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Compost and Vegetation Establishment Technical Memorandum

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1. Introduction

This draft Technical Memorandum (TM) evaluates the effects of compost on the establishment of vegetation, as defined in the Scope of Work for Task Order No. 51 – Statewide Compost Reconnaissance Study. The primary goal of the study is to identify the risks and benefits of compost use as a standard California Department of Transportation (Caltrans) best management practice (BMP), address concerns on compost use stemming from Water Quality Objectives, identify the most appropriate and effective application methods and rates, and research the use of compost to achieve long-term low impact development (LID) goals outlined by the State Water Resources Control Board (SWRCB).

Compostable organics can increase soil porosity and water-holding capacity, improve soil structure and fertility, improve infiltration, reduce runoff, reduce erosion, and, as a result, improve water quality. Established vegetation also reduces erosion and can slow runoff and helps increase water quality through increased infiltration and filtration. Traditional methods for implementing and establishing vegetation for transportation projects include hydroseeding and container planting. However, there is evidence that the use of compost is very beneficial for facilitating the establishment of vegetation.

The purpose of this TM is to use available research to evaluate the effect that compost has on the establishment of vegetation in different site conditions (e.g., problem soils), to compare compost and commercial fertilizer applications, and assess the short-term versus long-term effects of compost on vegetation establishment.

The TM is organized as follows:

- Section 2 presents a background summary.
- Section 3 describes how compost is used in the establishment of vegetation both in the short and long term. Additional case studies describe vegetation establishment for cut and fill slopes and difficult environmental sites.
- Section 4 compares the use of compost and commercial fertilizer for vegetation establishment.
- Section 5 describes the pollutant removal qualities of bioremediation systems based on compost established vegetation.
- Section 6 provides a summary of findings.
- Section 7 includes a list of references.

2. Background

Compost originates from various organic sources, also known as feedstock materials, including green waste, food waste, manure, biosolids (treated sewage sludge), paper pulp, agricultural crop residues, and mixed solid wastes. Composting is the controlled biological process of decomposition and recycling of organic material into a humus-rich soil amendment known as compost. Compost has a variety of uses and is known to improve soil quality and productivity as well as prevent and control erosion, thereby improving the quality of water in stormwater runoff. Mixed organic materials (e.g., manure, yard trimmings, food waste, biosolids) must go through a controlled heat process before they can be used as high-quality, biologically stable, and mature compost (otherwise it is just mulch, manure, or byproduct).

The process of composting takes the raw source materials and stabilizes them under controlled conditions. Stabilizing the material takes the nutrients, such as nitrogen, and ties them up in the compost's organic matter. The nutrients are slowly released over time, increasing the opportunity for uptake by plants and potentially reducing downstream water pollution problems. For that reason composting is recognized as a BMP by the U.S. Environmental Protection Agency's (EPA's) Non Point Source Program (EPA 2003).

Compost application has previously been considered for use as a standard BMP by Caltrans and other private and public entities; however, several barriers prevented this from occurring. In 2005, the California Integrated Waste Management Board (CIWMB) partnered with Caltrans; the University of California, Riverside Extension; the Association of Compost Producers; the U.S. Composting Council; UC Cooperative Extension; Filtrexx; and Soil Control Laboratories to identify and address the barriers preventing Caltrans from maximizing the use of compost. Working together, these various stakeholders developed a suite of compost specifications (Caltrans 2008).

The barriers to standard use of these specifications by Caltrans includes the cost-effectiveness of the outlined application rates and methods, lack of guidance for quality control (including water quality impact and agronomic analyses), and continued concern from the SWRCB and Regional Water Quality Control Board (RWQCB) for water quality standard exceedance (particularly pertaining to biosolids and pathogens). This TM will summarize the use of compost to facilitate the establishment of vegetation under different environmental conditions and the potential implications on water quality. Water quality is discussed in greater detail in the complementary Technical Memorandum on Compost and Water Quality.

3. Vegetation Establishment on Cut and Fill Slopes

Slopes adjacent to constructed freeways are typically comprised of disturbed compacted soils which can be difficult to vegetate, particularly on cut slopes, due to compromised soil structure and reduced pore space. However, establishing vegetation on disturbed sites is a very effective means of stabilizing soil and reducing accelerated erosion. Vegetation is also the most cost-effective means of controlling sheet and rill erosion on disturbed sites. Compost can also provide longer term erosion prevention by providing a substrate for seed growth, conserving moisture, suppressing weeds, and reducing and delaying runoff. While the presence of some constituents in compost causes concern about pathogens being discharged into receiving waters, their presence also facilitates the acceleration of plant growth (D.E. Rider, M.J. Curtis and V. P. Claassen, ND).

