WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Biosolids Management Guidelines for Washington State

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Washington State Department of Ecology
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Foreword

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Beneficial Use of Biosolids

Biosolids are material derived from municipal wastewater solids. They are a source of plant nutrients and organic matter, and meet state and federal criteria for application to land. The Washington State Department of Ecology supports the properly managed, beneficial use of biosolids for land application, consistent with legislative mandates (Chapter 70.95J RCW). Chapter 173-308 WAC is the regulatory framework for beneficial use of biosolids in Washington.

Biosolids Management Guidelines

Purpose

Biosolids must be used in ways that meet all regulations. The law establishes minimum standards for the management of biosolids. The primary purpose of these guidelines is to assist biosolids managers in developing proper requirements for biosolids management programs, and to assist regulatory officials in developing proper requirements for biosolids permits. These guidelines are not a regulation and are subject to some interpretation, depending on the circumstances of a particular application site or treatment works. These guidelines will also aid other interested persons in gaining an understanding of proper biosolids management. Knowledgeable interpretation is necessary to apply the concepts presented here.

What's Covered

These guidelines are intended to assist and direct landowners, treatment plant operators, biosolids managers and others in complying with rules and laws pertaining to biosolids use. A short synopsis of each chapter begins on page 2.

What's Not Covered

The guidelines do not:

- Re-examine work in the areas of risk analysis, contaminant behavior, or pathogen and vector attraction reduction. This work has already been done by the U.S. Environmental Protection Agency (EPA) and others.
- Take the place of a thorough understanding of applicable laws or substitute for practical experience.

- Address every situation that may be encountered and every issue that may be raised.

Target Audiences

The primary audiences for the guidelines are:

- Regulatory personnel.
- Those who prepare or apply biosolids, (e.g., treatment works operators, composters and contractors).

A secondary audience is individuals seeking to learn about biosolids management on either a personal or professional level.

How to Use the Guidelines

Following is a brief synopsis of each chapter:

Chapter 1 Managing Biosolids as a Resource

Describes what biosolids are and how they can be beneficially used in land application. Suggested for those with little or no background in biosolids management.

Chapter 2 Overview of Biosolids Regulations

Describes key points of the Washington State regulations for biosolids management (Chapter 173-308 WAC), including the General Permit for biosolids management. Directed to those who must recycle biosolids so they can understand their responsibilities.

Chapter 3 Biosolids Quality

A review of regulations for biosolids quality under EPA 40 CFR Part 503. Describes regulatory standards for pathogens, vector attraction, trace elements and contaminants. Gives a brief overview of important practices in biosolids sampling programs.

Chapter 4 Agricultural Site Design

Provides a framework for evaluating current and future biosolids application sites including criteria for soils, crops, access and buffers.

Chapter 5 Worksheet for Calculating Agronomic Application Rates

A step-by-step calculation worksheet to match biosolids nitrogen to crop need.

Chapter 6 Agricultural Site Management

Describes best management practices for soil conservation, water management and winter applications in western Washington.

Chapter 7 Forest Site Design and Management

A guide to using biosolids on forested sites. Includes design, application procedures, application rate and timing calculations, and application equipment for forest sites.

Chapter 8 Other Beneficial Uses of Biosolids

Describes the use of biosolids at land reclamation, rangeland and public contact sites, and as a final landfill cover. Includes labeling requirements for biosolids used on lawns and gardens.

Chapter 9 Site Monitoring

Describes appropriate monitoring methods to document biosolids safety for public health and the environment.

Chapter 10 Composting

Benefits and costs of the composting process. Compost facility management, composting methods, and pathogen reduction and vector attraction reduction requirements.

Chapter 11 Site Operation Plan

An outline that can be used to develop land application plans and operations plans for biosolids application sites.

Chapter 12 Record Keeping and Reporting

A guide to record keeping for those who prepare and apply biosolids.

Chapter 13 Septage

Describes what septage is and how it can be beneficially applied to land under current Washington laws.

Appendices Additional background information on proposed dioxin regulations, calculating geometric means for pathogen density reporting, and references used in preparing the guidelines.

Guideline Updates - Your Input Is Wanted

Biosolids management is a complex endeavor. New information is available on a regular basis. Ecology anticipates that these guidelines will be revised from time to time to keep pace with new regulatory requirements, emerging technologies, and in response to practical field experience. You should notify the Department of Ecology to be placed on the mailing list of manual holders. Updates, errata sheets and notices of revisions will be sent to those on the list. If you note any errors in these guidelines or believe additional information should be included, please notify the department in writing (by regular or electronic mail). Your recommendations will be maintained on file and reviewed at a future date when these guidelines are revised or updates are published.

For More Information

Those who need more information or who wish to be placed on the mailing list for updates should write to:

Biosolids Coordinator
Solid Waste and Financial Assistance Program
Washington State Department of Ecology
Box 47600
Olympia, WA 98504-7600

You can also get information and contact the department by going to the Ecology Biosolids homepage at: http://www.wa.gov/ecology/swfa/biosolids/index.html

Biosolids Management Guidelines

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Chapter 1

Managing Biosolids as a Resource

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Introduction

A waste is sometimes called a resource out of place. This is certainly the case with the huge volume of organic wastes such as paper, lawn clippings and farm manures. These materials can be recycled, composted or applied to land — all of which benefit society.

Biosolids[1] are a resource derived from an organic waste. They contain a variety of nutrients which can be used by plants, and organic matter that improves the soil. Biosolids also contain small amounts of contaminants that can limit how they are used. Fortunately, advances in wastewater pretreatment have reduced these problems, opening the door to increased land application of biosolids.

Historical Perspective — Waste to Resource

Historically, the problem of human waste disposal began when communities first formed. Then, population densities were low enough that the surrounding land or waterways could handle human wastes. Wastes that were applied to land increased soil fertility. As populations grew, the nearby land couldn't handle all the wastes, so they were dumped into streams and rivers that carried the problem downstream.

Night Soil as a Fertilizer

Some early cultures put their human waste to good use. For thousands of years, Chinese society returned sewage, called night soil, to surrounding farmland. This practice helped maintain soil fertility by closing the nutrient cycle — nutrients from farms were exported to the cities in crops, and the nutrients in the municipal wastes were returned to the farms. This type of system was ideal because two problems were solved at once: maintaining soil fertility and treating a source of pollution. Night soil was valued so highly that farmers were reputed to compete with one another by locating attractive outhouses along roads to entice users.

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[1]In this publication, the term *biosolids* refers to municipal wastewater solids that meet the regulatory requirements for beneficial use on land. If wastewater solids do not meet these standards (for trace element content, pathogen content and vector attraction reduction), they cannot be applied to land in Washington.

Sewer Systems

Chinese society was unique in its development of an ecologically sound system for recycling waste. Most other urban civilizations focused on improving ways to dispose of wastes from cities. Many civilizations developed sewer systems, which helped protect local public health but usually created problems downstream.

In the 1850s, two British researchers, Snow and Budd, proved the connection between sewage-contaminated drinking water and outbreaks of cholera and typhoid. This raised public awareness about water pollution and set the stage for the many changes in sewage treatment during the next century.

In Europe, North America and Australia, municipal sewage farms were developed, where untreated sewage was spread on nearby farms. This approach cut down on water pollution while improving soil fertility. The Werribee Farm, near Melbourne, Australia, has been in operation since 1897.

Water Pollution Control

In the United States, federal legislation aimed at controlling water pollution first appeared in 1899, and was strengthened during the 1950s and 1960s. Thousands of municipal sewage treatment systems were built, but ocean dumping of wastewater solids was still permitted. The Federal Water Pollution Control Act of 1972 (PL 92-500) placed further restrictions on the discharge of pollutants to waterways and encouraged beneficial uses of biosolids, such as land application. Subsequent legislation has continued to encourage land application of biosolids while simultaneously increasing the regulations surrounding such application. Most communities have adopted land application as part of their recycling ethic, and as their most environmentally and economically sound biosolids option.

Recent Events

Industrial effluent contributes trace elements and other contaminants to municipal sewage. In the past, these compounds have limited the ways in which biosolids could be used. In 1985, EPA regulations required industries to pretreat their wastes so trace elements and other contaminants would be removed before they entered the municipal wastewater system. The result of these regulations is a significantly lower amount of these contaminants in biosolids, creating more opportunities for safe land application. Table 1.1 demonstrates the dramatic drop in the trace element content of biosolids from the King County Department of Natural Resources.

Before 1970, much of the biosolids from the Seattle metropolitan area were dumped in Puget Sound. Now, cities like Seattle, Tacoma and Spokane operate successful land application programs. On a state-wide basis, about 85 percent of all biosolids produced are applied to land.

Farmers and landowners are becoming more aware of how their lands can benefit from biosolids. In some areas, demand for biosolids products far exceeds the available supply.

Table 1.1 Change in trace element content of King County biosolids due to improved industrial pretreatment (in mg/kg).

	King County Biosolids[1]		EPA Table 3 Limit[2] (1992)	Nat'l Sewage Sludge Survey[3] (1988)
Metal	**1981**	**1998**	**USEPA**	**NSSS**
Arsenic	N/A	7.5	41	7.7
Cadmium	47	4.0	39	44
Copper	1310	524	1500	783
Lead	760	138	300	232
Mercury	6	2.7	17	2
Molybdenum	N/A	11.4	-	8.1
Nickel	200	38	420	90
Selenium	N/A	5.9	100	5.2
Zinc	1800	710	2800	1400

[1]West Point treatment plant.

[2]Represents USEPA regulations for trace element concentrations in Exceptional Quality biosolids (40-CFR 503.13, Table 3).

[3]Mean concentrations from National Sewage Sludge Survey, USEPA, 1988, for POTWs >100 MGD flow rate.

Biosolids as a Fertilizer and Soil Amendment

Nutrients

Plants need 17 elements to grow. They get three of these — carbon, hydrogen and oxygen — from air and water. The other 14, called mineral nutrients, come from the soil and fertilizer (Table 1.2). These 14 nutrients can be further divided into macronutrients (required in large amounts by plants) and micronutrients (required in small amounts). All are essential to plant growth. Other elements, such as selenium and iodine, are needed by animals but not by plants.

Table 1.2 Essential mineral nutrients.

	Macronutrients	Symbol	Micronutrients	Symbol
Essential to plants	Nitrogen Phosphorus Potassium Sulfur Calcium Magnesium	N P K S Ca Mg	Chloride Iron Boron Manganese Zinc Copper Molybdenum Cobalt[1]	Cl Fe B Mn Zn Cu Mo Co
Essential to animals but not plants			Selenium Iodine Chromium	Se I Cr

[1]Cobalt is essential for nitrogen fixation in legumes.

Nutrients in Biosolids

Biosolids contain all these elements, as well as several that are not needed by plants or animals. These include contaminants, such as lead, mercury, and cadmium.

Biosolids can supply a wide range of nutrients to crops, thus improving soil fertility. The nutrient composition of the biosolids varies, depending on the treatment process (Table 1.3). For an individual treatment plant, the composition is relatively stable and predictable over time.

Table 1.3 Nutrient composition of biosolids.

Nutrient	Typical Range	Content
	- - - - - % - - - - -	lb/dry ton
Total Nitrogen (N)	3 – 8	60 - 160
Total Phosphorus (P)	1.5 – 3	30 - 60
Sulfur (S)	0.6 - 1.3	12 - 26
Calcium (Ca)	1 - 4	20 - 80
Magnesium (Mg)	0.4 - 0.8	8 - 16
Potassium (K)	0.1 - 0.6	2 - 12

Source: Sullivan, D. 1998. Fertilizing with Biosolids PNW 508. Oregon State Univ. Corvallis, OR.

The Nitrogen Cycle

Most soils contain small amounts of available nitrogen. One of the major benefits of biosolids is that they add some or all of the nitrogen needed by a crop. Nitrogen (N) often sets the limit for biosolids applications, since too much N can contaminate groundwater and harm crops.

Nitrogen exists in three basic forms: gas, organic and inorganic (see Table 1.4).

- Organic — Carbon-based compounds such as protein. Not available to plants. Soil microorganisms convert organic N to inorganic N.
- Inorganic — Plants use inorganic N for nutrition in the form of nitrate (NO_3^-) and ammonium (NH_4^+) ions (the plant-available forms). This is the main type of N in commercial fertilizers. Microbes and plants compete for inorganic N in the soil, converting it to organic N.

- Gas — N_2 makes up 78% of the atmosphere. A few soil micro-organisms (such as those living in nodules of legume roots) convert N_2 gas into ammonium (NH_4^+), which is then used by plants.

Table 1.4. Common forms of nitrogen in soils and fertilizers.

Form	Name	Symbol	Remarks
Organic	Proteins, Amino acids	$R\text{-}NH_2$	Contained in biosolids, manures, composts, plant residues and soil organic matter. Over 95% of soil N is in organic form. Immobile, not plant available. Converted to ammonium by soil microbes (mineralization).
Inorganic	Ammonium	NH_4^+	Can be adsorbed by clay and organic matter, preventing large amounts from moving with water. Plant-available. Converted to nitrate by soil microbes (nitrification).
	Nitrite	NO_2^-	Concentration in soil and biosolids is usually insignificant.
	Nitrate	NO_3^-	Typically present in soil and very mobile with water. Not much present in biosolids, but produced from biosolids N by mineralization and nitrification. Plant-available.
Gases	Nitrogen	N_2	Comprises about 80% of soil atmosphere. Source of N for legumes. Not utilized by other crops. End product of denitrification.
	Ammonia	NH_3	A component of biosolids and fresh manure. Can be lost to the atmosphere as a gas. Rapidly converted to ammonium in soil.

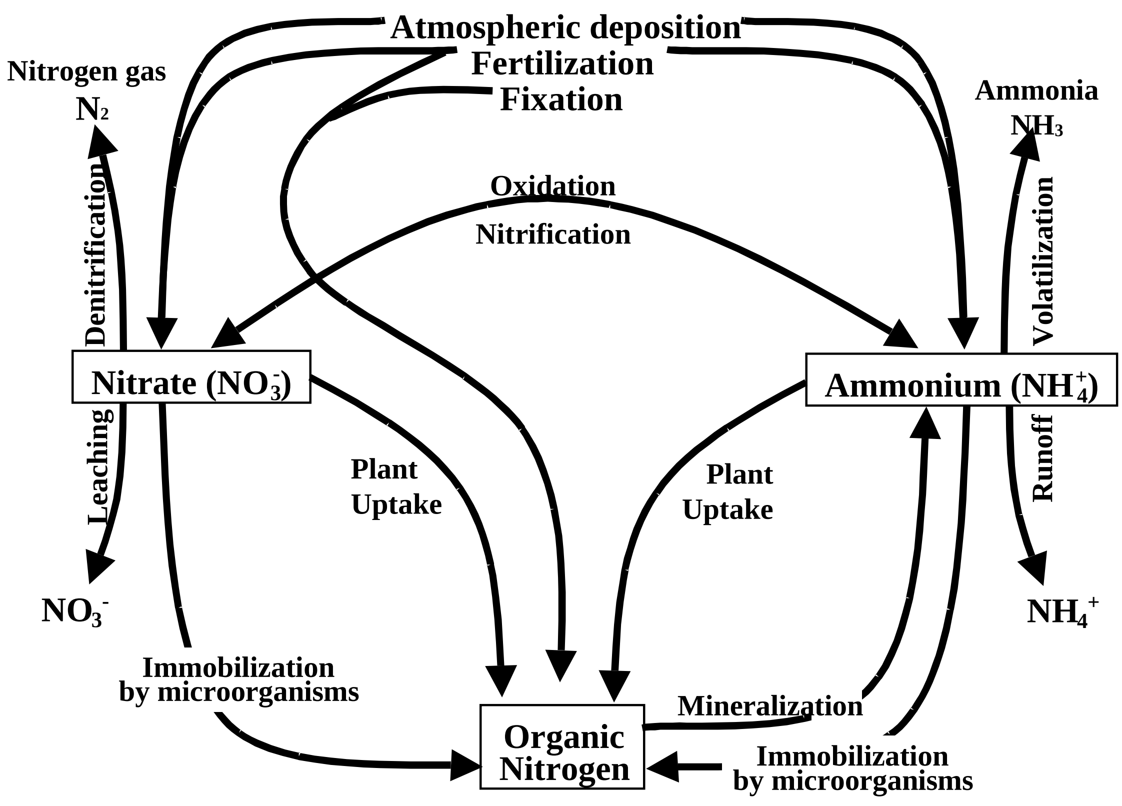
In a biologically active soil, N is always undergoing chemical changes (Figure 1.1).

