendl.	Areca Palm	M
Nolina recurvata Hemsle	Ponytail Palm (not a true palm)	M
Phoenix carariensis Chabaud.	Canary Island Date Palm	M
Phoenix dactylifera L.	Date Palm	T
Phoenix reclinata Jacq.	Senegal Date Palm	M
Phoenix roebelinii O'Brien.	Pygmy Date Palm	M
Rhapis excelsa Henry	Lady Palm	M
Sabal palmetto Lodd.	Cabbage Palm	T
Serenoa repens Small	Saw Palmetto	T
Syagrus romanzoffiana L.	Queen Palm	M
Washingtonia robusta Wendl.	Mexican Fan Palm	T

Table 3. Tolerance of landscape shrub species to soil salinity.*

Botanical name	Common name	Tolerance to soil salinity (**)
Abelia grandiflora Rehd. Edward Goucher	Abelia	S
Acacia redolens Maslin.	Prostrate Acadia	T
Acalypha wilkesiana Muell.	Copper Leaf	S
Agave americana L.	Century Plant	T
Arctostaphylos densiflora M.S. Bac	Vine Hill Manzanita	T

Bambusa sp. Schreb.	Bamboo	M
Buddleja davidii Franch.	Butterfly Bush	S
Buxus microphylla Mull. Arg.	Japanese Boxwood	M
Calliandra haematocephala Hassk.	Powder Puff Tree	S
Callistemon rigidus R. Br.	Bottle Brush	M
Camellia japonica L.	Camellia	S
Canna x *generalis* Bailey.	Canna Lily	M
Carica papaya L.	Papaya	M
Carissa macrocarpa A. DC.	Natal Plum	T
Ceanothus thyrsiflorus Esch.	Blue Blossom	M
Cestrum aurantiacum Lindl.	Orange Cestrum	M
Codiaeum variegatum Blume.	Croton	S
Cornus mas L.	Cornelian Cherry	S
Cotoneaster congestus Baker	Pyrenees Cotoneaster	S
Cotoneaster microphylla Lindl.	Rockspray Cotoneaster	S
Dracaena deremensis Engler.	Dracaena	M
Elaegnus pungens Thunb.	Silverthorn, Silverberry	T
Escallonia rubra Pers.	Escallonia	M
Eugenia uniflora L.	Surinam Cherry	S
Euphorbia milii Ch. Des Moulins	Crown of Thorns	H
Euphorbia pulcherrima Willd.	Poinsettia	S
Euryops pectinatus L.	Golden Shrub Daisy	M
Forshthia x *intermedia* Zabel	Hybrid Forsythia	M
Gamolepis chrysanthemoides DC.	African Bush Daisy	T
Gardenia augusta Merrill	Cape Jasmine, Gardenia	M
Heliconia sp.	Heliconia	M
Hibiscus rosa-sinensis L.	Rose of China, Garden Hibiscus	M
Hydrangea macrophylla Ser.	Hydrangea	M
Ilex cornuta Burford	Chinese Holly	M
Ilex vomitoria Nana	Dwarf Yaupon Holly	T
Ilex vomiotoria Ait.	Yaupon Holly	T
Ixora coccinea L.	Ixora	S
Jasminum polyanthum Franch.	Jasmine	M
Jatropha multifida L.	Coral Plant	M

Justicia brandegeana Wassh.	Shrimp Plant	S
Lantana camara L.	Lantana	T
Mahonia aquifolium Nutt.	Oregon Grape	S
Mahonia pinnata Fedde	California Holly Grape	S
Murraya paniculata L.	Orange Jessamine	S
Myrica cerifera L.	Wax Myrtle	T
Myrtus communis L.	True Myrtle	T
Nandina domestica Thunb.	Heavenly Bamboo	S
Nerium oleander L.	Oleander	T
Opuntia sp. Miller	Opuntia Cactus	T
Parthenium argentatum Gray.	Guayule	H
Pentas lanceolata Deflers	Pentas, Egyptian Starcluster	S
Photinia fraseri Dress	Photinia	S
Photinia glabra Maxim.	Japanese Photinia	S
Pittosporum tobira Aiton	Mock Orange	T
Plumbago auriculata Lam.	Cape Plumbago	T
Podocarpus macrphyllus D. Don	Yew Pine	S
Pyracantha coccinea Roem.	Red Firethorn	M
Raphiolepis indica Lindl.	India Hawthorn	T
Rosa sp. L.	Rose	S
Russelia dquisetiformis Schlecht @ Cham.	Firecracker Plant	M
Sambucus callicarpa Greene	Coast Red Elderberry	M
Schefflera arboricola L.	Dwarf Schefflera	M
Strelitzia reginae Bankses Dryander	Bird of Pardise	M
Viburnum odoratissimum Ker.	Sweet Viburnum	M
Viburnum suspensum Lindl.	Sandankwa Viburnum	M
Yucca aloifolia L.	Spanish Bayonet	H

*Excerpted from Wu, L. and L. Dodge. 2005 Landscape Plant Salt Tolerance Selection Guide for Recycled Water Irrigation. Special Report for the Elvenia J. Slosson Endowment Fund. Dept. of Plant Sciences. University of California, Davis, CA, 95616.

** H: Highly tolerant (acceptable soil EC greater than 6 dS m^{-1}

T: Tolerant (acceptable soil EC greater than 4 and less than 6 dS m^{-1}

M: Moderately tolerant: acceptable soil EC greater than 2 and less than 4 dS m^{-1}

S: Sensitive: acceptable soil EC less than 2 dS m^{-1}.