Revegetation can take many forms, from establishing a natural ground cover to landscaping using ornamental plants. In all cases, the plantings must be compatible with soil conditions, climatic factors, and topography (High Sierra Resource Conservation and Development Council 2005).

3.1 Tilling and Incorporation

Incorporating compost into compacted soil through various techniques such as tilling, particularly on cut slopes, can increase the availability of nutrients to plants when compared to sites without incorporation into the underlying soil. A relevant study evaluating the sediment nutrient runoff for a series of compost applications was performed by the University of California, Davis and the California Department of Conservation in 2004. These applications included mature and immature compost applied directly to the ground surface or through incorporation. To test the impact of infiltration, the compost blankets were applied to tilled and untilled surfaces. It was found that the highest nitrate losses resulted from compost applications to plots with reduced infiltration due to either lack of tillage or no compost incorporation. The study found that ammonium losses were highest from plots with compost blankets applied over soil with lack of tillage or without compost incorporated into the soil (leading to reduced infiltration). Ammonium and phosphorous losses, and therefore availability to plants, were reduced with the presence of grass cover or improved infiltration. The overall conclusion of the study was that the three treatments with the lowest sediment or nutrient losses were the treatments that had grass growth or enhanced infiltration (compost mulch over compost incorporated into the soil). The poorest performing treatments (greatest losses of sediment and nutrients) were those treatments that had a missing treatment component, such as no tillage or no mulch cover, or tillage without compost incorporation, leading to reduced infiltration (Claassen and Carey 2004). This study highlights the importance of enhanced infiltration, particularly on compacted or cut slopes, for maximizing the benefits of compost for water quality improvement and vegetation establishment.

3.2 Short-Term versus Long-Term Effects

While the short-term effects of compost are well documented, the long-term effects of compost materials have not been fully studied. For the purpose of this study, long term is defined as more than 3 years. A majority of the case studies analyzed for this TM were performed recently or did not evaluate the test sites for a long enough period to be considered "long term." However, the short-term effects of compost are positive in regard to their influence on the establishment of vegetation. For sites tested for less than 2 years, a majority of researchers found the vegetative cover of sites with compost amendments to be much greater when compared to sites without compost amendments (Salisbury 2006; Florida Department of Transportation, Idaho Department of Transportation, Texas Department of Transportation).

The Caltrans project at Buckhorn Summit was the only site where annual evaluations were performed long term. Following the first year, there were no differences in plant shoot biomass cover between composted and noncomposted treatment plots. Following the second year, however, the biomass for tilled, composted plots was three times that of tilled, noncomposted plots. On plots with no tillage (plants installed directly into the very porous but untilled decomposed granite matrix), plant growth for composted plots was 10 times that for noncomposted plots. Third-year infiltration data documented an increase in infiltration on vegetated plots (McCullah 2003), which suggests a positive benefit for reducing the volume of stormwater runoff.

Compared to sites without compost, regardless of timeframe, compost-amended test plots exhibited improved soil stability by binding soil aggregates together; decreased soil bulk density for better vegetation growth; and increased soil water retention, which increased the plant available moisture. However, questions remain such as the ability of test sites to make the transition between compost-enhanced infiltration and natural soil structure that is generated by plant growth. Additionally, there is the question regarding continued fertility requirements to support adequate plant growth and maintain infiltration rates (McCullah 2003). Loss of topsoil during disturbance reduces the ability of the vegetative community to regrow because the soil's nutrient reserves are depleted. Inadequate pools of plant-available nitrogen (N) can restrict growth on the site for extended periods of time because N is needed in relatively large amounts for regeneration of the shoots, roots, litter layers, and for microbial biomass. In research performed by Claassen, he found that that compost can actually overcome the deficit of N pools needed for revegetation (CIWMB 2000).

As summarized below, other Departments of Transportation (DOTs) in the U.S. are using compost in their construction projects. While many of these studies are pilot studies, the results indicate that compost-amended soils do assist with accelerated plant growth even on difficult sites.

3.3 Difficult Sites: Case Studies from U.S. Transportation Departments

Degraded roadside soils and arid conditions impede the ability of vegetation to establish quickly. Revegetation of these difficult sites typically requires the application of a large

amount of water and commercial fertilizer. However, research has shown that with integration of compost, the demand for water resources and fertilizer can be reduced.