Mineralization is the conversion of organic N to inorganic N (in the form of ammonium). This occurs when microbes decompose plant residues, soil organic matter or organic amendments such as biosolids.

Another set of microbes converts ammonium to nitrate. This process is called **nitrification**.

Immobilization is the conversion of inorganic N to organic N. Rapidly growing soil microbes can tie up most of the ammonium and nitrate in soil. This process can deplete the available N in the soil, which can slow plant growth.

Figure 1.1 The nitrogen cycle.



Nitrogen can be lost by several processes:

- In saturated (anaerobic) soils, microorganisms convert nitrate to N_2 and N_2O gases, which escape to the atmosphere. This process is denitrification.

- Ammonia (NH_3 gas) can be lost from surface-applied biosolids.
- When pH adjustment is used for pathogen reduction or vector attraction reduction, nearly all ammonia will be lost from the biosolids.
- If water moves through the soil (because of winter rainfall or overirrigating) nitrate can be lost by leaching.
- Ammonium (NH_4^+) can be lost in surface water runoff
- Nitrogen is also removed from a field through crop harvest removal.

When designing an application program, consider the many variables affecting the nitrogen cycle at the site, such as plant uptake, leaching potential, nitrogen losses and transformations. You can adjust the application rate, timing, and method as needed for the site and in accordance with the requiements of state rules and permits. Your goal is for crops or other vegetation to have the best possible uptake of nitrogen *and* no leaching below the root zone.

Phosphorus

In many ways, the cycle for phosphorus (P) is similar to the nitrogen cycle. However, unlike nitrogen, phosphorus does not have a gaseous phase so it cannot be lost to the atmosphere.

Most phosphorus is chemically fixed — or tied up — in soil and is unavailable for plants. Repeatedly applying biosolids can lead to an increase in both total and available phosphorus in soil. This can reduce or eliminate the need for additional phosphorus fertilizer. At sites with a history of heavy manure applications available P may reach excessive levels.

Other Nutrients

Biosolids also help meet plant requirements for other nutrients. Sometimes there are shortages of potassium, calcium and magnesium in western Washington, where they are leached from the soil by rainfall. Biosolids are a good source of sulfur (S) and can replace the S fertilizers widely used in cereal grain and forage crops.

Micronutrient deficiencies are less common and are harder to predict. In Washington there are documented deficiencies of boron and zinc in alfalfa, asparagus, carrots, crucifers and grapes on certain soils. In these situations, the micronutrients in biosolids may lead to better crop growth.

Nutrient Balance

Plant growth and yield are limited by the essential nutrient that is in shortest supply. Since most soils do not contain enough nitrogen for good yields, nitrogen is often the limiting element. When enough nitrogen is applied, another element — such as sulfur, potassium, or zinc — may become the limiting element. Biosolids add a variety of micronutrients to the soil and may satisfy needs for other nutrients besides nitrogen.

However, nutrients in biosolids are not available in the same ratios needed by a crop. For instance, applying biosolids to supply N needs also supplies more phosphorus (P) than the crop can use, and less potassium (K) than it needs. In many soils, P becomes chemically bound quickly; therefore plant-available P levels may rise more slowly than total P levels.

> **Example**: After calculating agronomic nitrogen application rates (see Chapter 5 for details), biosolids containing 2.3 percent P and 0.3 percent K (dry weight basis) were applied at a rate of 6 dry tons per acre for a 30 ton corn silage crop. This application supplied 276 lb P / acre, far *more* than the 75 lb / acre removed by the crop. In contrast, a total of 36 lb K per acre would be added, far *less* than the 200 lb / acre removed by the crop.

When the rate of application is based on the nitrogen needs of the crop, many nutrients — especially micronutrients — will be added in sufficient quantities for several years. To get the greatest benefits from biosolids, a good strategy is to move applications around to fields where production is limited by micronutrients or phosphorus.

The Effects of Biosolids on Soil Properties

Soil organic matter is made of carbon-based compounds resulting from the decay of plant, animal, and microbial residues. These compounds can be stable for a few days or for hundreds of years. Fresh green plants break down very quickly with little lasting impact, while roots from perennial grasses decay more slowly.

The stability of organic matter in biosolids also varies, partly based on the wastewater treatment processes that produced the biosolids. As shown in Table 1.5, both the quickly degraded and stable (slowly degraded) organic matter make important contributions to the soil's physical, chemical and biological processes:

- Quickly degraded organic matter releases nutrients for plants, energy for soil organisms, and compounds that improve soil structure.
- More stable material builds organic matter levels in the soil.

Table 1.5 Ways that soil properties benefit from organic matter additions.

Physical	• Improved soil aggregation • Better soil structure • Better aeration • Greater water-holding capacity • Greater water infiltration • Reduced soil erosion • Decreased bulk density • Easier root penetration • Less power needed for tillage
Chemical	• Increased cation exchange capacity • Less nutrient leaching • Greater pesticide adsorption • Higher nitrogen reserve
Biological	• Greater microbial biomass • Faster pesticide breakdown • Growth-promoting compounds • Certain plant diseases reduced

Physical

Adding organic matter improves the physical condition of the soil in many ways. The overall improvement is often referred to as better *tilth*. Tilth refers to how easy it is to till the soil, its fitness as a seedbed, and how easily roots can penetrate the soil.

Adding organic matter leads to specific improvements:

- **Greater water-holding capacity** — Organic matter holds two to three times its weight of water, giving plants access to more water.
- **Greater soil aggregation and stability** — This leads to a more porous soil surface, which promotes water infiltration and reduces runoff. In dry areas, soils can then hold more water, reducing the frequency of irrigation.
- **Better aeration** — Because of the increase in soil aggregation and structure, soils have better aeration. Aeration reduces the frequency of anaerobic conditions, resulting in better root health, less nitrogen lost to the atmosphere (by denitrification) and fewer soilborne diseases.
- **Reduced soil erosion** — Soil aggregates are less likely to break down into smaller particles that can be carried off by water or blown away by wind.
- **Reduced bulk density** — Bulk density is a measure of soil density. It is expressed as weight per unit volume, such as grams per cubic centimeter. With reduced bulk densities, there is more pore space for storing air and water. Root penetration is therefore easier, which improves uptake of water and nutrients.
- **Resistance to compaction** — Organic matter helps resist soil compaction by farm machinery.

Finally, organic matter additions are especially beneficial for sands and clays, the two extremes of soil texture. In sandy soils, organic matter promotes aggregation and water-holding capacity. In clay soils, it reduces the bulk density, loosens the soil, and improves root penetration and ease of tillage.

A single application of biosolids to agricultural or forest land usually contributes a relatively small amount of organic matter compared with what is already in the soil. Biosolids indirectly add more organic matter through the increased production of crop residues. The greatest organic matter benefits would occur with repeated applications of biosolids, or in land reclamation projects where large amounts of biosolids are applied, often together with another source of organic matter. Although repeated applications of biosolids would supply more organic matter benefits to a site, the overall benefits are probably greatest when biosolids applications are spread over a number of sites.

Chemical

The organic matter in biosolids improves the soil's ability to hold nutrients by increasing the cation exchange capacity (CEC). Soils with higher CECs can store more positively charged nutrient ions, reducing nutrient losses to leaching. Both the organic matter and inorganic matter in biosolids increase the binding of trace elements, including contaminants such as cadmium or lead.

Biological

Organic matter is the food that soil organisms need to function. Each percent of soil organic matter contains the energy equivalent of 1200 gallons of fuel oil per acre. Since carbon, or energy, often limits the microbial action in soil, adding organic materials increases microbial activity, which benefits plant growth. Increased microbial activity also increases the rate of pesticide breakdown in soil, reducing risk to the environment. As earthworms and other soil animals eat organic additions, their by-products — for instance, earthworm castings — also enhance plant nutrition.

Soil organic matter buffers the soil from the extremes of the surrounding environment (e.g., drought, nutrient supply, contamination), ultimately reducing risk for the farmer. Increasing the content of soil organic matter can improve crop production, and rebuild the soil's "bank account" for the future.

Matching Biosolids Nutrients to Crop Needs

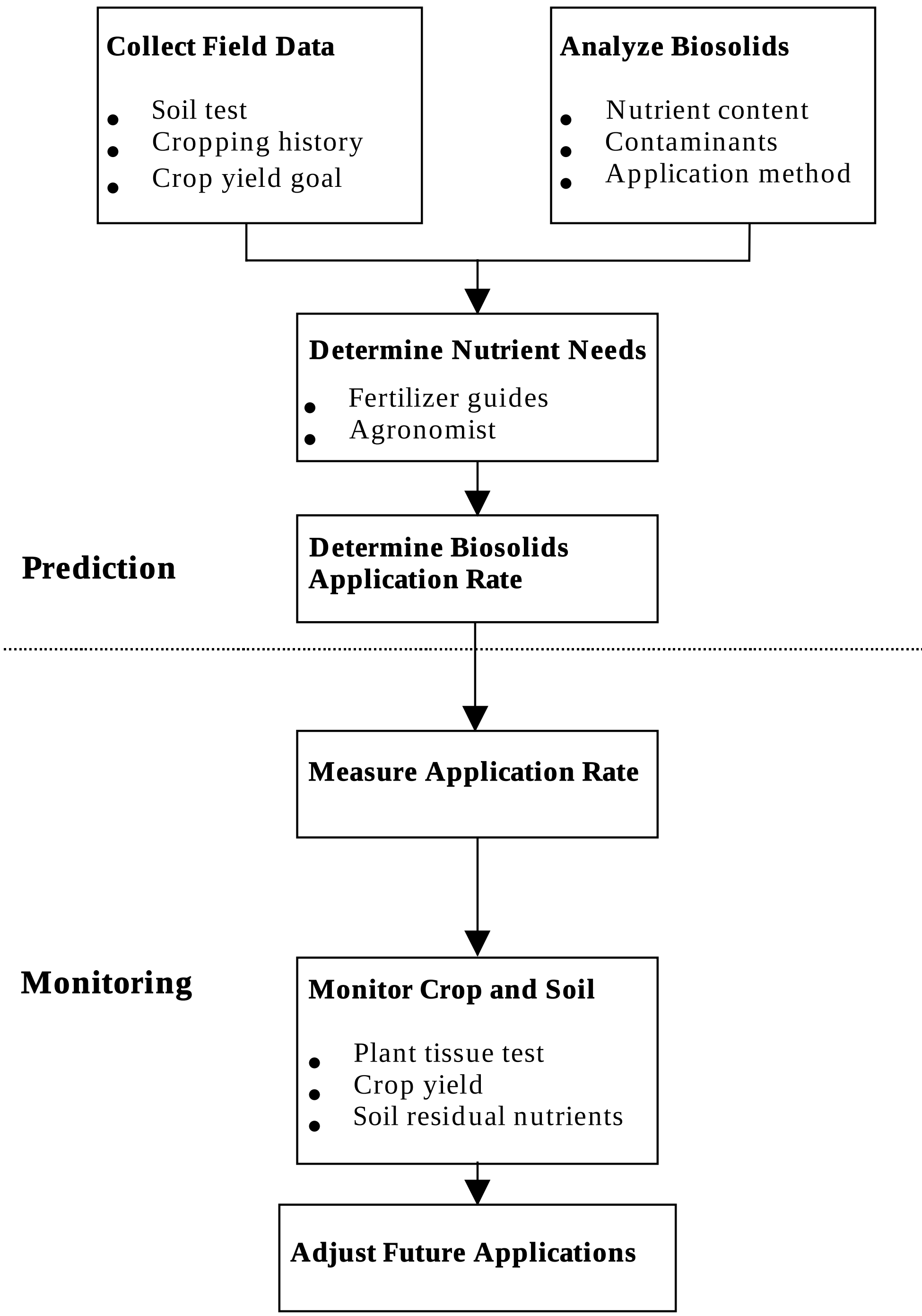
To apply biosolids properly, match crop need with those nutrients the biosolids can contribute. For agricultural crops, biosolids nutrient management is similar to that for manure.

Figure 1.2 shows the process to follow to make the best use of biosolids applications. The level of detail for these steps may vary, depending on economic constraints, environmental concerns or regulatory requirements. This process has two parts: prediction and monitoring. After predicting the outcome of a biosolids application to a crop, monitor the results to improve future applications.

Collect Field Data

Field data include information about the application site, field history (previous crops, fertilization, and special problems), realistic yield goals, and soil types. A soil test shows the amount of available nutrients. Soils tests are a standard part of

Figure 1.2 *Recommended steps for predicting and monitoring plant response to biosolids applications.*



agricultural production, and are important when making biosolids applications to agricultural land. The test should include pH and available phosphorus and potassium. Ask for a micronutrient test if you suspect micronutrient deficiencies. Chapter 9 describes soil testing in greater detail.

Analyze Biosolids

Agronomists and land managers use the biosolids analysis to determine how well biosolids can satisfy nutrient needs. Only a portion of the total nutrient content is immediately available for plant uptake. The remainder of the elements are in organic or mineral forms that only slowly become available to plants after application.

Determine Nutrient Needs

Washington State University, Oregon State University, and the University of Idaho have developed fertilizer guides that can be used to estimate the nutrient needs of a crop. The guides are based on the assumption that there is good management and average yield. Professional soil scientists, agronomists, and forest scientists can also help determine nutrient needs at a specific site. For more information, see Chapters 5, 7, and 9.

Determine Biosolids Application Rate

To calculate application rates, consult the worksheets in Chapter 5 (Agriculture) or 7 (Forestry). An on-line version of the agricultural worksheet is available at http://www.css.orst.edu/News/Publicat/Sullivan/. You can get assistance from Cooperative Extension and the Natural Resources Conservation Service. Independent agronomists specializing in soil evaluation and nutrient management can also help.

Measure Application Rate

A field check (Chapter 9) verifies actual nutrient loading. This step also allows you to adjust spreading equipment properly for future applications.

Monitor Crop and Soil

Monitoring activities for matching biosolids nutrients to crop needs may include:

- Plant tissue tests, which can indicate nutrient shortage, sufficiency or excess.
- Residual soil nitrate and other tests after harvest, which give information on how well the nutrient management program worked.
- Field observation, which identifies differences in plant vigor or color, or changes in pest incidence.
- On-farm testing.

The need for monitoring, and the amount and type of monitoring recommended varies from project to project. For example, soil nitrate monitoring may not be useful when biosolids are applied at sub-agronomic rates to pastures that receive little or no additional fertilization. Monitoring needs also are reduced where application rates are well defined, based on research and monitoring at similar sites. See Chapter 9 for more information on monitoring.

Adjust Future Applications

Based on the results of monitoring, you should adjust future application rates as appropriate.

Summary

Biosolids are a valuable resource for enhancing soil productivity. Improvements in pretreatment programs have reduced trace element contamination of biosolids that are applied to land. Biosolids provide essential plant nutrients and can improve the physical, chemical and biological properties of the soil. As with any nutrient source, careful management is required to gain the most benefits from biosolids applications.

Chapter 2

Overview of Biosolids Regulations

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Overview

How to Use This Chapter

This chapter describes the basic framework of the Washington State regulations for biosolids management. It does not cover all of the details necessary for interpreting the regulations, nor is it a step-by-step guide for preparing permit applications. You will need to refer to text of the Biosolids Management regulation (Chapter 173-308 WAC) and the General Permit for Biosolids Management for complete details.

This chapter:

- Describes the relationship of federal, state, and local programs;
- Outlines the key elements of the state regulation;
- Describes the general permit for biosolids management, including land application plans;
- Discusses exemptions for exceptional quality biosolids; and
- Lists other key regulations related to biosolids management.

How are Biosolids Regulated?

The Federal government and Washington State both regulate biosolids as a commodity that can be beneficially recycled on the land (Table 2.1). By statute (Chapters 70.95 and 70.95J RCW) the state considers recycling to be the preferred method of biosolids management.

The Department of Ecology administers the Washington State biosolids management program. The purpose of the program is to protect human health and the environment while encouraging beneficial use of biosolids. The program consists of technical rules implemented by a permit process. Federal, state, and local authorities all have roles in biosolids regulation, as described below. The goal of Ecology is to draw the federal, state, and local components together into a unified program.

Table 2.1 Summary of references for regulations.