Table 4. Relative yields of selected ornamentals at selected salt-index values.***

Plant Name	Scientific Name	Salinity effect threshold (dS/m)	% Yield decrease per subsequent dS/m increase
Sensitive			
Algerian ivy	*Hedera canariensis*	1.0	19 est.[1]
Burford holly	*Ilex cornuta*	1.0	23 est.
Heavenly bamboo	*Nandina domestica*	1.0	---
Hibiscus	*Hibiscus rosa-sinensis*	1.0	14 est.
Pittosporum	*Pittosporum tobira*	1.0	10 est.
Rose	*Rosa* spp.	1.0	---
Star jasmine	*Trachelospermum jasminoides*	1.6	20 est.
(Also in this group: burnet.)			
Moderately Sensitive			
Arborvitae	*Thuja orientalis*	2.0	10 est.
Bottlebrush	*Callistemon viminalis*	1.5	8 est.
Boxwood	*Buxus microphylla* var. japonica	1.7	10.8
Dodonaea	*Dodonaea*	1.0	7.8
Juniper	*Juniperus chinensis*	1.5	9.5
Lantana	*Lantana camara*	1.8	10 est.

Oleander	*Nerium oleander*	2.0	10 est.
Pyracantha	*Pyracantha bakeri*	2.0	9.1
Silverberry	*Elaeagnus pungens*	1.6	9 est.
Texas privet	*Ligustrum lucidum*	2.0	9.1
Viburnum	*Viburnum* spp.	1.4	13.2
Xylosma	*Xylosma senticosum*	1.5	13.3
Moderately Tolerant			
Alkali sacaton	*Sporobolus airoides*		
Dracaena	*Dracaena indivisa*	4.0	9.1
Euonymus	*Euonymus japonica* var. grandiflora	7.0	---
Tolerant			
Bougainvillea	*Bougainvillea spectabilis*	8.5	---
Rosemary	*Rosmarinus lockwoodii*	4.5	---
Bermudagrass	*Cynodon dactylon*	6.9	6.4
[1] est. = estimated slope. Slope may have been nonlinear or not reported. Use est. slopes with caution.			

*** Excerpted from Circular 1092, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Last Reviewed August 2002. **http://edis.ifas.ufl.edu**. E.A. Hanlon, center director and professor, Southwest Florida Research and Education Center; B.L. McNeal, Professor Emeritus, Soil and Water Science; and G. Kidder, professor, Soil and Water

Science, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611-0290.

Appendix B: Caltrans Overview

Caltrans Specifications

Caltrans is required to develop complete contract documents, consisting of specifications, plans and an estimate of cost prior to advertising a project. Specifications include a description of the work to be performed, materials, and construction activities that must be performed to achieve the desired work. Caltrans has developed a number of specifications that use organic materials, such as compost and mulch to help minimize storm water pollution and control erosion.

Standard Specifications

Standard specifications contain standard "boilerplate" requirements for bidding, constructing, and administering contracts that remain consistent from project to project. The *Standard Specifications Manual* is published and distributed every five years and is available on the internet at http://www.dot.ca.gov/hq/esc/oe/conststand.html.

Standard Special Provisions

Standard special provisions (SSPs) are specifications that may need to be modified for a particular project. SSPs supplement the contract language included in the Standard Specifications. For example, for a particular item of work, where the Standard Specifications might describe the strength of a mixture of concrete, the project SSPs would describe the finish, color or texture of the concrete used. Access the complete index of SSPs at: http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/SSPIndex/2006_Index.doc or http://www.dot.ca.gov/hq/esc/oe/conststand.html.

Nonstandard Special Provisions

Where unique project conditions require specific work not included in the Standard Specifications or SSPs, a nonstandard Special Provisions (NSSP) may be developed. Nonstandard specifications may not be used in a project without prior consent from the specification owner or technical expert for that work.

New Highway Planting and Highway Planting Restoration

Caltrans is responsible for design, construction and maintenance activities on over 230,000 acres of roadside. Caltrans uses compost and mulch materials as part of new highway planting and highway planting restoration projects. The process for programming new highway planting and restoration projects is primarily based upon criteria that rank proposed projects based upon purpose and need. The project development process includes the submittal of candidate projects by the district, field survey, development of an initial landscape concept and scope, preliminary cost estimate, district and headquarters collaboration, advertisement, award, project approval, and construction.

Caltrans Contract Process

Contractors interested in bidding upon new highway planting, highway planting restoration or erosion control contracts with Caltrans, should go to the Contractor Information website, located at: http://www.dot.ca.gov/hq/esc/oe/contractor_info/.

Selling Compost to Caltrans and its Contractors

A limited amount of compost is applied each year by Caltrans Maintenance staff as part of roadside maintenance activities. See Appendix C for a listing of Maintenance staff. Greater amounts of compost and mulch materials (approximately 16,000 cubic yards annually) are typically applied by erosion control or landscape contractors. See Appendix D for a list of erosion control and landscape contractors that frequently bid Caltrans work.

Compost producers looking to sell compost to Caltrans should be aware that Caltrans specifications now require the compost producer to participate in the United States Composting Council's Seal of Testing Assurance Program. Information on this program is available on the USCC website at http://www.compostingcouncil.org/index.cfm.