3.3.1 Cut and Fill Studies

Cut and fill slopes are used regularly in California by Caltrans, so there is great interest in the effect of compost on establishing vegetation for these land forms. Caltrans already provides Standard Special Provisions that are to be used together with Caltrans Standard Specifications to provide guidance for the use of compost in vegetation establishment on cut and fill slopes. An example is the Erosion Control (Type D), which includes applying seed, fiber, stabilizing emulsion, and compost to "cut" or "fill" slopes (Caltrans Compost Specifications 2006). Cut and fill slopes are common topographic forms constructed by transportation departments to develop and maintain roads and highways. Many of these other state transportation departments have successfully utilized compost on cut and fill land forms.

Washington State DOT Cut and Fill Study

The Washington State DOT (WSDOT) completed a project involving soil bioengineering on problematic slopes including steep cut and fill. Compost was used as part of the soil bioengineering solution. Class A biosolids compost was used at two of the sites tested. The use of a high carbon ratio product was used to suppress weeds and to enhance long-term survival of woody vegetation. Three months after application of the recommended material, grass was established on all terraces; however, where the composted biosolids were applied, the annual ryegrass was thicker, greener, and withstanding drought conditions better than the control section (CCREF 2002).

Idaho DOT Cut and Fill Study

Composts were used as a soil amendment and mulch in a project initiated by the Idaho DOT. Dairy manure compost was spread onto shallow slopes at a rate of 20 cubic yard per acre and anchored to the surface with a cultivator. A formulated organic soil amendment product was hydro-applied on steeper slopes at a rate of 2,000 pounds per acre. The slopes were treated with both products in fall 2000. Good germination and early growth were observed after 6 months; however, it was considered a dry and hot spring in Idaho, and continued growth and vigor were dependent on rainfall (CCREF 2002).

3.3.2 Florida DOT Turf Establishment Study

Three roadside test sites on major highways were selected with differing environmental conditions. One site was within a limestone road base without topsoil; the second was an area of deep, droughty sand with sparse vegetative cover; and the third was an area with a high water table and good cover of grasses, sedges, and broadleaf plants. Amendment of the road-shoulder soil with composts improved grass establishment and subsequent growth. One year after compost was incorporated and seeding occurred on the road shoulder, vegetative cover remained greater for all plots that received compost than for those that had not (CCREF 2002).

3.3.3 The Texas Department of Transportation Study

The Texas DOT used compost for revegetating a badly eroded and bare slope along a highway in Big Spring, Texas. The objective of this project was to demonstrate how the utilization of compost could effectively revegetate a barren slope. Two months after application, the site was heavily vegetated by a healthy, stable grass vegetation community. This use of compost coupled with site-specific mixtures of wood chips or other mulches has allowed for successful revegetation on projects with surfaces previously considered to be unrestorable (CCREF 2002).

Vic Claassen, a soil scientist with the University of California at Davis Department of Land, Air, and Water Resources, explored the use of compost to accelerate vegetation establishment while reducing water and fertilizer demand. One of his studies was performed on two types of compost sources: (1) yard waste lawn clippings and chipped brush and (2) biosolids/yard waste (co-compost material). The study discusses compost as a resource for replacement of organic matter (specifically nitrogen) in topsoil on disturbed sites, in terms of using yard waste compost as a soil amendment. In the study, composts were shown to provide a suitable replacement source of slowly available nitrogen for plant establishment on drastically disturbed, low-nutrient soils (Claassen and Carey 2004)

In research performed by Dr. William Sopper of Pennsylvania State University, compost (and biosolids) was applied to a gravely site, possessing a low pH and organic matter content, and contaminated with zinc. Within 15 months of the application, the hillside was covered by a combination of orchard grass, tall fescue, and crown vetch. Newly planted trees showed a survival rate of over 70 percent. In this example, the compost not only supplied plant nutrition and moderated soil pH, but also established a nitrogen and organic matter cycle in the soil and immobilized heavy metals (CCREF 2002).