Federal	
40 CFR Part 503	Technical standards for biosolids management
Part 501	Federal delegation program
Part 122	Federal permitting program
State	
RCW 70.95J	Enabling statute for state biosolids program
WAC 173-308	Technical and permitting rules
General Permit for Biosolids Management	Statewide general permit to implement rules

Relationship of Federal, State, and Local Programs

Federal. The federal program is derived from the Clean Water Act and is implemented by the Environmental Protection Agency. Congress directed EPA to develop science-based technical standards for biosolids (40 CFR Part 503) and implement them in permits (40 CFR Part 122). EPA wants to delegate authority for the federal program to states, while maintaining an oversight and guidance role. Washington plans to seek federal delegation in 2001.

State. The Washington State legislature gave the Department of Ecology authority to implement a program that meets or exceeds federal requirements and to take delegation of the federal program from the EPA (RCW 70.95J). The State technical regulations in (Chapter 173-308 WAC) are based on the federal standards (40 CFR Part 503).

Local. Local health departments had responsibility for regulating biosolids projects in the past when biosolids were treated as a solid waste. Ecology's goal under the current regulations is to continue in working regulatory partnerships with local health departments. Many aspects of the state program can be delegated to the local level. The specific roles of Ecology and local health departments will vary, depending on the delegation agreement between Ecology and each jurisdiction.

Which Agency Should I Contact?

If you are managing a biosolids program or preparing a permit application, contact the regional office of the Department of Ecology first. They can tell you the roles of Ecology and the local health departments in the counties where you treat, store or apply biosolids to land.

What Do the State Regulations Cover?

Key elements of Chapter 173-308 include biosolids monitoring, biosolids quality standards, land application requirements, reporting, record keeping, requirements to obtain and provide information, public notice, permitting, and other administrative regulations. Table 2.2 summarizes the key elements and gives references to the sections in the rules that cover each element. The table also references chapters in the Biosolids Management Guidelines that provide guidance for the rules.

General Permit for Biosolids Management

The general permit is the vehicle for implementing the biosolids management regulations in Chapter 173-308 WAC. A single general permit will cover most uses of biosolids in the state.

Who Needs to Apply for Permit Coverage?

Treatment works treating domestic sewage (TWTDS) and *beneficial use facilities* need to apply for coverage under the general permit. They use the permit application to describe their operation and demonstrate how it complies with state regulations. About ninety-five percent of the TWTDS are wastewater treatment plants, most of which are publicly owned. TWTDS also can include other facilities that treat, use, transport or apply biosolids.

Beneficial use facilities are land application sites that apply for separate coverage under the permit. An example is a private contractor that assumes full responsibility for managing a land application project. Beneficial use facilities take on site planning and management obligations that would otherwise remain with the biosolids generators. A land application site does not have to be a beneficial use facility. In this case, the biosolids generator is responsible for meeting all regulatory requirements.

Refer to WAC 173-308-080, WAC173-308-310, and the General Permit for Biosolids Management for details on the definitions of treatment works treating domestic sewage and beneficial use facilities.

Table 2.2. Overview of WAC 173-308, Biosolids Management.

Element	Section in WAC 173-308	Chapter in Biosolids Guidelines
Explanation of biosolids. Includes domestic septage as defined in regulations.	070	1
Requirement to obtain and provide information. This assures that all who prepare, apply, or receive biosolids have the necessary information to comply with the regulations.	120	
Biosolids sampling and analysis.	140	3
Biosolids monitoring.	150	3
Biosolids quality (pollutant limits, pathogen reduction, and vector attraction reduction).	160, 170, 180	3
Land application – agronomic rate requirement. This is to protect groundwater from the risk of nitrate contamination..	190	5
Exemptions for Exceptional Quality biosolids. Includes site management, access, labeling, permitting, and record keeping exemptions.	200	2
Application to agricultural land. Includes requirements for biosolids quality, site management, access restrictions, record keeping, and reporting.	210	4,6,9
Application to forest land.	220	7,9
Application to a public contact site.	230	8,9
Application to a land reclamation site. Includes regulations for applications exceeding agronomic rates.	240	8,9
Biosolids applied to a lawn or home garden..	250	8
Biosolids sold or given away in a container. Includes quality and labeling requirements.	260	8
Domestic septage management..	270	13
Record keeping and reporting.	290, 295	3,9,12
Permitting and permit fees.	310, 320	2, 11

Key Elements of the Permit Program

The key elements of the permit program are:

- Notice of intent
- Permit application
- Land application plans
- Public notice requirements
- Hearing and meeting requirements
- Additional or more stringent requirements
- Record keeping
- Annual reports
- Permit fees

Notice of Intent

This is the first step in the permit process. It includes a brief description of biosolids management activities and sites used by the applicant, and notifies Ecology of intent to apply for coverage under the general permit. When Ecology receives a complete Notice of Intent, the permit applicant obtains provisional coverage under the statewide general permit.

Permit Application

This is a comprehensive description of the applicant's biosolids management program, and includes biosolids production and quality data, site monitoring data, maps, a listing of other environmental permits, names of contractors applying biosolids, and detailed land application plans.

Land Application Plans

Land application plans are a key part of the permit application. They are required for land application of all biosolids that do not meet Exceptional Quality standards. In some cases Ecology may also require land application plans for bulk application of Exceptional Quality biosolids. There are two types of land application plans: site specific and general. If a treatment works contracts to a beneficial use facility for land application, the beneficial use facility is responsible for preparing the land application plans.

Site Specific Plans.

The purpose of a site specific land application plan is to provide enough information to determine if a proposed site and site management are suitable for application of biosolids. The plan needs to contain the following information:

- Crops grown and their intended use.
- Agronomic rate determinations.
- Method and timing of biosolids applications.
- Any monitoring data for soil, surface water, or ground water collected during the previous two years.
- How biosolids will be stored on and off site.
- How public access will be restricted.
- Site location.
- Information on past biosolids applications, if the biosolids previously used exceeded Table 3 standards for trace elements (See Chapter 3).
- Groundwater management plan for sites with seasonal ground water within three feet of the surface.
- Detailed site maps including means of access, adjacent properties, buffers, and all environmentally sensitive areas (e.g. wetlands, wellhead protection areas, etc).

See Chapter 11 for details on preparing site specific plans.

General Land Application Plans

A general land application plan is only required when a facility does not identify all the sites where biosolids may be applied during the life of the permit. It allows an applicant to submit additional site-specific plans at a later date. This may often occur with large programs and programs in a state of transition. This situation will also occur with lagoons where biosolids removal and land application are not currently under way.

Think of a general land application plan as a scoping document. It includes the geographical area under consideration and site selection and management criteria. The plan provides advance notice to the regulatory authorities and the public. Once specific sites are selected, it is necessary to file site specific plans for those sites.

Public Notice Requirements

Public notice is required when applying for permit coverage and when adding or expanding land application sites. Notice must be made to the general public (through newspapers and posting of land application sites), to local health departments, and to interested parties (by direct mail). The notice must include a period for comments. Public notice may be done in conjunction with State Environmental Policy Act (SEPA) requirements.

Hearing and Meeting Requirements

In some cases the regulatory authority (Ecology or local health department) may decide to hold public meetings or hearings based on issues raised during the public notice process. The regulatory authority determines the need for public meetings or hearings on a case-by-case basis.

Supplemental Conditions

Both the state rule and general permit authorize Ecology to impose additional or more stringent requirements for permit coverage on a case-by-case basis if they determine that the requirements are necessary to assure protection of public health and the environment. This authority is necessary to assure compliance with the federal program.

Annual Report

All facilities must submit an annual report by March 1 of each year. Larger facilities[1] must include copies of records and certification statements that they are required to keep during the course of the year. Smaller facilities do not have to include as much information in their reports, unless otherwise directed. All facilities, regardless of size, must keep records on file for at least five years.

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[1] Larger facilities include Class I biosolids management facilities and publicly owned treatment works with a design flow of at least 1,000,000 gallons per day or serving at least 10,000 people.

Permit Fees

The Department of Ecology assesses permit fees based on the size of the facility and type of management. Local health departments may also assess fees, depending on the types of regulatory activities they do.

Exemptions for Exceptional Quality Biosolids

The regulatory emphasis on *exceptional quality* biosolids (see definition in Chapter 3) is at the time of treatment. Because of this, exceptional quality biosolids require little or no regulation when they are applied to the land. Since there are fewer site management requirements, there are fewer permit and record keeping requirements. Record keeping for exceptional quality biosolids products is focused on documenting the treatment they receive and that they meet exceptional quality standards before they are marketed or distributed to the public.

Exemptions include:

- Waiting periods for crop harvest
- Posting of sites and buffers
- Preparation of land application plans for the permit application
- Record keeping regarding site access and application of trace elements

Agronomic rate considerations still apply for exceptional quality biosolids, although land application plans are not required.

Relationships to Other Agencies and Regulations

Not all of the regulatory issues related to biosolids management are contained within the biosolids regulations. Other key issues are compliance with the State Environmental Policy Act, transportation regulations, and fertilizer regulations. Biosolids facilities and sites must also comply with any other laws and regulations not listed below.

State Environmental Policy Act (SEPA)

The purpose of SEPA is to determine whether a project may result in a significant adverse effect to the environment. All biosolids projects must undergo a SEPA review. This normally happens when an application for coverage under the general permit is submitted. It may also happen later if there are modifications to permit coverage, such as when a new site is added. A Responsible SEPA Official does the review, which is based on information provided in an environmental checklist and other relevant documents. The SEPA process includes a public notice, which can be coordinated with the public notice required for a permit application under the biosolids regulations. In the past most biosolids projects have been given a Determination of Nonsignificance following SEPA review. If the review leads to a Determination of Significance, a full environmental impact statement must be prepared.

Transportation

The transportation of biosolids is subject to regulation by the Washington State Utilities and Transportation Commission.

Fertilizer Regulations

The Washington State Department of Agriculture (WSDA) oversees regulations for commercial fertilizers. WSDA requires that fertilizer products be registered, and fertilizer producers must pay registration or tonnage fees to the WSDA. Fertilizers are also subject to WSDA quality standards, which are different from the Ecology standards for biosolids. Biosolids that are sold or distributed as fertilizers are subject to WSDA regulations and fees as well as Ecology regulations.

Exemption from WSDA Fertilizer Regulations

<u>Unpackaged Biosolids</u>

Biosolids that are used for land application are exempt from WSDA fertilizer regulations if two conditions are met.

- They must not be called a fertilizer in any marketing or promotional materials.
- A conspicuous disclaimer must be included on a label or information sheet that is provided with the biosolids. The disclaimer must state 1) that the product is not a commercial fertilizer, and 2) that any nutrient claims are estimates or averages and are not guaranteed. (See Chapter 8). Note that this disclaimer is the only context where the word "fertilizer" may be used in labeling, marketing, or promotional information.

For marketing purposes, producers and distributors of unpackaged biosolids products that meet those two conditions may state that their products contain plant nutrients and/or enhance plant growth (if these statements are true). They may not use the word fertilizer in any marketing or promotional material associated with the product. This does not prohibit the use of the word fertilizer in guidance documents, technical presentations and publications, or in other contexts not associated with marketing.

<u>Packaged Biosolids</u>

Producers and distributors of packaged biosolids products who 1) make any statements about plant nutrients or plant growth, or 2) call their product a fertilizer are regulated by the WSDA in addition to any regulation by Ecology. If producers and distributors of packaged products do not want their products recognized or regulated as commercial fertilizers, they must include the disclaimer statement (above) on their package or in an accompanying information sheet.

Some producers of packaged biosolids may decide it is beneficial to market their product as a fertilizer and compete directly with other commercial fertilizers. The extra regulatory burden may be worth the potential for extra market value.

Summary

- If you produce or distribute an unpackaged biosolids product and you don't want to be subject to WSDA fertilizer regulations, do not call the product a fertilizer, and be sure to include the required disclaimer on a label or information sheet.
- If you produce or distribute a packaged product and you don't want to be subject to WSDA fertilizer regulations, do not use the word fertilizer or make any claims about plant nutrients or plant growth.
- If you produce or distribute a biosolids product and you want to be recognized as a commercial fertilizer, contact WSDA for more information on your regulatory obligations.

Local Regulations

Local land use and zoning laws can affect the location and operation of biosolids projects. Check with local authorities when selecting sites.

Chapter 3
Biosolids Quality

Table of Contents

Introduction

Biosolids are wastewater solids that meet quality standards for land application. These standards cover three parts of biosolids quality: pathogens, trace element content, and the potential for biosolids to attract vectors such as flies and rodents. State and federal rules use the same standards.

The regulations specify two levels of standards for each of these parts of biosolids quality. If biosolids meet the higher standards for all three parts, they are called exceptional quality (EQ) biosolids. EQ biosolids can be applied to land with few reporting and management requirements. This chapter describes pathogens, vector attraction and trace elements, as well as the standards for both biosolids and EQ biosolids.

Pathogens

Background

Fate of Biosolids Pathogens

Municipal wastewater contains disease-causing microorganisms called pathogens. Pathogens include bacteria, viruses, protozoa and helminths (parasitic worms). As water is reclaimed in the treatment process, some of these pathogens collect in the settled solids. The amount of a pathogen that causes infection in animals or humans depends on the pathogen and the host. For a pathogen to cause disease, it must have a susceptible host, a pathway of exposure and there must be an infective dose. Without these three elements, disease cannot occur. Biosolids treatment before land application and management practices at the land application site are designed to eliminate one or more of these elements.

Biosolids treatment occurs at the wastewater treatment plant. Pathogens are destroyed by chemical, physical, and biological processes, including:

- High temperatures (from chemical, physical or biological processes)
- Chemical disinfectants (e.g., lime, chlorine)
- Destruction of the microbial food source (volatile solids reduction)
- Desiccation (drying processes)
- Predation and competition from other microorganisms

Pathogens are also reduced through land application. After biosolids application, pathogens are destroyed by:

- Heat
- Sunlight
- Drying
- Unfavorable pH
- Other microorganisms

To allow time for final pathogen reduction to take place, public access may be restricted after biosolids application. In addition, waiting periods may be required before harvesting food crops or allowing grazing by livestock.

Where public access or waiting periods cannot be controlled (e.g., home gardens, biosolids distributed in bags), pathogen reduction must be complete before the biosolids are distributed. Regulations allow two levels of pathogen removal before land application: a less stringent level (Class B) for applications where final removal will occur in the field, and a more stringent level (Class A) where access or waiting periods can’t be controlled. When proper site management and access restrictions are observed, the use of Class B biosolids is considered to be as safe as Class A biosolids.

Pathogen Longevity and Public Health

How long a pathogen lives depends on the type of pathogen and its environment. The soil surface is a more hostile environment than the subsurface because the pathogens are exposed to more sunlight, drying, and heat on the surface, all of which shorten their survival.

Bacteria and viruses do not survive for long on the soil surface. The 30-day waiting period for livestock grazing after Class B biosolids application is based on the survival rates of exposed viruses and bacteria on soil or vegetation surfaces. Helminths, the hardiest of the pathogens, live much longer because their eggs can survive harsh environmental conditions. For Class B biosolids, the waiting periods for the harvest of root crops and crops whose edible parts may come in contact with the biosolids-soil matrix, are based on survival of the helminth eggs and can extend as long as 38 months.

Pathogen regrowth is also a consideration. Viruses, helminths and protozoa cannot regrow outside their specific host. Once the populations of these pathogens are reduced, they stay reduced. Bacteria can regrow if they are not completely destroyed or if outside contamination is introduced.

Most fecal coliform bacteria are not pathogenic, but their density is often used as an indicator of the potential presence of pathogens. Fecal coliforms are used as an indicator because:

- Fecal coliforms are abundant in feces.
- Reliable and inexpensive methods are available to enumerate fecal coliforms.
- Research has shown a correlation between fecal coliform numbers and the presence of pathogens.

Regulations

Biosolids must meet either Class A or Class B pathogen requirements when they are applied to land. Material that does not meet at least Class B requirements can not be applied to land. To meet Class A requirements, pathogen destruction must be complete before the biosolids are applied to land. Class B biosolids are treated to reduce pathogens before land application, and final pathogen destruction occurs through natural processes at the application site. Public access and harvest of crops are restricted for a period after application of Class B biosolids to allow for pathogen destruction (see Tables 4.11A and 4.11B). Exceptional Quality biosolids must meet Class A standards, as well as the standards for trace elements and vector attraction reduction (described later in this chapter).