Appendix C: Caltrans Maintenance Landscape Specialists

Caltrans Districts

Caltrans Maintenance Landscape Specialists

District	Name/Mail Address	Phone
1	**Bob Melendez** 1656 Union Street P.O. Box 3700 Eureka, CA 95502	(707) 445-6391

2	**John Dobson** 1657 Riverside Drive P.O. Box 494040 Redding, CA 96049-4040	(530) 225-2460

3	**Duane Scheurer** 703 B St. P.O. Box 911 Marysville, CA 95901 **Walter Rilling** (same as above)	(530) 218-2392 (530) 740-4882
4 North Bay & Delta Region (Chemical Inventory Control)	**John Silva** 111 Grand Ave. P.O. Box 23660 Oakland, CA 94623-0660	(510) 715-6852
West Bay & South Bay Regions	**Ray Kwan** 111 Grand Ave. P.O. Box 23660 Oakland, CA 94623-0660	(510) 286-4410
Contra Costa and Alameda	**Vacant**	(510) 286-4412

5	**Roy Freer** 50 Higuera Street San Luis Obispo, CA 93401	(805) 549-3124

6	**Fred Steele** P.O. Box 12616 Fresno, CA 93778-2616	(559) 488-4143

7 (West & North Regions)	**Kit Flom** 4821 Adohr Lane Camarillo, CA 93012	(805) 383-8844
Landscape Architect	**Ed Siribohdi**	(213) 620-4746
	Tom Van Schaick	(760) 247-0433

8	**Mike Nakama** 464 W. 4th Street M.S. 1108 San Bernardino, CA 92401	(909) 877-9253

9	**Monty Packard** 500 South Main St. Bishop, CA 93514	(760) 872-0633

10	**Bill Nantt** 1604 South B Street, Bldg. #2 Stockton, CA 95201	(209) 948-7941

11	**Steve Davidson** 7183 Opportunity Rd. San Diego, CA 92111	(858) 467-3252

12	**David Perez** (interim)	(714) 974-8097
	Dan Clanton (interim coordinator)	(714) 685-3221
Headquarters Maintenance 1120 N Street, M.S. 31 Sacramento, CA 95814		
Linda Hamel		(916) 654-7078
Sheree Edwards		(916) 654-5784
Bruce Flaws		(916) 654-4465
Jennifer Malcolm (landscape specialist)		(916) 653-0086

Byron Pierce (landscape specialist)		(916) 654-4329
Wes Wilson (landscape specialist)		(916) 654-6070

Appendix D: Caltrans Erosion Control and Landscape Contractors

Note: Identification of individuals, companies, and products on the following list does not constitute endorsement by the California Integrated Waste Management Board. The Board publishes/distributes this information to increase public awareness and to build markets for compost and mulch products derived from materials collected in California jurisdictions. This list should not be considered comprehensive.

Company	Name	Address	Phone	E-mail
3-D Enterprises, Inc.	Shawn Elihu	2180 Garnet Ave., Suite 1A San Diego, CA 92109		
A B Hashmi, Inc.	Ahmad Hashmi	4347 Meadow Spring Way Oceanside, CA 92057	(760) 672-8059	Abhashmi_inc@hotmail.com
A J Diani Construction Company, Inc.		295 N. Blosser Road Santa Maria, CA 93456-0636		
Acacia Erosion Control		604 S San Marcos Rd. Santa Barbara, CA 93111		
ACCU Construction		23135 Beatty Road Perris, CA 92570	(951) 657-8200	
Aerco Pacific Inc.	Fred Habenicht	11370 Amalgam Way, Suite J Ranch Cordova, CA 95670	(916) 635-5635	
Aerco Pacific Inc.	Bob Houck	11370 Amalgam Way, Suite J Ranch Cordova, CA 95670	(916) 635-5635	rhouck@aercopacific.com
Allen L. Bender Inc.		2798 Industrial Blvd. West Sacramento, CA 95691		

America West Landscape, Inc.	Duanne Groen	P.O. Box 1698 Bellflower, CA 90707	(562) 803-6800	
Auburn Gardening and Landscape		P.O. Box 2080 Pollock Pines, CA 95726	(530) 941-4344	
Amland - American Landscape	Kevin Phan	3168 Knights Bridge Road San Jose, CA 95132	(510) 568-6828	
Belaire West Landscape, Inc.	Donavon Groen	P.O. Box 6270 Buena Park, CA 90622-6270	(714) 523-9200 x113	namw@belairewest.com
Brutoco Engineering	Jose Gonzalez	P.O. Box 429 Fontana, CA 92334	(909) 350-3535	bec@brutoco.net
Cagwin & Dorward	Charlie Thompson	P.O. Box 1600 Novato, CA 94948-1600	(800) 891-7710	charles.Thompson@cagwin.com
Cimarron Inc.		10424 Cimarron Trail Oakdale, CA 95361		
Cleary Bros Landscape Inc.	Mile Cleary	P.O. Box 3577 Danville, CA 94526	(925) 838-2551	mikec@clearybros.com
D W Powell Construction Inc.		P.O. Box 1406 Fontana, CA 92334-1406	(909) 356-8880	
Dietz Hydroseeding	Ron Dietz	15745 Kadota Street Sylmar, CA 91342-3520	(818) 364-7333	rdietz@dietzhydroseeding.com
Diversified Landscape Co.	Rick Bean	33801 Washington StreetWinchester, CA 92596	(951) 926-7444	rick@diversifiedlandscape.com
Diversified Landscape Co.	Anthony Rodriguez	33801 Washington Street Winchester, CA 92596	(951) 926-7444	
Elite Landscaping, Inc.	Glen Bennett	2972 Larkin Ave. Clovis, CA 93612-3916	(559) 292-7760	
Elite Landscaping, Inc.	Guy Stockbridge	2972 Larkin Ave. Clovis, CA 93612-3916	(559) 292-7760	guy@elitelandscaping.com