4. Compost versus Commercial Fertilizer

As mentioned above, typical processes to achieve vegetation establishment include the use of irrigation and commercial fertilizers. Compost has been shown to provide a method for reducing or eliminating this need. Compost and commercial fertilizers are actually quite different and have quite different usage patterns and application purposes, although there is some overlap in their benefits. Fertilizers are meant to provide plant nutrients in greater concentration and release these nutrient compounds more quickly to the plant. However, while the application of commercial fertilizer can produce timely plant growth responses or rapidly correct plant nutrient deficiencies, commercial fertilizers alone cannot produce both the benefits of healthy soil characteristics and sustained plant development. Compost can also provide varying amounts of these same nutrients; however, the concentrations of these nutrients in compost are usually in an organic form and are available more slowly than those found in commercial chemical fertilizers. In addition, compost is more properly described as a "soil amendment," which returns many other valuable organic materials and constituents to the soil that are not provided by a fertilizer. Compost benefits the soil by improving soil structure, aeration, and water retention.

Compost can be used in place of commercial fertilizers, because of its many additional benefits. Compost is one of nature's best-made mulches and soil amendments. Compost usage improves soil structure, texture, and aeration; significantly increases soil water-holding capacity; reduces water runoff; and reduces soil erosion. Compost loosens clay soils, yet helps sandy soils retain water. Adding compost improves soil fertility and stimulates healthy root development in plants. The organic matter in compost provides food for soil microorganisms, which keeps the soil healthy and balanced. Nitrogen, phosphorous and potassium (N-P-K) will be made available naturally by soil microorganisms that are introduced and supported by compost. Few, if any, additional soil amendments are needed with the application of compost (Martin and Gershuny 1992).

Advantages to using commercial fertilizer are that they can contribute more quickly to bringing about a plant response, and they can be easier to apply since they can be dissolved into, for example, irrigation water. Commercial fertilizers are primarily used to add plant "macronutrients" of nitrogen, phosphorous, and potassium (N-P-K). However, when these salt nutrients are applied, if they are not taken up immediately by the plant, they are free to leach out of the soil and can become a source of water pollution in downslope aquatic environments. Because of the leaching risk of commercial chemical fertilizers, they must be applied carefully to avoid pollution risks, both in quantity to not exceed plant needs and in timing so that they are available when the plant needs the benefit of their nutrients. For example, application of fertilizer in the fall will actually stimulate growth in the plant during a dormant or slow-growth period making it more susceptible to disease and winter damage.

Using compost can provide not only what a plant needs for nutrition but also what the soil needs for desired physical properties. Often roadway construction areas result in

extremely disturbed soils that are not optimized for plant revegetation. Landscape vegetation not only benefits from the long-term release of nutrients from compost to the root matrix, but the roadway construction site can benefit from the improved soil mechanical properties that compost can create. Compost joins the soil and the vegetation into a system for achieving the benefits of aesthetics, long-term landscape sustainability, a reduction in landscape consumable resources (e.g., water), physical soil stability, and resistance to erosion. The advantages and disadvantages of compost and commercial fertilizer are summarized in the table below.

Table 1 Summary of Advantages and Disadvantages of Compost and Commercial Fertilizer

	Advantages	**Disadvantages**
Commercial Fertilizer	The primary advantage of using commercial fertilizer is that nutrients are immediately available to vegetation. Proper amounts of a given element can be calculated and provided to plants.	Commercial fertilizer, especially nitrogen, is easily washed below the level of the plant's root system through leaching by rain or irrigation. An application that is too heavy, or too close, to the roots of the plants can also cause "burning" (actually a process of desiccation by the chemical salts in the fertilizer). Additionally, overly heavy applications of commercial fertilizers can build up toxic concentrations of salts in the soil, creating chemical imbalances with negative effects. The expense of the commercial fertilizer should also be considered, in relation to the multiple benefits of compost.
Compost	There is less danger of overfertilization by adding quality compost to landscaping. Compost provides a slow release of nutrients as microorganisms in the soil break the organic material down into an inorganic, water soluble form that the plants can use. The addition of organic material improves soil stability and landscape sustainability. Compost also vastly improves the water-holding capacities of sandy soils, a distinct advantage in the arid climate and drought conditions common to southern California.	As noted above, these "slow-release" features can be an advantage. However, if there is an immediate need for nutrients, compost does not typically supply them rapidly. In contrast, when manufactured commercial fertilizer is applied, the specific kinds and amounts of desired nutrients can be delivered more rapidly to meet landscape needs. Compost application can also be more complicated than fertilizers.

Whether the choice is to use compost, commercial fertilizers, or a combination of both, it is important to follow the guidelines regarding application timing, placement, and quantity.

5. Pollutant Removal

The use of compost as a BMP has the potential to reduce pollutants in waters by facilitating the establishment of vegetation that has the potential to uptake pollutants and reduce erosion, by providing a substrate for pollutant removal by organic processes, and by controlling erosive flows. Pollutant removal mechanisms associated with the vegetation and biological components of a compost biofiltration system are provided below. Water quality is discussed in greater detail in the complementary Technical Memorandum on Compost and Water Quality.