Class A Biosolids

Biosolids can meet Class A requirements through any of the six treatment and documentation alternatives listed in Table 3.1. In addition, for all alternatives, Class A biosolids must have fecal coliform densities less than 1000 most probable number (MPN) per gram of total solids, or salmonella less than 3 MPN per 4 grams total solids. Monitoring fecal coliform or salmonella in Class A biosolids helps ensure quality.

Salmonella testing to meet Class A biosolids requirements is more expensive and requires greater expertise than fecal coliform testing. The basis for using fecal coliform instead of salmonella testing is the correlation between fecal coliform density and the presence of salmonella. Research with a variety of biosolids types and stabilization methods has shown that salmonella are usually not detectable when fecal coliform density is less than 1000 MPN per gram of dry solids.

The regulations do not specify the number of samples needed to determine if biosolids meet class A pathogen reduction standards. To demonstrate that biosolids meet class A fecal coliform standards, you must collect representative samples. For example, for a composting operation you will need to sample at multiple locations in the pile at the end of the treatment period. For a thermophilic digester, you can collect fewer samples, but on a more frequent basis. In some cases you may need to sample for viable helminth ova and enteric viruses. See EPA document 625/R-92-013, *Control of Pathogens and Vector Attraction in Sewage Sludge*, 1999 revision, for more specific guidance on sampling for pathogens and indicators. The guidance is summarized beginning on pg. 3-18.

Table 3.1 Class A requirements for biosolids. Source: EPA 40 CFR Part 503.32 and WAC 173-308-170. Solids expressed on a dry weight basis.

All Alternatives: Fecal coliform less than 1000 most probable number (MPN) per gram total solids, *or* salmonella less than 3 MPN per 4 grams total solids.
Alternative 1: **Thermally treated biosolids.** Meet specified time/temperature requirements (see Table 3.2).
Alternative 2: **Biosolids treated in a high pH - high temperature process.** Maintain pH above 12 for 72 hours, with temperature during the 72-hour period greater than 52°C for 12 hours. After 72 hours at pH above 12, biosolids are air-dried to greater than 50% total solids.
Alternative 3: **Biosolids treated in other processes.** Procedure for documenting that a biosolids *treatment process* meets Class A standards. Viable helminth ova less than one per 4 grams total solids *and* for enteric viruses less than one plaque-forming unit per 4 grams total solids. Retesting required when biosolids meet these requirements before the pathogen treatment process. When the treatment process is shown to reduce helminths and viruses, and the pathogen treatment conditions are documented, the biosolids are Class A when the documented conditions are used.
Alternative 4: **Biosolids treated in unknown processes.** Procedure for documenting that a biosolids *product* meets Class A standards. Viable helminth ova less than one per 4 grams total solids *and* for enteric viruses less than one plaque-forming unit per 4 grams total solids. This alternative requires testing of each batch of the biosolids that is used.
Alternative 5: **Biosolids treated in a PFRP.** Use a recognized Process to Further Reduce Pathogens (PFRP), as described in Table 3.3.
Alternative 6: **Biosolids treated in a process equivalent to a PFRP.** Use a process approved by the state or EPA as equivalent to an approved Process to Further Reduce Pathogens.

Table 3.2 summarizes time and temperature requirements for Alternative 1. Processes that meet Alternative 5 (approved Processes to Further Reduce Pathogens, or PFRP) are listed in Table 3.3.

Table 3.2 Time and temperature requirements for Class A biosolids, Alternative 1. In addition to the time/temperature requirement, Class A biosolids must also be sampled and meet standards for fecal coliform or salmonellae.

Temperature Degrees C	Solids greater than or equal to 7 percent			Solids less than 7 percent		
	Days	**Hours**	**Minutes**	**Days**	**Hours**	**Minutes**
50	14			5		
52	7			3		
54	4			2		
56	2			1		
58		24			10	
60		13			5	
62		7			3	
64		4			2	
66		2				41
68			57			30
70			30			30
72			20*			16
74			20			8.5
76			20			4.5
78			20			2.3
80			20			1.2
82			20			0.7
84			20			0.33
above 84			20			0.25

Source: WAC 173-308-170 and 40 CFR Part 503.32

* When the biosolids are small particles heated by contact with warmed gases or an immiscible liquid, and the temperature is maintained above 70°C, use the column entitled “Solids less than 7%” to find minimum time-temperature requirements.

*Table 3.3 Processes to further reduce pathogens (PFRP).**

Composting. Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the biosolids are maintained at 55°C or higher for three days. Using the windrow composting method, the temperature of the biosolids is maintained at 55°C or higher for 15 days or longer. During the period when the compost is maintained at 55°C or higher, there shall be at least five turnings of the windrow.
Heat drying. Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content to 10% or lower. Either the temperature of the biosolids particles exceeds 80°C or the wet bulb temperature of the gas in contact with the biosolids as it leaves the dryer exceeds 80°C.
Heat treatment. Liquid biosolids are heated to a temperature of 180°C or higher for 30 minutes.
Thermophilic aerobic digestion. Liquid biosolids are agitated with air or oxygen to maintain aerobic conditions, and the mean cell residence time of the biosolids is 10 days at 55 to 60°C.
Beta ray irradiation. Biosolids are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (approximately 20°C).
Gamma ray irradiation. Biosolids are irradiated with gamma rays from certain isotopes, such as Cobalt 60 and Cesium 137, at room temperature (approximately 20°C).
Pasteurization. The temperature of the biosolids are maintained at 70°C or higher for 30 minutes or longer.

* Biosolids stabilized to these standards meet Class A pathogen reduction requirements if the end-product has:

- Fecal coliform less than 1000 MPN per gram total solids; or
- Salmonellae less than 3 MPN per 4 grams total solids.

Class B Biosolids

Pathogen removal for Class B biosolids does not have to be as complete as for Class A because final pathogen removal occurs at the land application site. Table 3.4 lists the three alternatives for meeting Class B requirements. Only Alternative 1 requires that microbial populations be monitored.

Table 3.4 Class B requirements for biosolids. Source: EPA 40 CFR Part 503. Solids expressed on a dry weight basis.

Alternative 1: Fecal coliform are less than 2,000,000 Most Probable Number or 2,000,000 Colony-Forming Units per gram of total solids, based on a geometric mean of seven samples.
Alternative 2: Use a Process to Significantly Reduce Pathogens (PSRP).
Alternative 3: Use a process determined by the state or EPA to be equivalent to a Process to Significantly Reduce Pathogens.

The fecal coliform limit for Alternative 1 is based on a correlation between fecal coliform numbers and viral and bacterial pathogen numbers. Operators must take seven samples during each sampling event, and report the geometric mean of the samples. Multiple samples and the geometric mean are used because fecal coliform numbers vary widely from sample to sample. The EPA recommends that the seven samples be collected over a period of about 2 weeks, to obtain a result that is representative of biosolids quality over time. See *Control of Pathogens and Vector Attraction in Sewage Sludge* for more specific guidance on sampling for pathogens. See Appendix 2 for calculating geometric means. Alternative 2 (approved Processes to Significantly Reduce Pathogens, or PSRP) is listed in Table 3.5.

Table 3.5 Processes to significantly reduce pathogens (PSRP). Biosolids stabilized to these standards meet Class B pathogen reduction requirements.

Aerobic digestion. Biosolids are agitated with air or oxygen to maintain aerobic conditions for a specific time and at a specific temperature, ranging from 40 days at 20°C to 60 days at 15°C.
Air drying. Biosolids are dried on sand beds or on paved or unpaved basins. The biosolids must be dried for at least three months. During two of the three months, the ambient average daily temperature is above zero °C.
Anaerobic digestion. Biosolids are treated in the absence of air for a specific time and at a specific temperature, ranging between 15 days at 35 to 55°C and 60 days at 20°C.
Composting. Using either the within-vessel, static aerated pile or windrow composting methods, the temperature of the biosolids is raised to 40°C or higher and remains at 40°C or higher for five days. For four hours during the five days, the temperature in the compost pile exceeds 55°C.
Lime stabilization. Enough lime is added to the biosolids to raise the pH to 12 after two hours of contact.

Vector Attraction Reduction

Background

What is vector attraction reduction? Vector attraction is the characteristic of unstabilized biosolids that attracts rodents, flies, mosquitoes or other organisms that can spread disease. Vector attraction is reduced when biosolids are processed through digestion, lime stabilization, composting, drying or when biosolids are tilled into soil. Composting and digestion destroy the organic carbon compounds in raw sludge that serve as an attractant and food source for vectors. Lime stabilization and drying reduce vector attraction by creating environmental conditions (high pH or dryness) unfavorable to vectors. Some vector attraction reduction processes (digestion, composting) that destroy volatile organic solids also reduce odors after application. Volatile organic solids are *not* destroyed by lime stabilization and drying. Rewetting of lime-stabilized or dried biosolids can sometimes result in odor problems after application. Odors can be controlled by soil incorporation after application.

Regulations

Under the current federal and state rules, vector attraction reduction is evaluated separately from pathogen reduction. Ten alternatives to demonstrate acceptable vector attraction reduction for biosolids applied to land are listed in Table 3.6. Alternatives 1 to 8 reduce vector attraction through treatment. They include digestion, lime stabilization, or drying processes, and are acceptable for biosolids applied at any site, including lawns and home gardens. These eight alternatives meet the vector attraction reduction requirements for Exceptional Quality biosolids. Biosolids sold or given away in bags or other containers must meet at least one of these alternatives.

Alternatives 9 and 10 reduce vector attraction by creating a barrier between the biosolids and potential vectors. These alternatives involve tilling or injecting biosolids into the soil at the land application site. They can be used for biosolids that do not meet Alternatives 1 to 8. They do not meet vector attraction reduction requirements for Exceptional Quality biosolids and are not acceptable for biosolids applied to lawns or home gardens. Alternative 11 is for sludge monofills and does not apply to land application of biosolids. Alternative 12 is suitable for septage only, and is discussed in Chapter 13.

Table 3.6 Biosolids vector attraction reduction alternatives.
Source: EPA 40 CFR Part 503 and WAC 173-308-180.

Alternative	Description
1.	Biosolids digestion processes with greater than 38% volatile solids reduction.
2.	Test end-product of anaerobic digestion process. Forty day anaerobic test at 30–37°C. Acceptable stabilization if less than 17% volatile solids reduction occurs during the test.
3.	Test end-product of aerobic digestion process having less than 2% solids. Thirty day aerobic test at 20°C. Acceptable stabilization if less than 15% volatile solids reduction occurs during the test.
4.	Facilities with aerobic digestion. Specific oxygen uptake rate (SOUR) test using end-product of digestion process. Acceptable stabilization if uptake is less than 1.5 mg oxygen per g total solids per hour at 20°C.
5.	Time/temperature requirement for composting: Fourteen days residence time at temperatures greater than 40°C, with average temperature greater than 45°C.
6.	High pH stabilization. Biosolids pH above 12 for 2 hours and greater than 11.5 for 24 hours.
7.	Treatment by drying. Not to include unstabilized primary wastewater solids. Total solids content greater than 75% before mixing with other material.
8.	Treatment by drying. Can include unstabilized primary wastewater solids. Total solids greater than 90% before mixing with other materials.
9.	Barrier process. Injection into soil. No biosolids on soil surface 1 hour after application. For Class A biosolids, injection must occur within 8 hours of discharge from the pathogen reducing process. See WAC 173-308-210, 220,230,240(3)
10.	Barrier process. Soil incorporation by tillage. Soil incorporation by tillage within 6 hours of application. For Class A biosolids, application must occur within 8 hours of discharge from the pathogen reducing process. See WAC 173-308-210, 220,230,240(3)
12.	**Septage only**. High pH treatment before land application. Acceptable stabilization if pH is greater than 12 for 30 minutes. See WAC 173-308-270 (4)

Trace Elements

Background

What Are Trace Elements?

There are small amounts of trace elements in biosolids. They also occur naturally in soils and animal manure. Some of these trace elements — called micronutrients — are essential to plant growth in small quantities. Others have no known beneficial function.

Under certain conditions, some trace elements can become pollutants, affecting plant growth, human or animal health or environmental quality. Nine trace elements are considered potential pollutants when biosolids are applied to land. These include seven metals (cadmium, copper, lead, mercury, molybdenum, nickel and zinc), a metalloid (arsenic) and a nonmetal (selenium).

Sources of Trace Elements

Trace elements are naturally found in human wastes. They also leach into water supply lines from pipes and solder, and enter the wastewater stream in industrial and household wastes. Since the early 1980s, the concentrations of trace elements in biosolids have decreased a great deal. This is the result of industrial wastewater pretreatment programs and the adjusted pH of water supplies (which has reduced leaching from pipes and solder). For example, trace element concentrations in King County biosolids declined significantly between 1981 and 1998 (see Table 1.1).

Trace Element Regulations

Regulation of trace elements is based on their behavior in the soil and their potential to harm humans, animals, plants and the environment through the food chain, soil, or water. The risks from trace elements depend on:

- How tightly they are bound to the soil.
- How bio-available they are.
- Their concentration in biosolids.

Availability of Trace Metals in Biosolids

Soil binding affects how available trace elements are for uptake by plants and leaching to ground water. Therefore, the more tightly they are bound to soil, the lower the risk of plant uptake or leaching. Trace elements are bound to soils in several ways:

- Most trace metals are cations (positively charged) and can bind weakly to the negatively-charged surfaces of clay and soil organic matter. This process is called cation exchange. The exchangeable ions are easily released into the soil solution to become available to plants. Only a small fraction of the trace elements added to soil are held in an exchangeable form.
- Most trace elements are more tightly bound in the soil. Soil minerals — called hydrous oxides — can bind trace metals because the metals react with the surface of the oxides. Trace elements are also tightly bound by precipitating out of solution, becoming trapped within the solid phase of the soil. In addition, elements are trapped by soil organic matter. All of these mechanisms bind the trace elements so they are not available for plant uptake or leaching.
- Biosolids are rich in organic matter and iron oxides, providing many binding sites for trace elements. Because of these binding sites, trace elements in biosolids added to soil are much more tightly bound and much less available than the same elements added to soil in unbound inorganic forms (salts). When levels of trace elements in biosolids are low (as is the case for biosolids produced in Washington), most studies have shown little or no increase in plant uptake of trace elements, even when large quantities of biosolids are added to the soil.
- Soil acidity affects the availability of many trace metals. In the pH range suitable for most crops, most trace elements are nearly insoluble in water and therefore remain tightly bound by the soil. If soil pH drops below the range suitable for crops, the plant uptake of many trace elements increases, which could lead to greater accumulation in the food chain.

Crop Uptake of Trace Elements

In addition to binding by soil and biosolids, trace elements can be excluded by plants and prevented from entering the food chain. When plants do take up trace elements, the elements accumulate in different plant parts. For example, many metals accumulate in the leaves, but mercury accumulates in fibrous roots. Most trace elements are excluded from the grain.

Different species of plants take up trace elements in varying amounts. Leafy vegetables such as spinach and lettuce accumulate cadmium and zinc, while corn and forage grasses tend to exclude them.

Trace elements interact with each other to affect the amount of uptake. For example, uptake of cadmium is reduced when zinc is present. Thus, zinc in biosolids can reduce the risk of cadmium accumulation in plants.

Risk Assessment

Different trace elements affect the food chain and environment in different ways. Some, such as nickel and zinc, are most toxic to plants. Molybdenum can accumulate at levels in plants that are toxic to animals. Lead is hardly taken up by plants at all, and enters the food chain only when biosolids are ingested (such as when children eat soil, or when people eat unwashed vegetables with soil adhering to them).

Based on these differences in behavior, EPA developed a risk assessment to estimate acceptable trace element loading rate limits for land application of biosolids. They evaluated 14 pathways for the transfer of trace elements from biosolids to plants, animals, humans and the environment (Table 3.7). For each pathway, they defined a *highly exposed individual* who would have a higher exposure to biosolids applications than the general public. They then estimated the highest application of each trace element that would have no effect on highly exposed individuals in that pathway.

The loading limit for each trace element was based on the lowest limit estimated for any of the pathways. The limiting pathway for each trace element is shown in Table 3.8. Note that the limiting pathways vary depending on the element. For some elements the limiting pathway is toxicity to plants; for others it is toxicity to animals or humans eating crops, or toxicity to animals or humans directly eating biosolids.