FCI Constructors Inc.	Dana Smola	2585 Business Park Drive Vista, CA 92083-8831	(760) 727-9767	
Forster & Kroeger Landscape Maint.	Raul Garcia	P.O. Box 184 Corte Madera, CA 94976	(415) 456-6684	
Forster & Kroeger Landscape Maint.	Chuck Kroeger	P.O. Box 184 Corte Madera, CA 94976	(415) 456-6684	
Freedlun Hydroseeding Inc.		518 Baywood Ct. Vacaville, CA 95688		
Genesis Paving and Landscape		13369 Dronfield Ave. Sylmar, CA 91342		
Ghilotti Bros. Construction, Inc.	Tom Barr	525 Jacoby Street San Rafael, CA 94901	(415) 454-7011	
Gold Valley Construction, Inc.	Mario Cruz	P.O. Box 1535 Rocklin, CA 95677		
Granite Construction Company	Patrick Amaris	P.O. Box 50085 Watsonville, CA 95077-5085	(831) 763-6100	
Hanford Applied Restoration		23195 Maffei Road Sonoma, CA 95476	(707) 996-6633	
Hydrogrow	Matt Swanson	4055A E Walnut Blvd. Visalia, CA 93292		
Hydrosprout Inc.	Mark Webster	460A Corporate Drive Escondido, CA 92029	(760) 432-8233	info@hydrosprout.com
Hydrosprout Inc.	Gregg Weed	460A Corporate Drive Escondido, CA 92029	(760) 432-8233	info@hydrosprout.com
J & M Land Restoration	John Juette	1640 James Road Bakersfield, CA 93308	(661) 872-7039	Johnjmland2@aol.com
J & M Land Restoration	Tony Paz	1640 James Road Bakersfield, CA 93308	(661) 872-7039	Jmland2@aol.com

J L Construction		P.O. Box 492381Redding, CA 96049		
Jet Mulch Inc.	Marlin Ensign	P.O. Box 1667 Capitola, CA 95010	(925) 250-5590	
Jet Mulch Inc.	Phil Reiker	P.O. Box 1667 Capitola, CA 95010	(925) 250-5590	reikerphil@yahoo.com
KCI Environmental	Jim Gorter	P.O. Box 3307 San Luis Obispo, CA 93403-3307	(805) 543-3311	jimg@kcienv.com
KCI Environmental	Ernie Peterson	P.O. Box 3307 San Luis Obispo, CA 93403-3307	(805) 543-3311	erniep@kcienv.com
Kelley Erosion Control, Inc.	Claudia J. Chambers	2395-B Tampa Street Reno, NV 89512	(775) 322-7755	czechreson@aol.com
Kelley Erosion Control, Inc.	Kym Kelley	2395-B Tampa Street Reno, NV 89512	(775) 322-7755	
KMF Construction		P.O. Box 5486 Shasta Lake, CA 96089		
Lone Star Landscape, Inc.	Bob Samaniego	1910 E. San Martin Avenue San Martin, CA 95046	(408) 682-0100	bob@lonestarland.net
M & S Environmental Landscapes, Inc.		12192 Macs Road Redding, CA 96003		
McEntire Landscaping	Gus McEntire	P.O. Box 419381 Redding, CA 96040	(530) 245-4590	
McEntire Landscaping	Terry Paseo	P.O. Box 419381 Redding, CA 96040	(530) 245-4590	
McGuire and Hester		9009 Railroad Ave. Oakland, CA 94603	(510) 632-7676	

McGuire Pacific Constructors	John McGuire	P.O. Box 4072 Auburn, CA 95604	(530) 888-0527	
Metamorphosis	Nina Lewis	1060-C Kaiser Road Napa, CA 94558	(800) 994-7333	nlewis@controlerosion.com
Metropole		1657 Wilson Ave. Upland, CA 91784	(909) 985-4814	
Nakae & Associates, Inc.	Jack Donahue	11501 Jeffrey Road Irvine, CA 92602	(949) 786-0405	
Nakae & Associates, Inc.	Russ Nakae	11501 Jeffrey Road Irvine, CA 92602	(949) 786-0405	
Native Landscape, Inc.	Debbie Fromme	9746 Tamarack LaneEscondido, CA 92029	(760) 735-8700	
Nature's Image, Inc.	Grady Banister	20472 Crescent Bay, Suite 102 Lake Forest, CA 92630	(949) 454-1225	lr@naturesimage.net
Neary Landscape Inc.		P.O. Box 249 Cotati, CA 94931	(707) 762-2799	
Nitta Construction, Inc.	Laura Bills	3778 Delmar Ave. Loomis, CA 95650-9051	(916) 652-7459	
Nitta Construction, Inc.	Bill Kuhl	3778 Delmar Ave. Loomis, CA 95650-9051	(916) 652-7459	
Nitta Construction, Inc.	Scott Nitta	3778 Delmar Ave. Loomis, CA 95650-9051	(916) 652-7459	nittahydroseeding@covad.net
Northstate Hydroseeding		8850 Old Oregon Ttl Redding, CA 96002		
Nye and Nelson, Inc.		1860 Eastman Ave. Ventura, CA 93003		

Oakhills Landscaping		4404 Flower Street Shasta Lake, CA 96019		
Odyssey Landscape Company, Inc.		800 W. Eight Mile Road Stockton, CA 95209		
P&D/EcoSystems Restoration Associates	Mike Ritenour	55 Sierra College Blvd. Lincoln, CA 95648		
Pacific Restoration Group, Inc.	Danny Richards	P.O. Box 77038 Corona, CA 92877-0101	(951) 734-9809	prconst@earthlink.net
Pacific Restoration Group, Inc.	John Richards	P.O. Box 77038 Corona, CA 92877-0101	(951) 734-9809	
Perma-Green Hydroseeding	Chuck Mitchell	8881 Muraoka Drive Gilroy, CA 95020-8026		
Proseed Landscape and Erosion control		967 Highway 128 Philo, CA 95466		
Reliable Tree Expert		2960 Chapman Street Oakdale, CA 94601		
Restoration Resources		3868 Cincinnati Ave. Rocklin, CA 95765	(916) 408-2990	
Reyco Smith & Reynolds	Rick Reynolds	7177 Brockton Ave. Riverside, CA 92506	(951) 787-1177	
Scheidel Contractors and Engineers	Carolyn Scheidel	P.O. Box 1796La Mesa, CA 91944		
Selby's Soil Erosion Control, Inc.	Dustin LaMantain	P.O. Box 2120 Loomis, CA 95650		
Selby's Soil Erosion Control, Inc.	Eric Van Der Welle	P.O. Box 2120 Loomis, CA 95650	(800) 578-2354	eric@selbysoil.com
Sunrise Consolidated Inc.		337 Preston Ct. Livermore, CA 94551		