5.1 Bioremediation/Phytoremediation

The ability to remove pollutants by organic processes before they enter the water is gaining recognition as an effective process. This action, bioremediation, can be defined as any process that uses microorganisms, fungi, green plants (phytoremediation), or their enzymes to return the natural environment altered by contaminants to its original condition. Bioremediation may be employed to attack specific soil contaminants, such as degradation of chlorinated hydrocarbons by bacteria. The use of compost as a bioremediation tool is being used to restore contaminated soils, manage stormwater, control odors, and degrade volatile organic compounds. Mature, stable compost is a biological system, consisting of beneficial microorganisms, that consumes contaminants in soil, ground and surface waters, and air. Compost microorganisms effectively digest and metabolize contaminants into inert byproducts, thereby reducing the bioavailability of these pollutants.

Many types of contaminants are rapidly degraded by the microbial matrix in compost, including chlorinated and nonchlorinated hydrocarbons, solvents, motor fuels and lubricants, heavy metals, pesticides and herbicides, petroleum products, and wood-preserving chemicals. Many designs exist for the use of compost bioremediation systems, or “biofilters,” capable of filtering water or air, and removing physical and chemical contaminants. The biofilters either break them down into harmless products such as carbon dioxide and water vapor, or sequester them into very stable, insoluble compounds.

The advantages of using compost biofiltration for bioremediation are that these treatment systems tend to be lower in operating and capital cost, low in maintenance requirements, and highly reliable; have consistent destruction rates; and do not require secondary disposal.

5.2 Erosion Control

The emphasis in stormwater management over the last 50 years has been on “peak rate” control so that the highest rate of stormwater flow was no more than would have been expected before the development. There is now a shift toward management systems that recognize that the most effective stormwater management is a practice that emulates the natural processes of soil and plants that were in place before being disrupted by the

development. Practices that prevent erosion are much more effective at preventing pollution than those that attempt to clean the water after it has already gained a pollutant loading.

New management practices that reemphasize the roles of soil and plants are gaining prominence. These "bioretention" systems include and often depend on the incorporation of quality compost into their design. Compost incorporation in biorention designs has been shown to dramatically reduce peak flow rates and runoff volume, increase biofiltration, increase infiltration and soil water retention, and decrease pollutant loads.

These bioretention systems help prevent erosion by:

- Protecting the soil surface from the impact energy of falling rain (splash erosion)
- Reducing and delaying runoff
- Absorbing moisture
- Promoting infiltration
- Encouraging soil aggregate formation
- Promoting desired vegetative cover growth
- Reducing undesired weed growth

These desirable attributes are gained by improving soil health, and the basis for a healthy soil is soil organic matter. Incorporating compost is one of most efficient ways to increase soil organic matter. Improving soil health provides the desired stormwater management benefits of water infiltration and retention, absorption of excess nutrients, filtration of sediments, and biological decomposition of pollutants, moderation of peak storm flows, and encourages plant revegetation and regrowth. LID methods are discussed in greater detail in the complementary Technical Memorandum on Compost and Low Impact Development.

Established vegetative stands provide increased storage capacity and subsequent water infiltration into healthy soil. Depending on the timing, depth, and intensity of precipitation, more water has a chance to infiltrate a well-drained soil compared to a poorly drained soil. This increased storage capacity is often referred to as the "sponge effect." The extent to which the effect is realized depends on soil type, vegetation type, seasonal temperatures, and both rainfall and soil moisture characteristics prior to and during precipitation (Sands 2001).

Compost-amended soils have been shown to accelerate the establishment of healthy vegetative stands and subsequently develop healthy porous soil. This healthy, well-drained soil has adequate pore space with abundant organic material allowing it to capture and hold precipitation and runoff. In turn, the healthy soil provides a strong base for vegetation to grow and continue the cycle.

6. Summary of Findings

As of 2006, at least 32 state transportation departments, plus many federal and local agencies, have adopted compost as a BMP for erosion control, generally based on the generic BMP adopted by the American Association of State Highway and Transportation Officials as MP-10. However, concerns remain from the SWRCB and RWQCB regarding impacts to water quality (particularly pertaining to biosolids and pathogens).