Table 3.7 Risk assessment pathways modeled for the transfer of trace elements from biosolids to plants, humans, animals and the environment. Source: "A Guide to Biosolids Risk Assessments for the EPA Part 503 Rule," EPA832-B-93-005.

Pathways	Examples
1. Biosolids → Soil → Plant → Human	Consumers in regions heavily affected by land application of biosolids.
2. Biosolids → Soil → Plant → Home Gardener	Farmland converted to residential home garden use in 5 yr.
3. Biosolids → Soil → Human Child	Farmland converted to residential use in 5 yr. with children ingesting soil.
4. Biosolids → Soil → Plant → Animal → Human	Farm households producing a major portion of their dietary consumption of animal products on biosolids-amended soil.
5. Biosolids → Soil → Animal → Human	Farm households consuming livestock that ingest soil while grazing.
6. Biosolids → Soil → Plant → Animal	Livestock ingesting food or feed crops.
7. Biosolids → Soil → Animal	Grazing livestock ingesting soil.
8. Biosolids → Soil → Plant	Crops grown on biosolids-amended soil.
9. Biosolids → Soil → Soil biota	Soil biota living in biosolids-amended soil.
10. Biosolids → Soil → Soil biota → Predator	Animals eating soil biota.
11. Biosolids → Soil → Airborne dust → Human	Tractor operator exposed to dust.
12. Biosolids → Soil → Surface water → Fish → Human	Water quality criteria for the receiving water.
13. Biosolids → Soil → Air → Human	Farm households breathing fumes from any volatile pollutants in biosolids.
14. Biosolids → Soil → Groundwater → Human	Farm households drinking water from wells.

*Table 3.8 Limiting risk assessment pathways for each trace element.**
Source: "A Guide to Biosolids Risk Assessments for the EPA Part 503 Rule," EPA832-B-93-005.

Element	Limiting Pathway
Arsenic	3 — Ingesting biosolids
Cadmium	3 — Ingesting biosolids
Copper	8 — Plant toxicity
Lead	3 — Ingesting biosolids
Mercury	3 — Ingesting biosolids
Molybdenum	6 — Livestock feed
Nickel	8 — Plant toxicity
Selenium	3 — Ingesting biosolids
Zinc	8 — Plant toxicity

* Chosen from pathways 1 to 14 (Table 3.7). The limiting pathway represents the lowest loading limit for a given trace element.

Regulations

Trace Element Standards and Loading Limits

The regulations combine two important pieces of information: (1) the bioavailability of trace elements in land-applied biosolids and (2) the risk assessment. They set ceiling limits (maximum allowable concentrations for land application) and a lower "clean" threshold for all 9 regulated trace elements.

- Biosolids with low levels of trace elements meet the *Table 3*[1] criteria for trace elements (Table 3.9). The regulations place no restrictions on cumulative loading rates based on trace elements for these biosolids. This is because levels of trace elements are low compared with the binding capacity of the biosolids and soil. Most biosolids in Washington State meet Table 3 standards for trace elements.

[1] Table 3 refers to Pollutant Concentration limits in Table 3 of section 503.13 of the Federal regulation.

- If any of the trace element concentrations do not meet Table 3 limits, biosolids applications are limited by cumulative loading limits (Table 3.10). *Cumulative limits* specify the highest amount of any trace element that can be applied to a land application site during its lifetime.

If any of the trace element levels do not meet the EPA *Table 1*[2] ceiling concentration limits in Table 3.9, the material does not meet criteria for biosolids and can not be applied to the land.

Table 3.9 Biosolids concentration limits for land application. Source: EPA 40 CFR Part 503 and Chapter 173-308 WAC.

		Concentration Limit	
Element	**Symbol**	**Table 3**	**Table 1 (Ceiling limit)**
		mg/kg	mg/kg
Arsenic	As	41	75
Cadmium	Cd	39	85
Copper	Cu	1500	4300
Lead	Pb	300	840
Mercury	Hg	17	57
Molybdenum	Mo	*	75
Nickel	Ni	420	420
Selenium	Se	100	100
Zinc	Zn	2800	7500

*Molybdenum Table 3 level is under reconsideration by EPA.

[2] Table 1 refers to Ceiling Concentrations from Table 1 of the Federal and state regulations.

Table 3.10 Cumulative loading rate limits for bulk biosolids that do not meet EPA-Table 3 criteria and are applied to agricultural land. Source: EPA 40 CFR Part 503.13 and Chapter 173-308 WAC.

Element	Cumulative limit (lb/acre)	Cumulative limit (kg/ha)
Arsenic	37	41
Cadmium	35	39
Copper	1340	1500
Lead	268	300
Mercury	15	17
Molybdenum	*	*
Nickel	375	420
Selenium	89	100
Zinc	2500	2800

*Molybdenum limit is under reconsideration by EPA.

The 503 regulations have no pH requirements. They assume that soil pH will be maintained at levels compatible with good crop growth, therefore, the soil pH will also be adequate to bind trace elements in the soil. To be sure that pH is maintained at proper levels, test biosolids sites for soil pH and lime requirements.

Summary of Biosolids Quality and Use

Exceptional Quality biosolids must meet Class A standards for pathogens, vector attraction reduction alternatives 1-8 (Table 3.6), and EPA-Table 3 criteria for trace elements. EQ biosolids can be used for any type of land application, including lawns and home gardens. They can be distributed in bulk or containers, and are not subject to loading restrictions for trace elements or waiting periods for pathogen removal. A complete description of requirements for EQ biosolids is given in Table 3.11. If biosolids do not meet all of the EQ criteria, then cumulative loading restrictions, waiting periods, and/or use restrictions apply.

The following chapters include information on managing biosolids that do not meet EQ criteria:

- Chapter 4. Agricultural Site Design
- Chapter 6. Agricultural Site Management
- Chapter 7. Forest Site Design and Management
- Chapter 8. Other Beneficial Use of Biosolids

Table 3.11 Requirements for exceptional quality biosolids. EPA 40 CFR Part 503 and WAC 173-308.

Trace element content at or below Table 3 criteria (see 40 CFR Part 503.13, Table 3 or WAC 173-308-160 (4)).

Pathogen reduction to meet Class A standards (one of Alternatives 1 to 6, Table 3.1) (WAC 173-308-170).

Vector attraction reduction (one of Alternatives 1 to 8, Table 3.6) (WAC 173-308-180).

Monitor biosolids quality at least at the minimum required frequency (see below) for trace element content, pathogen density and vector attraction reduction, or more often as required by permit condition:

Biosolids Applied or Processed		Frequency of Monitoring	
English Tons / yr	Metric tons / yr	Times / Year	Interval
<320	<290	1	365 days
320-1650	290-1500	4	90 days
1650-16500	1500-15000	6	60 days
16500	15000	12	30 days

Note: Monitoring requirements for trace elements (pollutants) and pathogen density may be reduced by permitting authority after two years of monitoring. Permitting authority must require monitoring at least once per year.

Certification Statement. Keep on file for five years a certification statement describing how the trace element concentrations, Class A pathogen requirements and vector attraction reduction requirements were met. (See WAC 173-308-290.)

Annual reports are required (See WAC 173-308-295)

Developing a Biosolids Sampling Program

Introduction

This section outlines the major points to consider when establishing or evaluating a biosolids sampling and analysis program. It does not cover all details or situations and should be used along with other guidance. The following EPA documents provide useful background and details for biosolids sampling:

Control of Pathogens and Vector Attraction Reduction in Sewage Sludge (EPA/625/R-92/013). Revised, 1999.

A Plain English Guide to the EPA Part 503 Biosolids Rule (EPA/832/R-93/003).

POTW Sludge Sampling and Analysis Guidance Document (EPA, 1989).

A biosolids sampling program has three main parts:

- Getting started — Deciding when, where and how to sample; and who will be in charge of sample collection, analysis and interpretation.
- Collecting samples — Preparing sample containers; and collecting and delivering samples to the laboratory.
- Documentation — Recording the who, what, when and where for each sampling event; and summarizing the analytical data in a useful way.

Getting Started

This section gives general guidance on sampling. Sampling frequency, sample numbers, and other requirements may vary, depending on specifications in individual permits.

Analyses and Analytical Methods

To determine the analyses and analytical methods appropriate for your program, review WAC 173-308-140.

How Often Should Sampling Be Done?

Sampling frequency is based on the amount of biosolids applied to the land or received for processing on an annual basis (see 40 CFR Part 503.16). The minimum frequency ranges from 1 to 12 times annually for trace elements, pathogens, and vector attraction reduction. Additional sampling may be required as a permit condition.

To develop a baseline of biosolids quality, more intensive initial sampling may be needed where existing data are inadequate to make sound land application decisions. This initial sampling can be used to estimate variability in biosolids quality, to improve the ability to identify outlier values, and to develop an efficient sampling program.

<u>Example Baseline Sampling Program</u>

A typical short-term baseline sampling program could include 7 biosolids samples collected over a 2-week period, and analyzed for nutrients and pathogen reduction. This approach is typical for sampling for pathogen indicators. Using this sampling method for nutrients allows for estimation of means, standard deviations, and developing a protocol for routine sampling. This is especially important for nitrogen, since confidence in biosolids application rates depends in part on confidence in nitrogen analysis values.

Analyze trace elements in a composite of the 7 samples. If any of the trace element levels in the composite samples are close to Table 1 or Table 3 limits, analyze more individual samples to estimate means, standard deviations, and determine the appropriate number of samples to collect on a routine basis.

Repeating the 2-week sampling event several times during the year will help to gain an understanding of longer term variability, and to choose appropriate sampling times. This sampling scheme allows rapid collection of baseline data, while keeping analytical costs at a reasonable level. If further cost savings are needed for small plants, pathogen indicator samples could be collected only at the times of year when pathogen reduction conditions were the poorest, to determine if Class A or Class B standards are met during the most adverse conditions.

How Many Samples Are Needed?

<u>Pathogens and Indicators</u>

The EPA requires 7 discrete samples for fecal coliform analysis for Class B biosolids when Alternative 1 is used (see *A Plain Language Guide to the EPA Part*

503 Biosolids Rule, EPA, 1994). They recommend that the samples be collected over a 2-week period.

The EPA also recommends 7 samples be collected over a 2-week period for virus and helminth ova analyses for Class A biosolids, but these samples can be combined into a composite rather than analyzed as 7 individual samples. Four duplicate samples from the composite should be analyzed, because of variability in the analytical procedure.

Nitrogen

The number of biosolids samples for total nitrogen analysis can be estimated from the standard deviation derived from previous N analyses and the desired accuracy of the estimate, using the equation:

$$n=4s^2/L^2, \text{ where}$$

n is the number of samples required,

s is the standard deviation estimated from previous results, and

L is the desired limit of accuracy.

This equation will estimate the number of samples required to be within the desired limit of accuracy with a 95% level of confidence.

Example:

Previous total nitrogen analyses had values of 4.8, 4.2, 5.2, 5.9, and 3.9%

The sample mean and standard deviation calculated from these values are 4.8% and 0.80%.

If the desired limit of accuracy of the total nitrogen analysis is 1.0% (20 lb/ton), then

$$n=4\,(0.80)^2/1.0^2$$

$$n=2.54$$

The number of samples rounded to the nearest whole number is 3. If the standard deviation is larger or the desired error limit smaller, the number of samples would increase.

Trace Elements

If your historical database shows that trace element levels are always well within Table 3 limits, then a single composite sample submitted at the required intervals should be sufficient. If levels sometimes exceed limits, then a statistical estimate for determining sample numbers similar to the one for nitrogen should be used.

Choosing a Lab

Find a lab that knows how to test biosolids and report results in a usable form. Confirm that the laboratory methods are acceptable to regulatory authorities. Where low method detection limits are critical, ask the lab to document its advertised detection limit. When possible, visit the lab to verify that it is qualified to run the required analyses. Determine what quality control information the lab can provide. Be sure that results will be reported in useable fashion (i.e. dry weight, with units, sample number, analytical method, etc.) all listed. It's a good idea to ask for a sample reporting form.

Laboratory representatives will need to know the number of samples to be analyzed and any special handling considerations. Become familiar with holding time requirements for the needed analyses, so you can sample and deliver to the laboratory in a timely manner. You will need to know the amount of sample needed by the laboratory, shipping and analysis schedules, and the cost of analyses.

Number of Products to Test

If you market or apply different products to the land, you may be required to submit separate samples for each product, even if they are from the same treatment facility. An example is Class B biosolids applied to the land in bulk form, and a Class A compost product for public distribution derived from Class B dewatered cake.

Responsibility for Sample Collection

The operator has final responsibility for sample collection. You can run the sample program yourself, or you can contact an environmental consulting firm. There are many firms with expertise in collecting samples and interpreting the analytical results.

Plan Documentation

Samples must be documented thoroughly. Set up a:

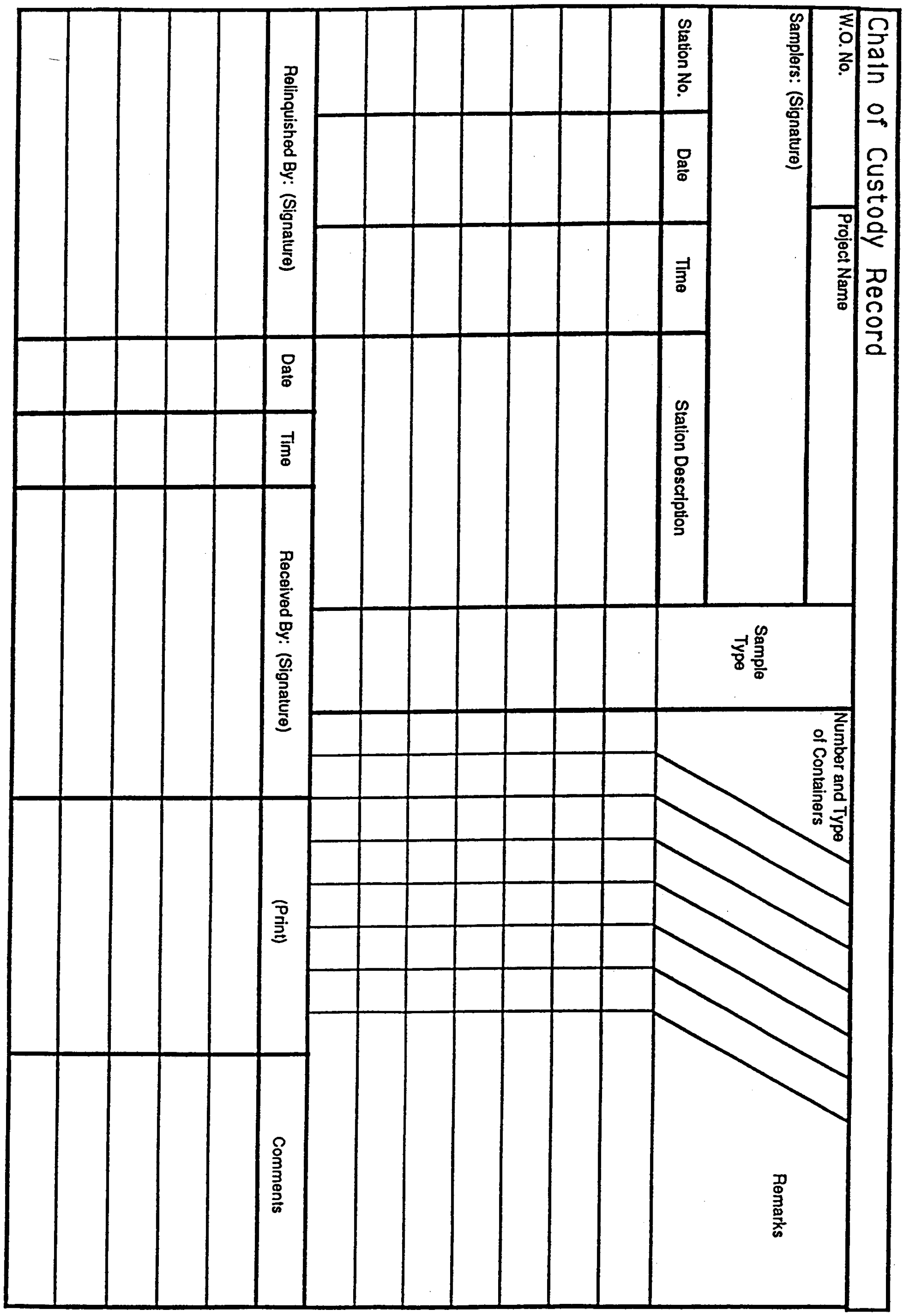
- System for labeling samples (an example is shown in Table 3.12)
- Chain of custody for samples (an example is shown in Figure 3.1)
- Logbook of sampling activities

Table 3.12 Example of a label for a biosolids sample container.