Southern CA Hydroseed & Hydromulch	Mike Santoro	42396 Rio Nedo Temecula, CA 92590-3708	(951) 296-0650	
Stevens Creek Quarry, Inc.		12100 Stevens Canyon Road Cupertino, CA 95014		
Superior Hydroseeding	Morgan Kost	250 West Riverside Drive Watsonville, CA 95076-5106	(831) 763-1811	hydroseed@earthlink.net
T.B. Penick & Sons, Inc.	J C Valdez	9747 Olson Drive San Diego, CA 92121	(858) 558-1800	pattif@tbpenick.com
TCB/P & D Landscape	Cliff Bice	999 Town & Country Road, 4th Floor Orange, CA 92868	(714) 835-4447	Cliff.bice@tcb.aecom.com
Terra-Cal Construction		14530 Joanbridge Street Baldwin Park, CA 91706	(310) 589-9402	
Thunder Mountain Enterprises, Inc.	James Chincholo	P.O. Box 292821 Sacramento, CA 95829	(916) 281-3400	dsmiley@tme1.com
Tiffany Group, Inc.		5530 Corbin Ave. Tarzana, CA 91356	(818) 342-0330	
Truxell & Valentino Landscape Development, Inc.	John Valentino	3661 N. Highland Clovis, CA 93619		
Valley Crest Landscape Development, Inc.	Mary Jean Hallem	8450 Miramar Place San Diego, CA 92121	(858) 458-9900	
Valley Crest Landscape Development, Inc.	Mike Lyons	8450 Miramar Place San Diego, CA 92121		
Viking Construction Company	Randy Jenco	1105 D Folsom Blvd. Rancho Cordova, CA 95670		
Watkin & Bartolussi, Inc.	Phil Bortolussi	77 Larkspur Street San Rafael, CA 94901	(415) 453-4691	admin@wabo.com

Western Rim Constructors, Inc.		912 S. Andreasen Drive, Suite 108 Escondido, CA 92029	(760) 489-4328	

Bibliography

Alexander, R. 1999. Compost markets grow with environmental applications. BioCycle. 40(4):43-44, 46, 48.

Baldwin, K.R. and J.E. Shelton. 1999. Availability of heavy metals in compost-amended soil. Bioresour. technol. 69(1):1-14.

Bary, A.I., C.G. Cogger, and E.A. Myhre. 2004. Yard trimmings as a source of nitrogen for crop production. Compost sci util. 12(1):11-17.

Bernal, M.P., C. Paredes, M.A. Sanchez-Monedero, and C. Cegarra. 1998. Maturity and stability parameters of composts prepared with a wide range of organic wastes. Bioresour. technol. 63(1): 91-99.

Boulter, J.I., J.T. Trevors, and G.J. Boland. 2002. Microbial studies of compost: bacterial identification, and their potential for turfgrass pathogen suppression. World j. microbial. biotechnol.18(7):661-671.

Block, D. 2000. Controlling erosion from highway projects. BioCycle. 41(1):59-62.

Block, D. 1999. Quality compost from the end users' perspective. BioCycle. 40(11): 56-58.Block, D. 1999.

Composting for erosion control in Texas. BioCycle. 40(9):40-41.

Block, D. 1999. Compost plays role in riverfront restoration. BioCycle. 40(8):26-29.

Boyette, R.A. 1998. Getting down to (biofilter) basics. BioCycle. 39(5):58-62.

Bresson, L.M., C. Koch, Y. Le Bissonnais, E. Barriuso, and V. Lecomte. 2001. Soil surface structure stabilization by municipal waste compost application. Soil sci. soc. Am. j. 65 (6).

Brown, K.W., J.C. Thomas, and F. Whitney. 1997. Fate of volatile organic compounds and pesticides in composted municipal solid waste. Compost sci. util. 5(4): 6-14.

Butler, T.A., L.J. Sikora, P.M. Steinhilber, and L.W. Douglass. 2001. Compost age and sample storage effects on maturity indicators of biosolids compost. J. environ. qual. 30(6): 2141-2148.

Burger, D.W., T.K. Hartz, and G.W. Forister. 1997. Composted green waste as a container medium amendment for the production of ornamental plants. HortScience. 32(1): 57-60.

Buyuksonmez, F., R. Rynk, T.F. Hess,and E. Bechinski. 1999. Occurrence, degradation and fate of pesticides during composting. Compost sci. util. 7(4): 66-82.

Canet, R, F. Pomares., R. Albiach., F. Tarazona., M.A. Ibanez, and F. Ingelmo. 2000. Analyzing chemical properties of MSW composts. BioCycle 41(12):72, 74-76.

Ceuster, T.J.J. and H.A.J. Hoitink. 1999. Using compost to control plant diseases. BioCycle. 40(6):61-64.

Chong, C. 2000. Relationship of soluble salts content in MSW compost media and rooting of evergreen cuttings. Compost sci. util. 8(1):29-35.

Ciba, J., T. Korolewicz, and M. Turek. 1999. The occurrence of metals in composted municipal wastes and their removal. Water air soil pollut. 111 (1/4):159-170.

Claassen, V. and J. Carey. 2004. Regeneration of nitrogen fertility in disturbed soils using composts. Compost sci util. 12(2):145-152.

Claassen, V. 2000. Compost demonstration project, Placer County final report: Use of compost and co-compost as a primary erosion control material. http://www.ciwmb.ca.gov/Publications/Organics/44399018.doc

Cogger, C.G. 2005. Potential compost benefits for restoration of soils disturbed by urban development. Compost sci util. 13(4):243-251.