The results of this analysis reveal that compost is beneficial, at least in the shortterm, toward the establishment of vegetation for cut and fill slopes and difficult sites as tested. Case studies are limited in regard to the comparison of compost to traditional methods such as hydroseeding and container planting. In many circumstances, compost is used in conjunction with hydroseeding and container planting, not exclusive of these traditional methods. In addition, the case studies reveal that no one application type or method is appropriate in all situations. Site conditions vary greatly and there are many environmental factors to consider when establishing project goals.

When establishing vegetation, the decision to use compost depends on many variables that influence decision making. The most important variables are summarized below:

1. **Type of vegetation being treated**
   a. Desired vegetation effect (configuration of revegetated area)
   b. Plant nutrient requirements
   c. Soil classification (soil conditions and structure related to texture, organic matter, pH, and availability of moisture)
   d. Slope
   e. Solar exposure (azimuth and hours per day) and surface temperature
   f. Climate and seasonal weather variations and extremes at site
2. **Compost and fertilizer characteristics**
   a. N-P-K ratios
   b. Seasonal time of year added
   c. Plant needs and receptiveness to nutrients
3. **Available application methods**
   a. Hand application
   b. Hydraulic or mechanical application
   c. Incorporation or blanket and depth of incorporation
4. **Compost quality**
   a. Compost maturity
   b. Organic matter content
   c. Presence of physical contaminants (glass, metal, or plastic)
   d. pH
   e. Particle size
   f. Nutrient content
   g. Moisture content

h. Trace element content or contaminant

The existing information and studies evaluated suggest that there can be significant benefits to the establishment of vegetation with the use of compost, particularly when used in place of other conventional methods. A summary of the findings follows.

1) Compost has the ability to enhance infiltration by increasing soil porosity and water holding capacity. This effect is often called the "sponge effect".

2) Compost amended soils accelerate the establishment of healthy vegetative stands.

3) Incorporating compost is one of the most efficient ways to increase soil organic matter.

4) In studies performed by several state DOTs, vegetation on compost amended plots was healthier than non-amended plots.

5) Compost use provides nutrients for vegetation growth and soil development.

6) Unlike most commercial fertilizers, compost can be considered a true "slow release" fertilizer.

7) Microorganisms in compost effectively digest and metabolize many contaminants into inert byproducts, reducing the bioavailability of these pollutants.

8) Compost can be incorporated into the soil as an amendment and placed on the surface as a mulch. While each provides an enhancement, best results occur when both methods are used together.

9) Compost incorporation is used to improve soil health. Improving soil health encourages plant revegetation and regrowth and provides the stormwater management benefits of water infiltration and retention, absorption of excess nutrients, filtration of sediments, biological decomposition of pollutants, and moderation of peak storm flows.

7. References

California Integrated Waste Management Board. 2000. "Compost Demonstration Project, Placer County: Use of Compost and Co-Compost as a Primary Erosion Control Material." January.

California Integrated Waste Management Board. 2007. "Compost Use for Landscapes and Environmental Enhancement." June.

Claassen, V.P. and J. L. Carey. 2004 "Regeneration of Nitrogen Fertility In Disturbed Soils Using Composts." Compost Science & Utilization 12, no. 2 (2004): 145-152.

Caltrans Landscape Architecture. 2006. "Compost Specifications:" http://www.dot.ca.gov/hq/LandArch/policy/compost_specs.htm . Accessed Oct. 7, 2008.

The Composting Council Research and Education Foundation (CCREF). 2002. "Compost Use on State Highway Applications". USEPA cooperative agreement X82826301.

High Sierra Resource Conservation and Development Council. 2005. "Vegetation Establishment Guidelines for the Sierra Nevada Foothills and Mountains"

Martin, Deborah L. and G. Gershuny. 1992. "Rodale Book of Composting". Rodale Press.

McCullah, J. 2003. "Final Construction Report." CTSW-RT-03-058.33.12. June.

Rider D.E., M.J. Curtis, V.P. Claassen, ND. "Literature Review: Compost Use for Erosion Control and Improved Stormwater Quality".

Salisbury, Sandy. 2006. "WSDOT Experience using compost on Roadside Applications". Washington Department of Transportation. October.

Sands, Gary. 2001. "Soil Water Concepts". Regents of the University of Minnesota. http://www.dot.ca.gov/hq/LandArch/policy/compost_specs.htm. Accessed Oct. 7, 2008.

US Composting Council. 2008. "Using Compost in Stormwater Management." Factsheet.

USEPA. 2003. National Management Measures to Control Nonpoint Source Pollution from Agriculture EPA 841-B-03-004