Facility*	Seaside Treatment Plant
Sample Type	Dewatered biosolids cake
Sample Location*	Belt filter press
Preservative*	Cool to 4°C
Analysis Parameters*	Total Kjeldahl Nitrogen Ammonia + Ammonium Nitrogen Percent Total Solids
Collector*	Jane Doe
Collection Time*	0100
Collection Date*	4/1/02
Sampling Organization	Black Environmental Consultants
Container Number	2A
Sample Number	040102-2A

*Mandatory label contents (EPA POTW sludge sampling and analysis guidance document, August 1989).

Figure 3.1 Chain of custody record.



Proper Equipment

You will need sampling equipment (listed in Table 3.13), sample containers and appropriate preservatives.

Table 3.13 Suggested materials for biosolids sampling equipment. Source: EPA "POTW sludge sampling and analysis guidance document," August 1989.

Analysis Parameter	Sampling Equipment Materials
Trace elements, nitrogen, plant nutrients	Glass Polyethylene Stainless steel Teflon
Organics	Glass (non-etched Pyrex) Teflon
Generally unacceptable materials	Galvanized steel (zinc-coated) Aluminum Etched glass

Accuracy of Analytical Results

One way to check for consistency in the laboratory is to submit a reference sample with every batch of samples. This is especially important if several labs will perform the same analytical test. You can compare reference sample results over time and among laboratories as a check on results. Prepare enough of the sample to last 5–10 years and mix it thoroughly. It is not necessary to specially formulate the sample, only that you have a consistent sample, which you can use over time.

Because element concentrations are stable for many years in dried material, a dried, finely ground biosolids powder will work well as a reference sample for trace elements, nitrogen and plant nutrients. Store the dried biosolids reference sample in a sealed container. Because pathogens are not stable when stored, reference samples cannot be used for pathogen testing.

Sampling Locations

For nitrogen, collect samples as close to the time of field application as possible. Ammonia loss occurs rapidly during the final processing steps (dewatering, lime stabilization and bed drying). This loss can also occur when biosolids are stored at the application site. Refer to *Managing Nitrogen from Biosolids* (joint publication of the Northwest Biosolids Management Association and the Washington State Department of Ecology, published as Ecology No. 99-508) for more information on sampling for nitrogen.

Since trace elements are not altered during transport and short-term storage, these samples can be collected at the wastewater treatment plant.

You should establish very specific sampling points for pathogen testing. Pathogen contamination can occur even after pathogen treatment processes have been completed.

Sampling Protocol

Determine the sampling protocol, which includes:

- Number of grab samples
- Time period and sampling points for compositing grab samples
- Volume or weight of grab samples

The sampling protocol varies depending on wastewater treatment and stabilization processes. Consult with the Department of Ecology and others using similar wastewater treatment and stabilization systems for guidelines on designing a sampling protocol. Also refer to the EPA documents listed on pg. 3-19.

Grab and Composite Samples

Grab samples are discrete samples collected at one location and time. Composite samples are a series of grab samples collected over several locations or times, and combined together. Composite sampling is a good way to account for sample variability without increasing analytical costs. It is used for samples collected for nutrient and trace metal analyses.

Composite sampling can be done over time, such as collecting periodic samples from a liquid stream or belt press during a work shift or a day. For stable constituents, such as trace elements, a series of daily composite samples can be combined into a longer-term (typically 2-week) composite.

For biosolids in a drying bed or compost pile, the composite sample consists of grab samples collected at different locations. Collect at least 5-10 grab samples per composite, using a grid system for locating sampling points. Sample the deeper parts of the pile more intensively, since they contain a larger volume of material per unit area. Collect the same size sample from each location in the grid. You may want to composite some, or all of the samples collected from the grid.

Biosolids quality in lagoons can vary considerably with depth, and composite sampling should be done over depth as well as area. Representative sampling of lagoons is difficult. Refer to *Control of Pathogens and Vector Attraction in Sewage Sludge* (EPA, 1992) for more information on lagoon sampling.

To obtain high-quality composite samples, observe the following precautions:

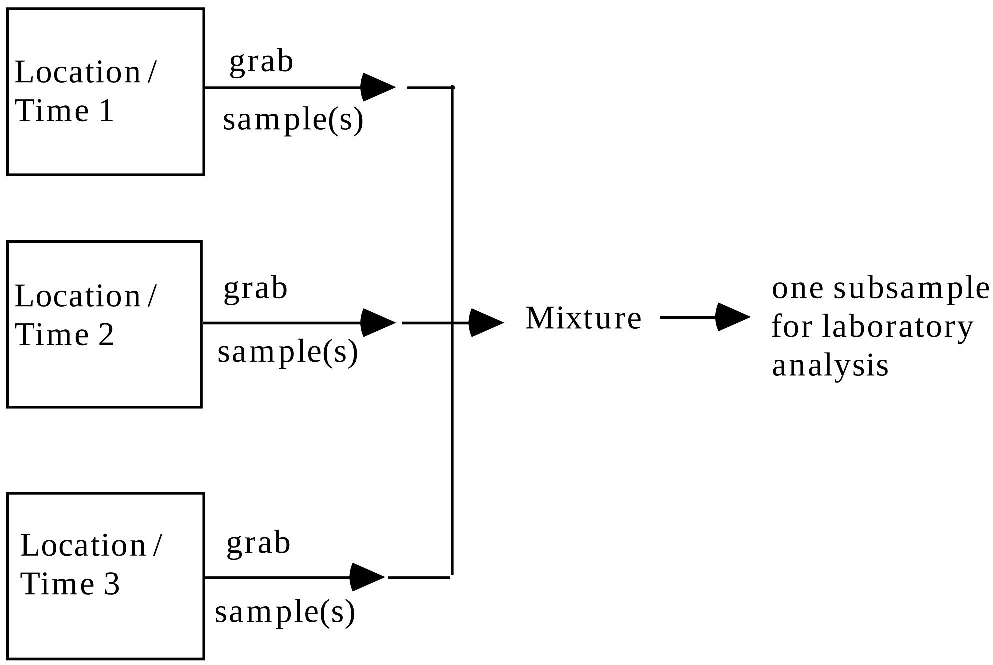
- To preserve samples during the collection period, cool them to 4^{o}C and keep them cool.
- Make sure the composite sample is well mixed. For liquid samples, combine the individual grab samples into a larger container, mix, and then sample from the mixed container using a ladle or similar device. Semi-solid and solid samples are more difficult to mix thoroughly. Mix them by hand, and then take many small subsamples from the mixture to get a representative sample for the laboratory.
- Microbial samples are often collected as grab samples rather than composite samples over time because the samples are perishable. The EPA recommends composite samples for viruses and helminth ova, but the samples need to be preserved in accordance with EPA guidelines in *Control of Pathogens and Vector Attraction in Sewage Sludge* (EPA, 1999).

<u>Sample Volume or Weight</u>

When biosolids are sampled at the end of a flowing process (for example, after dewatering, or liquid from a pipe), it is usually best to take a composite sample over time, as described above (an example is shown in Figure 3.2A). Individual samples that make up the composite should be uniform in volume or weight.

Figure 3.2A Example of composite sampling method.

Collect grab samples of equal volume or weight at each sampling location or time.



Where sources of unequal size are being mixed into a composite (i.e., piles of different size or tanks of different volume), use a weighted average composite sample (see example in Figure 3.2B). For this type of sample, collect a weight (or volume) of sample from each source in proportion to the weight (or volume) of the pile or tank.

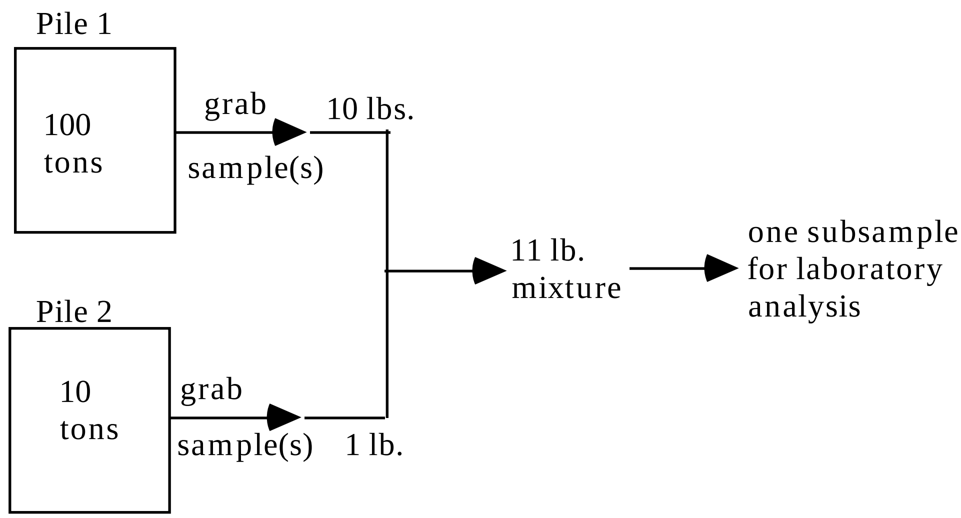
Collecting Samples

Cleaning Equipment

Sampling equipment must be cleaned before it can be used. Specific procedures vary depending on which tests will be run. The water, detergents and acids used during washing should be free of contaminants.

Figure 3.2B Example of weighted average composite sample method.

This sampling method is used for collecting composite samples from locations with unequal volume or weight. **Sample weights given are for example purposes only.**



Preparing Containers

For nutrient and trace element analyses of liquid samples, add appropriate chemical preservatives to the sample containers before use. Chemical preservatives cannot be used with dewatered, composted or dried biosolids, however, because they will not mix well enough. For all types of biosolids, refrigeration at 4^{o}C (40^{o}F) is an acceptable preservation method. Samples for virus analysis should be frozen at -18 ^{o}C (0^{o}F) or colder.

Systematically label all sample containers before using them. An example of a label is shown in Table 3.12.

Safety

Identify which safety precautions are needed for the planned sampling method. Toxic fumes (ammonia or other gases from anaerobic digestion) can be hazardous when samples are collected in an enclosed area.

To minimize pathogen exposure, personal hygiene is essential. For in-plant sampling, the sampling should be supervised by a certified operator.

Collecting

Chill all samples at 4°C during compositing and holding. An ice-water bath chills samples more quickly than a refrigerator or ice. Collect the same weight or volume at each time or location of sampling unless you are using the weighted average composite sampling method.

Composite Grab Samples

When collecting grab samples over time, store them at 4°C. Mix the grab samples thoroughly and transfer a portion of the mixture to the sample container as described previously. Liquid samples *must be agitated* before transferring them to the sample container (use glass or Teflon stirring rods).

Filling Containers

Before shipment, fill sample containers no more than 3/4 full. Check that the containers are completely labeled. To reduce biological activity and the risk of liquid samples exploding, use refrigeration or chemical preservatives.

Delivering Samples

Samples must be kept at 4°C (frozen for virus samples) and delivered promptly to the laboratory. Specify the analytical tests to be run and the appropriate reporting units.

Sample holding times will vary depending on which tests will be run. Holding time is the most critical for pathogen tests.

Documentation

Record Sampling Event

Record the sampling activity on a chain of custody document (see Figure 3.1 for an example) and in a bound logbook. In the logbook, note any conditions at the time of sampling that may affect analysis results. The chain of custody document identifies the handling history from the time of collection until analysis, showing who handled the sample and whether holding time requirements were met.

Historical Database

Convert all analyses to dry weight basis. If your analyses are on an as-is (wet weight) basis, divide each analysis by the percent solids in the biosolids and multiply the result by 100. Enter the analytical values into a historical database for your treatment plant (see example in Table 3.14).

Identify any values that are questionable, based on historical results, and try to determine the cause of these results. By reviewing each of the steps in the sample collection and analysis process, you can check whether they were properly conducted. Samples can be contaminated by dirty containers, dirty sampling equipment or in the laboratory. If necessary, repeat the analysis.

Statistical Tests

Finally, you should perform statistical tests to verify the quality of the data. This should include mean, standard deviation and coefficient of variation. The statistical methods should be consistent for each sample collection date. Statistical results are valuable for justifying revisions in sampling protocol and identifying outlier values. Consult a reference such as *Standard Methods for the Examination of Water and Wastewater* for statistical procedures.

Table 3.14 Suggested format for a biosolids historical database for a wastewater treatment facility.

Report all biosolids data on a dry weight basis.

Date of report _______________

				Year __________				
Element	**Required by 503 Rule?**	**EPA Table 3 Limit**	**Ceiling Limit**	**Sample Date 1***	**Sample Date 2**	**Sample Date 3**	**Mean**	**Standard Deviation**
		mg/kg	mg/kg	------------------------		mg/kg		------------------------
Arsenic (As)	yes	41	75					
Cadmium (Cd)	yes	39	85					
Copper (Cu)	yes	1500	4300					
Lead (Pb)	yes	300	840					
Mercury (Hg)	yes	17	57					
Molybdenum (Mo)	yes		75					
Nickel (Ni)	yes	420	420					
Selenium (Se)	yes	100	100					
Zinc (Zn)	yes	2800	7500					
Nitrogen:								
Total Kjeldahl N (TKN)	yes							
Ammonia + Ammonium-N (NH_3-N + NH_4-N)	yes							
Nitrate-N (NO_3-N)	varies**							
Nutrients:								
Total phosphorus (P)	no							
Total potassium (K)	no							
Other (as needed)	no							

*Required sampling frequency for trace elements varies. Be sure to check your permit requirements and consult with your regulatory staff contact if you have any questions. More than one sample may be collected and analyzed at each sampling date.

**Nitrate-N is required for composts and aerobically digested biosolids, but may not be required for anaerobically digested biosolids.

Chapter 4
Agricultural Site Design

Table of Contents

Agricultural Site Suitability

Why Assess Site Suitability?

Biosolids application can benefit almost any site that produces crops using normal farming practices. By evaluating the site thoroughly before proceeding, however, you can save money, improve public acceptance and gather information that will guide site design and management. Factors that determine site suitability include:

- Months of the year when biosolids can be applied.
- Ease of transportation and access to the site.
- Crop capacity to use biosolids nitrogen.
- Buffer requirements to wells, surface water, roads and property.
- Applicable crop harvest waiting periods.
- Monitoring requirements.

How Soil Physical Properties Affect Site Suitability

Soil properties directly affect the first three of these site suitability factors. In addition, soil properties may limit the type of biosolids applied, the method of application and the timing of the application. Sites with limiting soil characteristics are more expensive to manage because:

- Biosolids may need to be stored when the conditions for applying them are unfavorable.
- Special practices may be required for soils with seasonal high water tables, shallow bedrock or restrictive layers, or steep slopes.

Even though they may require greater management, less suitable soils often benefit more than other sites from biosolids applications. These sites may have crops such as dryland grains and perennial grasses, which require shorter waiting periods between application and harvest than the high-value vegetable and fruit crops grown on the best soils. Less suitable soils may also have had less fertilization in the past, and would therefore benefit more from the nutrients supplied by biosolids.

Soil properties are divided into three types: physical, chemical and biological (see Chapter 1). The physical properties are most important for siting, since they have the greatest effect on the site's suitability and management requirements.

Soil Texture

Soil texture influences many other soil characteristics. It is determined by the parent material of the soil (for examples: wind-blown silts in eastern Washington, glacial deposits in northwest Washington) and is not changed by management practices.

Soil texture ranges from coarse (sandy) to fine (clay). A soil texture class is defined by specific percentages of sand, silt and clay (for example, a loam contains about 20% clay, 40% silt and 40% sand). The clay fraction, along with organic matter, makes up most of the surface area where biological and chemical reactions take place in the soil. Therefore, as the clay content increases, so does the capacity of the soil to store water and hold nutrients.

Texture also affects the porosity of the soil. Sandy soils contain large pores so water drains through them easily. Soils containing mostly silt and clay have smaller pores that do not drain easily. The risk of runoff is greater in these fine-textured soils.

Soil Structure

Soil structure is the arrangement and stability of soil particles. Texture, organic matter, vegetation and management practices all have an effect on structure. For example, soil structure can be destroyed by heavy equipment on soils that are too wet.