Compost use on state highway applications. Updated Feb. 2006. US EPA. http://www.epa.gov/epaoswer/non-hw/compost/highway/

Cuevas, G., R. Blazquez, F. Martinez, and I. Walter. 2000. Composted MSW effects on soil properties and native vegetation in a degraded semiarid shrubland. Compost sci. util. 8 (4):303-309.

Day, M., M. Krzymien. K. Shaw, L. Zaremba, W.R. Wilson, C. Botden, and B. Thomas. 1998. An investigation of the chemical and physical changes occurring during commercial composting. Compost sci. util.. 6 (2):44-46.

Demars, K.R., R.P. Long, and J.R. Ives. Erosion control using wood waste materials. Compost sci util. 12(1): 35-47.

Eftoda, G. and D. McCartney. 2004. Determining the critical bulking agent requirement for municipal biosolids composting. Compost sci util. 12(3):208-218.

Eggen, T. and O. Vethe. 2001. Stability indices for different composts. Compost sci.util. 9(1):19-26.

Ekinci,. K., H.M. Keener, F.C. Michel, Jr., and D.L. Elwell. 2004. Modeling composting rate as a function of temperature and initial moisture content. Compost sci util. 12(4):356-364.

Emino, E.R. and P.R. Warman. 2004. Biological assay for compost quality. Compost sci util. 12(4):342-348.

Faucette, B., L.M. Risse, M.A. Nearing, J.W. Gaskin, and L.T. West. 2004. Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall J soil and water cons. 59(4):154-160.

Faucette, B. and M. Ruhlman. 2004. Stream bank stabilization utilizing compost. BioCycle. 45(1):27.

Faucette, B, W. King, and P. Germishuizen. 2003.. Compost-based erosion and sediment control demonstrations. BioCycle. 44(10):32-34.

Fauci, M., D.F. Bezdicek, D. Caldwell, and R. Finch. 2002. Development of plant bioassay to detect herbicide contamination of compost at or below practical analytical detection limits. Bull. environ. contam. toxicol. 68 (1):70-85.

Fauci, M.F., D.F. Bezdicek, D. Caldwell, and R. Finch. 1999. End product quality and agronomic performance of compost. Compost sci. util. 7(2):17-29.

Foseid, J. 2000. Certifying compost to increase markets. BioCycle. 41(6): 62-63.

Francou, C. M. Poitrenaud, and S. Houot. 2005. Stabilization of organic matter during composting: influence of process and feedstocks. Compost sci util. 13(1):72-83.

Gan, J., S.R. Yates, S. Papiernik, and D. Crowley. 1998. Application of organic amendments to reduce volatile pesticide emissions from soil. Environ. sci. technol. 32 (20):3094-3098.

Gerke, H.H., M. Arning, and H. Stoppler-Zimmer. 1999. Modeling long-term compost application effects on nitrate leaching. Plant soil 1999.213 (1/2):75-92.

Glanville, T.D., R.A. Persyn, T.L.. Richard, J.M. Laflen, and P.M. Dixon. 2004. Environmental effects of applying composted organics to new highway. Transactions of the ASAE. 47(2):471-478.

Glanville, T.D., T.L. Richard, and R.A. Persyn. 2003. Evaluating performance of compost blankets. BioCycle 44(5):48-54.

Glanville, T.D., T.L Richard, and R.A. Persyn. 2003. Impacts of compost blankets on erosion control, revegetation and water quality at highway construction sites in Iowa, (Executive summary of 3-yr project sponsored by IA Dept. of Natural Resources and IA DOT. project website: www.abe.iastate.edu/compost

Goldstein, N. 1999. Longer life for biofilters. BioCycle. 40(7):62.

Goldstein, N. 1999. Screening compost for market. BioCycle. 40(1):56-58.

Goldstein, J. 1997. Monitoring compost process and quality. BioCycle. 38(7):48-49.

Grey, M. and C. Henry. 1999. Nutrient retention and release characteristics from municipal solid waste compost. Compost sci util. 7(1):42-50.

Grundy, A.C., J.M. Green, and M. Lennartsson. 1998. The effect of temperature on the viability of weed seeds in compost. Compost sci util. 6(3):26-33.

Hallock, B., A. Power, S. Rein, and M. Scharff. 2004. Performance of Erosion Control Treatments and Native Vegetation on Reapplied Topsoil. Intl. Eros. Cont. Assoc.

Harrison, E. D. Olmstead,J. Bonhotal. 2003. What's behind a compost label or seal? BioCycle. 44(9)28-30.

Hartin, J., M. Henry, and A. Harivandi. 2001.Reusing clippings to improve turfgrass health and performance. Turfgrass trends. 10 (2):10-13.

Hartin, J., D. Pittenger, and J.M. Henry. 2000. Basic plant management techniques. 1. Turfgrass trends. 9(11):1-8.

Hartin, J., D. Pittenger, and J.M Henry. 2000. Best management practices. 2. Turfgrass trends. 9(12):1-7.

Hartz, T.K. and C. Giannini. 1998. Duration of composting of yard wastes affects both physical and chemical characteristics of compost and plant growth. HortScience. 33 (7):1192-1196.

Haynes, J. 1997. Applying compost and mulches to control erosion. BioCycle. 38(5):55-57.

Helfrich, P., B. Chefetz, Y. Hadar, Y. Chen, and H. Schnabl. 1998. A novel method for determining phytotoxicity in composts. Compost sci. util. 6(3):6-13.

Hue, N.V. and B.A. Sobieszczyk. 1999. Nutritional values of some biowastes as soil amendments. Compost sci. util. 7(1):34-41.

Innovative uses of compost bioremediation and pollution prevention. 1997. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. Washington, D.C. 6 p.

Johnson, G.A., Y.L. Oian, and J.G. Davis. 2006. Effects of compost topdressing on turf quality and growth of Kentucky bluegrass. Applied turfgrass science. Plant management network. 2006.