Structure influences water movement and soil aeration. Soils with good structure contain about half solids and half pore spaces. Water is held in the smaller pore spaces, while water drains through the larger pore spaces. At its maximum moisture-holding capacity, a soil with good structure has half of its pore space filled with water. The other half of the pore space is filled with air, which sustains biological activity.

Soil Color

Color is a good indicator of soil drainage. Well-drained soils have horizons (layers) that are uniformly red, brown or black. Poorly-drained soil horizons are gray, often with brownish or reddish mottles.

In a soil profile, the depth to gray, mottled colors is often the depth to the seasonal high water table. Seasonal water tables play a role in site suitability for biosolids because:

- Pathogens tend to survive longer in saturated soils.
- Soil wetness limits vehicle traffic on poorly drained sites.

Pathogens from biosolids are killed by physical processes such as heat or drying near the soil surface, or by microbial processes in the soil. If a soil is saturated, the rate of die-off of pathogens declines, increasing the risk of pathogen leaching or runoff. Bacteria and viruses are the pathogens most likely to leach or run off, because of their small size. To ensure good conditions for die-off of bacteria and viruses, avoid biosolids applications to wet soils in the spring until water tables have fallen below 24 inches. In the fall, allow time for die-off of bacteria and viruses (30-60 days) before high water tables are expected.

Soil Depth

Soil depth affects site productivity. Very shallow soils have low crop yields and can accept only low rates of biosolids. The risk of runoff is increased on some very shallow soils. Soil depth is limited by bedrock or by restrictive layers (compacted, cemented or dense clay layers). Restrictive layers often reduce the risk of leaching, but fractured bedrock can increase the risk of leaching.

Interpretations of Soil Physical Properties

By evaluating the texture, structure, color and depth in a horizon of the soil as it occurs in the field, scientists can estimate other properties, including:

- Infiltration
- Drainage
- Permeability
- Productivity
- Potential for leaching, runoff and erosion

Using Soil Surveys

Most counties in the state have a soil survey completed by the USDA Natural Resources Conservation Service. Copies can be obtained at local NRCS offices.

What's in a Survey?

A soil survey contains three parts: maps, text and tables. Soil maps show the spatial distribution of the different soils in an area. The text describes the properties of each soil series mapped in the county. Information for each soil series includes:

- Soil series name, general location and acreage
- Landscape position and slope
- Texture, color and structure of each soil horizon
- Soil depth
- Soil-water relations
  - Drainage and permeability (water movement through soil)
  - Water-holding capacity (water retention after drainage)
- Use and management of the soils
  - Average pH and native fertility
  - Average crop yields
  - Soil limitations and appropriate management practices

The tables provide more information about soil properties and how they may affect various land uses:

- Physical and Chemical Properties — Clay content, permeability, water holding capacity, pH, shrink-swell potential and, in some cases, organic matter content.
- Soil and Water Features — Runoff potential (hydrologic group), flooding, water tables and depth to bedrock.
- Engineering Properties — Additional data on texture and coarse fragments.
- Yields Per Acre of Crops and Pasture — Crops that are commonly grown and the relative yields that can be obtained under good management.

Soil Survey Map Units

On most soil maps, the smallest area that can be shown is from three to four acres. This area on the map is called a map unit. Rather than representing a uniform soil series (a set of soils whose profiles are alike), it usually contains small areas of several soil series. The map unit descriptions detail the kind and extent of soil series found in that map unit.

Landscape Distribution

The soil survey also shows the landscape distribution of suitable and non-suitable soils. Areas of uniform suitability are easier to manage than areas of non-uniform suitability. When areas of fair or poor soils are distributed throughout larger areas of good or excellent soils, management may be restricted to what is required for the least suitable soil. For example, access to the more suitable areas may be limited to times when the poorly suited soil can handle vehicle traffic.

Locating Potential Sites

To use the survey to locate suitable sites for biosolids application:

1. Locate the major soil associations on the General Soil Map. A soil association is a landscape that contains several soil series in a predictable pattern. It is usually named for the soil series that makes up the majority of the land area.
2. Read about each association in the text — usually near the beginning of the report.
3. Use these two sources to identify associations dominated by deep, well and moderately-well drained soils on nearly level landscapes. There are not many large areas of suitable soils in associations dominated by poorly drained soils, shallow soils, or soils on steep slopes.
4. Return to the General Soil Map and locate the areas where the more suitable associations occur. Investigate these areas further.

Soil Suitability Rating System

Introduction

This section outlines a way to rate sites based on soil suitability, using information from soil surveys. The rating will identify soil limitations, and can be used in preliminary comparison of potential sites. A soil limitation does not mean a site is unsuitable for biosolids applications; in fact most sites will have some limitations. Rather, the soil suitability rating is a way to identify the site management needed to make best beneficial use of the biosolids.

The importance of particular soil factors will vary throughout the state, depending on climate and local cropping practices. For example, soil infiltration rates can be a critical factor on winter sites in western Washington where runoff is a concern. Soil infiltration rates are not as important in drier climate areas or when biosolids are applied during summer months.

Who Should Use This System?

This system is condensed from Oregon State University Cooperative Extension Manual 8: *Guide to Soil Suitability and Beneficial Use of Domestic Wastewater Biosolids.* It is simple enough to be used by someone with a little background in soil science, after gaining some familiarity with the technical terms.

This rating system is suggested for those obtaining permits and those evaluating site permit applications. Although it is not as good as an on-site evaluation by a professional soil scientist, the system is good enough to spot sites with problems that require special management practices.

How the Soil Suitability Rating System Works

The rating system evaluates soil physical properties as they relate to biosolids application, using information from an NRCS soil survey. Table 4.1 outlines how the system works, and Table 4.2 is a worksheet for recording information.

The suitability of a soil depends as much on interactions among several properties as it does on each property individually. These interactions are expressed by combining information from two, three or four properties in each table (Tables 4.3 to 4.6).

Table 4.1 How the Soil Suitability Rating System works.

Table Number and Title	What is Rated	Data Needed from Soil Survey	Where to Find in Soil Survey
Table 4.3 Depth / Texture	Site productivity.	Subsoil texture (within 40") with highest clay content.	Soil profile description.
		Coarse fragments.	Soil profile description; map unit description.
		Depth to bedrock or restrictive layer.	Soil profile description; map unit description.
Table 4.4 Infiltration	Rate of water movement into soil.	Surface soil shrink / swell potential.	Table - physical & chemical properties.
		Surface soil texture.	Soil profile description; map unit description.
		Surface soil organic matter.	Table - physical & chemical properties.
		Surface soil structure grade.	Soil profile description, map unit description.
Table 4.5 Drainage / Permeability	How rapidly water moves through the soil.	Soil drainage class.	Soil profile description, map unit description.
	Affects leaching potential and duration of seasonal perched water tables.	Permeability (in. per hr).	Table - physical and chemical properties.
		Depth to restrictive layer.	Soil profile description, map unit description.
		Depth to rapidly draining horizon.	Soil profile description, map unit description.
Table 4.6 Slope	How slope affects runoff from site.	Slope.	Index to map units; map unit description.
		Depth to bedrock or restrictive layer.	Soil profile description, map unit description.
		Infiltration rating.	Table 4.4 (of this manual).

Table 4.2 Soil Suitability Rating System worksheet.

Worksheet for collecting information from an NRCS soil survey to use in soil suitability rating tables 4.3 to 4.6.

Surface soil:	**Your Soil**	**Example Soil**
Series		Kapowsin
Texture (choose one) Loamy sand Sandy loam Loam Silt loam Silty clay loam Clay loam Sandy clay loam Sandy clay Clay	_______	loam
Coarse fragments (choose one) None (0-15 percent by volume) Gravelly, cobbly (15-35%) Very gravelly, very cobbly (35-60%) Extremely gravelly, extremely cobbly (>60%)	_______	gravelly
Structure grade (choose one) Weak Moderate Strong Massive Single grain	_______	weak
Organic Matter Percent[1]	_______	4.0
Permeability (choose one) Very rapid (>20) inches per hour) Rapid and moderately rapid (2 to 20 inches per hour) Moderate and moderately slow (0.2 to 2.0 inches per hour) Slow (0.06 to 0.20 inches per hour) Very slow (<0.06 inches per hour)	_______	moderate
Shrink/swell potential (choose one) (sandy clay, silty clay or clay textures only) Low-medium High	_______	not applicable

[1]Organic matter and permeability data are not in some older soil surveys.

Table 4.2 (continued) Soil Suitability Rating System worksheet.

Worksheet for collecting information from an NRCS soil survey to use in soil suitability rating tables 4.3 to 4.6.

Subsoil: (Refer to terminology on previous page.)	**Your Soil**	**Example Soil**
Texture with highest clay content within 40 inches of surface	___________	loam
Coarse fragments	___________	gravelly
Permeability	___________	moderate
Soil profile characteristics:		
Drainage class (choose one) Excessively drained Somewhat well drained well drained moderately well drained somewhat poorly drained poorly drained very poorly drained	___________	moderately well drained
Depth to restrictive layer	___________ (inches)	20–40 (inches)
Kind of restrictive layer (choose one if present) clay pan fragipan duripan petrocalcic weathered bedrock (Cr) solid bedrock (R) none	___________	duripan
Depth to rapidly draining horizon (if present) (permeability greater than 6 inches per hour)	___________ (inches)	none present
Slope range of soil surface	____ to ___ %	0–6%

For all soil suitability evaluations, we compare characteristics to an ideal soil with the following characteristics:

- Deep, well drained.
- Medium textured (silt loam, loam or very fine sandy loam).
- Black to very dark brown surface soil.
- Brown or yellowish-brown subsoil, no gray matrix, or red / yellow mottles.
- No restrictive layers (claypan, fragipan, dense till) in subsoil within 40 inches of ground surface.
- No compaction zone beneath the depth of tillage.
- Greater than 3% surface soil organic matter content.
- Moderate to strong surface soil structure, low shrink-swell potential.
- Available water-holding capacity of 12 inches or more.
- Moderate to rapid infiltration.
- Moderately slow to moderately rapid permeability.
- Level to gently rolling land surface, 0–3% slopes.
- Not on an active floodplain.

Few sites have an ideal soil.

Suitability rating tables 4.3 to 4.6 are based on departures from the ideal soil. In each table, a soil is rated as excellent, good, fair or poor. The greater the number of properties that depart from ideal and the greater the degree of departure, the more severely limited the soil is for biosolids application. Many of these soils can still be used, but management is required to overcome the limitations.

Steps for Using the Soil Suitability Rating System

1. Make a list of all map unit symbols that cover the potential land application area. Use the legend and the Index to Map Units to find the soil name that corresponds to each symbol.
2. Read about the soils in the soil survey text. Use Table 4.2 to record the information needed to rank suitability.
3. Use Tables 4.3 to 4.6 to rate the suitability for each set of soil properties as excellent, good, fair or poor. Table 4.7 shows three examples of suitability ratings for soils in Washington.
4. Review the limitations of your site. Determine which soil characteristics (slope, drainage, permeability, etc.) impose the most severe limitations. Develop management practices to address site limitations (see examples in Table 4.8).

How to Overcome Limiting Properties

In the soil survey, you can find suggestions for management practices that will promote crop production while protecting soil and water resources. Refer to the section titled *Use and Management of the Soils,* and the map unit descriptions for the appropriate tillage, irrigation and cropping practices for each soil.

For specific recommendations for the management of biosolids on agricultural sites, see Chapter 6, Agricultural Site Management.

Table 4.3 Soil Suitability Rating System — Depth/texture rating.

Subsoil texture[1]	Coarse fragments[2] Name	% by Volume	Depth to restrictive layer (inches) >40	20-40	<20
			---- depth / texture suitability rating ----		
Sand, or loamy sand	None	<15	G[3]	G	F
	Gravelly, cobbly	15-35	F	F	P
	Very gravelly, very cobbly	35-60	P	P	P
	Extremely gravelly, cobbly	>60	P	P	P
Sandy loam, loam, or silt loam	None	<15	E	G	F
	Gravelly, cobbly	15-35	G	G	F
	Very gravelly, very cobbly	35-60	F	F	P
	Extremely gravelly, cobbly	>60	P	P	P
Sandy clay loam, clay loam or silty clay loam	None	<15	G	G	F
	Gravelly, cobbly	15-35	G	G	F
	Very gravelly, very cobbly	35-60	F	F	P
	Extremely gravelly, cobbly	>60	P	P	P
Sandy clay, silty clay or clay	None	<15	G	F	P
	Gravelly, cobbly	15-35	F	F	P
	Very gravelly, very cobbly	35-60	P	P	P
	Extremely gravelly, cobbly	>60	P	P	P

[1]Use the texture of the subsoil horizon within 40 inches of the surface that has the highest clay content.

[2]Coarse fragments are given by horizon in soil profile descriptions. Use average percent coarse fragments in top 40 inches of soil.

[3]Depth / texture suitability rating: E = Excellent; G = Good; F = Fair; P = Poor.

Table 4.4 Soil Suitability Rating System — Infiltration rating.

Note: These ratings are for dewatered, dried or composted biosolids. For winter applications or applications of liquid biosolids, reduce the rating by one class. Use data from the surface horizon only.

		Sand or loamy sand	Sandy loam, loam or silt loam	Sandy clay loam, clay loam or silty clay loam	Sandy clay, silty clay or clay	
					Shrink-swell potential[1]	
Grade of Structure[2]	**Organic Matter (%)[3]**				**Low-med**	**High**
Weak	0–1	E[4]	G	G	F	F
	1–3	E	E	G	F	F
	>3	E	E	E	G	F
Moderate	0–1	E	E	E	F	F
	1–3	E	E	E	G	F
	>3	E	E	E	G	F
Strong	0–1	E	E	E	G	F
	1–3	E	E	E	G	F
	>3	E	E	E	E	F
Massive	0–1	E	F	F	F	F
	1–3	E	G	F	F	F
	>3	E	G	G	F	F
Single grain	---	E	---	---	---	---

[1]Obtain from table of physical and chemical properties in soil survey.

[2]Obtain from soil profile description in soil survey.

[3]Obtain from soil test (0–6" depth) at site or estimate from table of physical and chemical properties.

[4]Infiltration Suitability rating: E = Excellent; G = Good; F = Fair, P = Poor.

Table 4.5 Soil Suitability Rating System — Drainage/permeability rating.

Note: Ratings are for dewatered, dried and composted biosolids. For winter applications or heavy applications of liquid biosolids, reduce the rating by one class.

	-------------- Drainage class[1] --------------				
	ED & SWED	**WD**	**MWD**	**SWPD**	**PD & VPD**
	------- Drainage / Permeability Rating -------				
Soils with uniform permeability (Same class or adjacent classes)					
Very rapid (>20 in. / hr)	F[2]	F	F	F	F
Rapid & moderately rapid (2 to 20 in. / hr)	G	E	E	G	F
Moderate & moderately slow (0.2 to 2.0 in. / hr)	E	E	E	E	G
Slow (0.06 to 0.02 in. / hr)	---	E	E	G	G
Very slow (<0.06 in. / hr)	---	G	G	F	F
Soils with slowly or very slowly permeable restrictive layers					
Depth to restrictive layer:					
<20 inches	F	G	F	F	F
20-40 inches	G	E	G	G	F
>40 inches	E	E	E	G	F
Soils with rapidly draining horizons (>than 6 inches per hour)					
Depth to rapidly draining horizon:					
<20 inches	F	G	G	F	F
20-40 inches	G	E	E	G	F
>40 inches	E	E	E	E	G

[1]Key to abbreviations:

ED = Excessively drained
SWED = Somewhat excessively drained
WD = Well-drained
MWD = Moderately well drained
SWPD = Somewhat poorly drained;
PD = Poorly drained
VPD = Very poorly drained.

[2]Drainage / permeability suitability rating: E = Excellent, G = Good; F = Fair; P = Poor.

Table 4.6 Soil Suitability Rating System — Slope effect rating.

Note: Determine infiltration ratings (see Table 4.4) before using this table.

		Infiltration Rating (from Table 4.4)			
Slope (%)	**Depth to restrictive layer (inches)**	**Excellent**	**Good**	**Fair**	**Poor**
		--------------- Slope effect suitability rating ---------------			
0-3	<20	G[1]	G	F	P
	20–40	E	E	G	G
	>40	E	E	G	G
3–8	<20	F	F	P	P
	20–40	G	G	F	P
	>40	E	G	G	F
8–15	<20	F	F	P	P
	20–40	F	F	F	P
	>40	G	F	F	P
15–30	<20	P	P	P	P
	20–40	F	F	P	P
	>40	F	F	P	P
>30	<20	P	P	P	P
	20–40	P	P	P	P
	>40	F	P	P	P

[1]Ratings apply equally to all biosolids. Slope effect suitability rating: E = excellent, G = Good, F = Fair, P = Poor.