Jones, K.D. and C. Banuelos. 2000. Using compost/wood chip material as biofiltration media. BioCycle. 41(10):50-52.

Klock, K.A. 1997. Growth of salt sensitive bedding plants in media amended with composted urban waste. Compost sci. util.5(3):55-59.

LeStrange, M., P. Elam, and R.D. Meyer. 1998. Topdressing compost on turfgrass: its effect on turf quality and weeds. Proc. annu. Calif. weed sci. soc. 50:28-31.

Levenson, H. and W.R. Orr. Managing organic residuals in California. 2000. BioCycle. 41(10):36-38, 40, 42, 44-45.

Li, Y.M., R.L. Chaney, G. Siebielec, and B.A. Kerschner. 2000. Response of four turfgrass cultivars to limestone and biosolids-compost of a zinc and cadmium contaminated soil at Palmerton, Pennsylvania. J. environ. qual. 29(5):1440-1447.

Linde, D.T. and L.D. Hepner. 2005. Turfgrass seed and sod establishment on soil amended with biosolid compost. HortTechnology. 15(3):577-583.

Linderman, R.G. and E.A. Davis. 2006. Survival of *Phytophthora ramorum* compared to other species of *Phytophthora*. HortTechnology. 16(3):502-507.

Logan, T.J., C.L. Henry, J.L. Schnoor, M. Overcaswh, and D.C. McAvoy. 1999. An assessment of health and environmental risks of trace elements and toxic organics in land-applied municipal solid waste compost. Compost sci. util. 7(3):38-53.

Mamo, M., C.J. Rosen, and T.R. Halbach. 1999. Nitrogen availability and leaching from soil amended with municipal solid waste compost. J. environ. qual. 28 (4):1074-1082.

Michel, F. 1999. Managing compost piles to maximize natural aeration. BioCycle. 40(3):56-68.

Mitchell, D. 1997. State transportation departments expand compost use. BioCycle 38(7):75-80.

Mo, S. 2000. Production and application of organic materials as fertilizers. J. crop prod. 2000. 3(1):23-39.

Movahedi, Naeini and H.F. Cook. 2000.Influence of municipal waste compost amendment of soil water and evaporation. Commun. soil sci. plant anal. 2000.31(19/20):3147-3161.

Ozores-Hampton, M. 1998. Compost as an alternative weed control method. HortScience. 33(6): 938-940.

Paplomatas, E.J., A.A. Malandrakis, and P.A. Nektarios. 2004. Compost management of brown patch disease in turfgrass. Acta horticulturae. 661: 487-489.

Persyn, R.A., T.D. Glanville, T.L. Richard, J.M. Laflen, , and P.M. Dixon. 2006. Environmental effects of applying composted organics to new highway embankments. III. Rill erosion. Transactions of the ASAE. 48(5):1765-1772.

Persyn, R.A., T.D. Glanville, T.L.. Richard, J.M. Laflen, and P.M. Dixon. 2004. Environmental effects of applying composted organics to new highway embankments. 1. Interrill runoff and erosion. Transactions of the ASAE. 47(2):463-469.

Pickering, J.S. and A. Shepherd. 2000. Evaluation of organic landscape mulches: composition and nutrient release characteristics. Arboric. j. 24(2/3):175-187.

Pickering, J.S., A.D. Kendle, and P. Hadley. 1998. The suitability of composted green waste as an organic mulch: effects on soil moisture retention and surface temperature. Acta hortic. 469:310-324.

Prasad, M. and M.J. Maher. 2001. The use of composted green waste (CGW) as a growing medium component. Acta horticulturae. 549:107-113.

Rainbow, A. 1999. Restoring landscape with acidified compost. BioCycle. 40(6):74.

Rainbow, A. and N. Wilson. The transformation of composted organic residues into effective growing media. Acta hortic. 469:79-88.

Raviv, M. 1998. Horticultural uses of composted material. Acta hortic. 469:225-234.Reinikainen, O. and M. Herranen. 2001. Different methods for measuring compost stability and maturity. Acta hortic 549:99-104.

Riahi, H. and J. Fakhari. Physical, chemical and biological studies of municipal compost. Acta hortic. 644:145-150.

Risse, Mark, and Britt Faucette. 2001. Compost Utilization for Erosion Control. Bulletin #1200, Cooperative Extension Service, The University of Georgia College of Agricultural and Environmental Sciences.

Saebo, A. and F. Ferrini. 2006. The use of compost in urban green areas - A review for practical application. Urban forestry & urban greening. 4(3-4):159-169.

Schaub-Szabo, S.M. and J.J. Leonard. 1999. Characterizing the bulk density of compost. Compost sci. util. 7(4):15-24.

Seekins, B. 1999. Troubleshooting the compost pile. BioCycle. 40(12):58-59.

Semple, K.T., B.J. Reid, and T.R. Fermor. 2001.Impact of composting strategies on the treatment of soils contaminated with organic pollutants. Environ. pollut. 112 (2):269-283.

Sikora, L.J. and N.K.Enkiri. 2000. Efficiency of compost-fertilizer blends compared with fertilizer alone. Soil sci. 165 (5):444-451.

Sikora, L.J. and N. Enkiri. 1999. Fescue growth as affected by municipal compost fertilizer blends. Compost sci. util. 7(2):63-69.

Sikora, L.J. and N.K. Enkiri. 1999. Growth of tall fescue in compost/fertilizer blends. Soil sci.164(1):62-69.

Sikora, L.J. 1998. Nitrogen availability from composts and blends of composts and fertilizers. Acta hortic. 469:343-351.

Stoffella, P.J., Ozores-Hampton, M., and D.T. Patterson. 2000. Potential of municipal solid waste compost as a biological weed control. Acta hortic. 533:211-213.

Stratton, M.L., A. Barker, and J. Ragsdale.2000. Sheet composting overpowers weeds in restoration project. BioCycle. 41(4):57-59.

Strom, P.F. 2000.Pesticides in yard waste compost. Compost sci. util. 8(1):54-60.

Sumner, M.E. 2000. Beneficial use of effluents, wastes, and biosolids. Communl. Soil sci. plant anal. 31(11/14):1701-1715.

Valenzuela-Solano, C. and D.M. Crohn. 2006. Are decomposition and N release from organic mulches determined mainly by their chemical composition? Soil bio and biochem. 38(2):377-384.

Verdonck, O. 1998. Compost specifications. Acta hortic. 469:169-177.

Walker, P., D. Williams, and T.M. Waliczek. 2006. An analysis of the horticulture industry as a potential value-added market for compost. Compost sci util. 14(1):23-31.

Warman, P.R. 1999. Evaluation of seed germination and growth tests for assessing compost maturity. Compost sci. util. 7(3): 33-37.

Wu, L., L.Q. Ma, and G.A. Martinez. 2000. Comparison of methods for evaluating stability and maturity of biosolids compost. J. environ. qual. 29 (2):424-429.

Resources

Books

Stoffella, Peter J. and Brian A. Kahn. 2001. Compost utilization in horticultural cropping systems**.** Lewis publishers, Boca Raton, FL. 414 p.

Dougherty, Mark (ed). Field guide to on-farm composting. 1999. Cornell University. Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Ithaca, NY. 118 p**.** Available from: www.nraes.org/publications/nraes114.html

EPSTEIN, E. 1997. THE SCIENCE OF COMPOSTING, TECHNOMIC PUBL.CCO., INC., LANCASTER, PA.

Hoitink, Harry, and Harold Keener (eds.). 1993. Science and engineering of composting: design, environmental, microbiological and utilization aspects. Proceedings of 1992 composting research symposium. Worthington, OH: Renaissance publications.

Insam, Heribert. 2002. Microbiology of composting. 2002. Springer pub. 632 p.

Magdoff, F., and H. Van Es. 2000. Building soils for better crops (2nd Edition). Handbook series book 4. Sustainable agriculture network. Beltsville, MD: National agricultural library. Available from: www.sare.org/publications/index.htm; pdf version also available online (4.0 MB).

Rynk, Robert, Maarten van de Kamp, George B. Wilson, Mark E. Singley, Tom L. Richard, John J. Kolega, Francis R. Gouin, Lucien Laliberty, Jr., David Kay, Dennis W. Murphy, Harry A. J. Hoitink, William F. Brinton. 1992. On-Farm composting handbook. Natural resources, agriculture, and engineering service (NRAES) publication #NRAES-54. Available from: www.nraes.org/publications/nraes54.html

Tyler, Rodney W. Winning the organics game: The compost marketer's handbook**.** 1996. ASHS Press, Alexandria, VA. 269 p.

Van Horn, Mark. 1995. Compost production and utilization: A grower's guide. publication #21514. Oakland, CA: University of California, division of agriculture and natural resources. Available from: anrcatalog.ucdavis.edu/

Cooperative Extension Publications

University of California Agricultural and Natural Resources publications. www.anrcatalog.ucdavis.edu

Cornell University Composting**.** http://compost.css.cornell.edu/Composting_homepage.html

University of Florida: compost.ifas.ufl.edu/Default.htm

Louisiana State University: www.agctr.lsu.edu/wwwac/compost/index.html

Natural Resource, Agriculture, and Engineering Service (NRAES). (Consortium of several northeastern states) www.nraes.org/publications/

North Carolina Cooperative Extension: http://www.ces.ncsu.edu/Publications/commercialhort.php

University of Minnesota (search: compost) www.extension.umn.edu/

Texas A & M: (search: compost) www-horticulture.tamu.edu:8080/search.html

Organizations and Government Resources

California Integrated Waste Management Board: www.ciwmb.ca.gov/Organics

California Compost Quality Council: www.crra.com/ccqc/ccqchome.htm

California Department of Transportation: http://www.dot.ca.gov/

U.S. Composting Council: www.compostingcouncil.org/

Association of Compost Producers: www.healthysoil.org/

US EPA Solid Waste Management: Composting Resources: www.epa.gov/epaoswer/non-hw/compost/

USDA National Organic Program (under Regulations/Standards and Guidelines): www.ams.usda.gov/nop/indexIE.htm

ATTRA - National Sustainable Agriculture Information Service http://attra.ncat.org/who.html

American Association of State Highway & Transportation Officials (AASHTO): http://www.transportation.org/

International Erosion Control Association: http://www.ieca.org/

California Stormwater Quality Association (CASQA): http://www.casqa.org/

Texas Department of Transportation (search ‘compost’): http://www.dot.state.tx.us/

Wisconsin Department of Transportation (search ‘compost’): http://www.dot.state.wi.us/

Composting Council of Canada: http://www.compost.org/

Trade Magazines

BioCycle
419 State Ave.
Emmaus, PA 18049
610-967-4135
610-967-1345 FAX
biocycle@jgpress.com
www.jgpress.com

Soil Erosion & Hydroseeding
6925 Canby Avenue, Suite 102
Reseda, CA 91335
Ph: 818-342-3204
Fax: 818-342-0731
Email**:** ira@soilerosiononline.com
http://www.soilerosiononline.com

Erosion Control Online
Forester Communications, Inc.
P.O. Box 3100
Santa Barbara, CA 93130
Ph: 805-682-1300
Email: eccirculation@forester.net
http://www.erosioncontrol.com/ecm_contact.html

Technical Journals

Compost Science & Utilization
419 State Ave.
Emmaus, PA 18049
Ph: 610-967-4135
Fax: 610-967-1345
biocycle@jgpress.com
www.jgpress.com