Table 4.7 Soil Suitability Rating System — Examples of soil suitability ratings for biosolids applications on three soil series in Washington.

	Kapowsin gravelly loam (Western WA)	**Quincy fine sand (Central WA)**	**Palouse silt loam (Eastern WA)**
Soil Properties *Surface Soil:*			
Texture of surface	loam	fine sand	silt loam
Coarse fragments	gravelly	none	none
Structure grade of surface	weak	weak	weak
Organic matter %	4.0	0.5	3.7
Permeability	moderate	rapid	moderate
Shrink-swell potential	NA	NA	NA
Subsoil:			
Texture of subsoil	loam	fine sand	silt loam
Coarse fragments	gravelly	none	none
Permeability	moderate	rapid	slow
Soil profile:			
Drainage class	moderately well drained	somewhat excessively drained	well drained
Depth to restrictive layer (in)	20–40	---	>40
Depth to rapidly draining layer (in)	---	<20	>40
Slope	0–6	2–15	7–25
Suitability Ratings (Tables 4.3 – 4.6)			
Depth / Texture (4.3)	G	G	E
Infiltration (4.4)	E	E	E
Drainage / Permeability (4.5)	G	F	E
Slope (4.6)	G	E	G
Most Limiting Factor	depth	excessive drainage	slope

Ratings are adapted from the *Guide to Soil Suitability and Site Selection for Beneficial Use of Municipal Wastewater Biosolids*, Oregon State University Extension Manual 8.

Table 4.8 Soil Suitability Rating System — Examples of management practices to overcome soil limitations at biosolids application sites.

Limitation	Management
Shallow soils	• Irrigate to increase productivity. • Apply light applications of biosolids to match productivity.
Soils high in coarse fragments	• Plant to perennial crops.
Soils with compaction zone below plow layer	• Use subsoil tillage (ripping, chiseling, subsoiling) to fracture compaction zone.
Silt loam surface soils with weak structure, and little organic matter	• Reduce vehicle traffic. • Use tillage practices that keep crop residue on the surface. • Include perennial grass crops in the rotation.
Soils with potential for leaching (i.e., rapid permeability or rapidly-draining horizons within 40 inches — NRCS hydrologic groups A and B)	• Apply light applications of biosolids several times a year rather than a single heavy application.
Clay soils with high shrink-swell capacity	• Apply biosolids in early summer when soil will support vehicle traffic, but before vertical soil cracking has occurred. • Keep soil from cracking with sprinkler irrigation.
Soils with fine textured (clay loam or clay) surface soil, slow permeability or poor drainage — NRCS hydrologic groups C and D	• Apply biosolids after surface soil has dried enough to permit traffic without compaction. • Apply after perched water table has receded to at least two feet below ground surface. • Apply light applications of biosolids during summer months.
Soils with slopes with potential for runoff	• Use tillage practices to keep crop residues on the surface. • Plant to permanent vegetative cover crops. • In the fall after harvest, chisel dryland soils on the contour.

Buffers

Purpose of Buffers

Buffers are non-application areas located within a permitted biosolids application site. Buffers:

- Keep biosolids applications on the permitted site.
- Control runoff from the treated area.
- Protect surface water and other non-target areas.
- Reduce off-site odors.

Kinds of Buffers

Site buffers can be grouped into three categories:

- Surface water
- Groundwater
- Property

Surface and groundwater buffers protect water quality. The design of these buffers are based on technical considerations.

Property buffers improve the aesthetics of biosolids applications and control potential public exposure to Class B application sites. These buffers are based on common sense, taking into consideration the desires of neighboring property owners.

Designing Site Buffers

Surface Water Buffers

Biosolids site managers design and establish adequate buffers to protect surface water. The following paragraphs give general guidance for buffers, which can be modified as needed for each site. For special situations, buffers may need to be larger than suggested; at all sites they must be large enough to protect receiving waters. Federal and state rules require minimum buffers of ten meters (33 feet) to all waters of the U.S. for biosolids that do not meet Exceptional Quality Criteria.

Surface water buffers must be increased for sites with:

- High potential for runoff. Slope and soil characteristics determine runoff potential.
- High potential for contaminant transport. Vegetation filters and slows runoff. A bare soil buffer provides little filtering of runoff, so these buffers should be larger than those with good vegetative cover.

Different types of surface water (e.g., rivers, lakes, seasonal waters and ditches) need different buffer sizes. The larger bodies of water need larger buffers because:

- Larger waterways are more likely to be used for domestic purposes.
- Larger streams have banks that are less well-defined and that are farther away from the normal waterline.

The following factors are used to design buffer widths (see Table 4.9):

- Biosolids application method (surface or injected / incorporated).
- Ground surface cover.
- Slope effect suitability rating (from Table 4.6, a rating of potential runoff). This rating estimates potential runoff based on percent slope and soil factors, such as texture, structure and organic matter.
- Type of water body.

The largest buffers are for sites where:

- Biosolids are applied to the surface and are not incorporated.
- The soil is bare.
- The slope effect suitability rating is poor / fair (slope and soil types result in high amounts of runoff).

The smallest buffers are for sites where:

- Surface runoff is slowed by permanent vegetation, or the biosolids are injected or incorporated.
- The slope effect suitability rating is good / excellent (slope and soil characteristics allow little runoff).

Table 4.9 Surface water buffers recommended for agricultural biosolids application sites. In some cases buffers may need to be adjusted based on site-specific considerations or monitoring data.

Application Method	Ground Surface Cover	Slope Effect Suitability Rating (Table 4.6)	Type of Water Body: River, Lake or Stream	Seasonal	Ditch
			buffer width, feet		
Surface	Bare soil	Poor / Fair	200	100	50
		Good / Excellent	100	50	33
Surface	Permanent vegetative cover	Poor / Fair	100	50	33
		Good / Excellent	50	33	33
Injected or incorporated	Bare soil	Poor / Fair	100	50	33
		Good / Excellent	50	33	33

Groundwater Buffers

Groundwater buffers protect groundwater from direct contamination by biosolids. By applying at agronomic application rates and using biosolids with acceptable quality, the groundwater under the application site is protected from becoming contaminated by nitrate, pathogens and trace elements.

All wells provide a potential direct path to groundwater, and have similar buffer requirements regardless of how they are used (e.g., for irrigation or domestic water supply). The suggested horizontal buffer from wells is 100 feet, similar to that for domestic on-site septic systems. In some cases buffers can be adjusted based on site-specific considerations. Buffer requirements in wellhead protection zones may override these recommendations.

A well that has been abandoned may provide a direct path to groundwater if it has a cracked or nonexistent well casing (as can any well in such a condition). If there are improperly abandoned wells on or near a biosolids application site, contact the Ecology regional office for guidance on well closure.

In cases where the seasonal high groundwater table is within three feet of the surface, a groundwater protection plan is required under the statewide general permit for biosolids management (see section 8.3 of the permit).

Property Buffers

Property buffers include non-application areas near roads, dwellings and fence lines. Property buffers must be designed to:

- Make sure that no biosolids will be applied off the permitted site.
- Reduce odors, public access and exposure to a Class B biosolids application site.

How biosolids are applied affects both application accuracy and the potential for odors. Accurate applications that control odors have the smallest property buffers. For example, required property buffers should be less for injected biosolids than for liquid biosolids applied with a high pressure big gun applicator. The big gun produces some small droplets that may drift off the site. The small droplets also increase odor. Injected biosolids remain on-site and have little odor after application.

Suggested property buffers are listed in Table 4.10. Generally, a minimum buffer of 5 feet is recommended to protect against off-site application. Where biosolids are injected into the soil and there are no sensitive adjoining property uses, the buffer may be reduced to near zero. Remember, however, that biosolids must not be applied or allowed to run onto non-permitted areas.

Table 4.10 Typical property buffers recommended for biosolids application sites.

Feature	Buffer (ft)
Property line	5 to 50
Dwelling	50 to 200
Major arterial or highway	50 to 100
Minor road (usually dirt or gravel)	5 to 50

Management of Buffers

Remember that a buffer is part of the permitted area. During biosolids application, buffers should be clearly marked and monitored. If you find that biosolids applications are encroaching on the buffer area, determine the cause and correct any application problems.

In practice, it may be better to increase the size of the buffer beyond what is required by the site permit. For example, a five-foot property buffer in a crop field might be increased to the width of the farmer's fertilizer applicator. This larger buffer would allow fertilization of the buffer strip without overlapping the biosolids application area.

Summary

Properly designed surface and groundwater buffers protect water quality off-site. Consider site-specific factors such as slope, soil infiltration and permeability characteristics, and vegetative cover when designing surface water buffers. When designing property buffers, your objective will be to reduce any nuisance to neighbors and the public.

Evaluating Crop Suitability for Biosolids

Introduction

When designing a plan for applying biosolids, you will be working with the management practices already followed by the farmer or site operator. The decision to use biosolids should not alter crop rotations, or other management decisions, such as whether to drain, irrigate or lime the soil.

The crops that are appropriate for a biosolids management program are:

- Food crops (for direct human consumption).
- Pasture and feed crops (for animal consumption).
- Non-food crops (e.g., ornamentals and fiber crops).

Grain (a food crop) and grass seed (a non-food crop) are similar in that both crops have harvested portions (seeds) that do not contact biosolids. Because of this common feature, they are managed similarly and will be discussed together in this section.

Whether a crop is suitable for biosolids depends on several factors:

- Months when biosolids can be applied to the crop.
- Potential for repeat applications at the same site.
- Capacity to use nitrogen.
- Required waiting periods between Class B biosolids application and harvest.
- Marketing restrictions imposed by food processors.
- Whether liquid, dewatered or composted biosolids can be applied.

Potential Crop Yields

When evaluating a site, estimate crop yield, since this will affect how much plant nutrients are used. Generally, a site with a higher yield potential will make better use of biosolids.

Each NRCS soil survey lists the general estimates of the yield potential for different soil types in an area. For each soil type, the relative yields remain the same, regardless of when the soil survey was published. As an example, the survey might say that soil A will produce 60% of the yield produced on soil B. Current yield levels (tons per acre or bushels per acre) may be higher than those listed in the soil survey because higher-yielding crop varieties are now grown.

Crop Marketing

Before using biosolids on a processed food crop (for instance, sweet corn, hops, and so on), discuss your plan with the food processor. Some food processors have refused to accept crops grown on land amended with biosolids. Other food processors have recognized recycling of biosolids as a sound crop production practice.

The U.S. Department of Agriculture supports biosolids recycling. Most facilities in Washington produce biosolids that meet the more stringent Table 3 standards for trace elements. The decisions made by food processors are not always guided by science; rather, they reflect public perception. By working with the food processors, you may be able to shed some light on how biosolids can benefit their products.

Soil pH

Soil pH should be maintained in the best range for the crop grown at a biosolids application site. Otherwise crops will not grow as well or use as much nitrogen. Crops differ in how they adapt to soil acidity (low pH). Tilling finely ground limestone or other liming materials into the soil can raise soil pH. Fertilizer guides from WSU or OSU give recommendations on how much lime to apply, based on soil tests.

Site Manure Application History

Applying manure for long periods reduces the need for nitrogen fertilization, which also reduces site suitability for biosolids. In areas where the predominant land use is for dairy and livestock, you can locate farms with non-manured acreage by consulting with the local NRCS office. Livestock enterprises often have farm plans (organic nutrient management plans) that relate the land base to animal manure production.

Applying Biosolids to Agricultural Crops

Food Crops

Food crops are consumed directly by humans. The feasibility of applying biosolids to a food crop site depends on:

- What class of biosolids (A or B) is applied.
- Whether the harvested portion of the crop is in contact with biosolids.

Waiting periods after biosolids application apply only to Class B biosolids. The waiting periods are required to allow time for pathogens to die off before harvest. Use Table 4.11A as a guide to applicable crop harvest waiting periods. For Class B biosolids, the following <u>minimum</u> waiting periods apply for food crops:

- Minimum of 30 days between biosolids application and harvest when the harvested portion of the crop does not come in contact with the soil/biosolids.
- Minimum of 14 months between biosolids application and harvest when the harvested part of the crop is above ground but comes in contact with the soil/biosolids.

- Minimum of 20 to 38 months between biosolids application and harvest when any portion of the harvested part of the crop is below the surface. The length of the waiting period depends on how long the biosolids remain on the surface of the ground. (see Table 4.11A).

It may not be feasible to raise some food crops (e.g., root crops and low-growing fruits and vegetables) on sites that use Class B biosolids because the waiting period is more than one growing season.

Table 4.11A Harvest restrictions for crops grown for human consumption. Class B biosolids. Source: Chapter 173-308 WAC and 40 CFR Part 503.32(b)(5).

Biosolids Application Method			
Harvested part of plant comes in contact with biosolids?	**Part of plant harvested**	**Biosolids remain on soil surface**	**Waiting period from biosolids application to harvest**
yes	Leaf/fruit/grain	no time specified	14 months
yes	Root	more than 120 days	20 months
yes	Root	less than 120 days	38 months
no	Leaf/fruit/grain	no time specified	30 days

Pasture and Perennial Animal Feed Crops

These crops offer flexibility for timing of biosolids applications because sites are accessible most of the year. The sod created by pasture and perennial animal feed crops promotes infiltration and controls erosion.

A disadvantage of pasture and perennial animal feed crops is that it is difficult to work biosolids into the soil. Also, with surface applications:

- Much of the biosolids inorganic nitrogen may be lost by ammonia volatilization. Therefore, this loss must be considered when calculating the amount of biosolids needed to meet nutrient requirements.

- For grazed pastures, animal access must be restricted for 30 days after Class B biosolids application.
- Some of the benefits of biosolids as a physical soil conditioner cannot be realized.

Harvest Restrictions for Animal Feed

The purpose of Class B biosolids harvest restrictions for animal feed crops (Table 4.11B) is to prevent the direct ingestion of biosolids pathogens by livestock, especially dairy cows. After biosolids application, sunlight, drying, heat and other lethal environmental factors kill pathogens (bacteria and viruses). State and federal regulations specify a minimum waiting period of 30 days between Class B biosolids application and harvest (grazing, hay or silage).

Apply Biosolids Soon after Harvesting Grass

The best time to apply biosolids to perennial animal feed crops (e.g., grasses) is immediately after harvest has been completed (ideally within 7 days). This reduces the amount of biosolids adhering to the leaves and eaten by cattle. Also, if biosolids applications are delayed too long, the pasture will be past peak grazing or harvest quality by the end of the 30 day waiting period. This defeats the purpose of using biosolids to improve pasture quality.

Table 4.11B Site access and harvest restrictions for Class B biosolids applied to animal feed and non-food crops. Source: 40 CFR Part 503.32(b)(5).

Site/Crop	Grazing or Harvest	Public Access
Animal feed and other crops not for humans	30 days until harvest	
Pasture	30 days until grazing	
Turf (includes sod production)	365 days until harvest	365 days
Public contact site		• 30 days (low potential for public exposure) • 365 days (high potential for public exposure)

Grazing

Many overgrazed pastures are not good sites for biosolids applications. Good pasture management includes rest periods for regrowth. Properly managed pastures will also be more productive and have a greater need for biosolids nutrients. To reduce direct ingestion of biosolids, animals should be removed from the pasture when there are at least 2–4 inches of standing forage remaining.

Biosolids can be used as part of a renovation program for overgrazed pastures. The nutrients from biosolids can help speed the establishment or recovery of desirable pasture grasses. In these cases, a clear plan for maintaining the renovated pasture in a healthy state will be needed.

Silage Corn

Silage corn for animal feed is a good cropping alternative in some parts of Washington. Biosolids are applied in the spring before planting. Since the biosolids do not contact the edible portion of the crop, the waiting period (30 days after application for Class B biosolids) does not interfere with normal farming activities.

Legumes

Legumes, such as alfalfa and clovers remove a great deal of nitrogen and are suitable for biosolids application sites. When fertilizer or biosolids are applied regularly, legumes make use of applied nitrogen, and do not fix atmospheric nitrogen (their usual N source).

Several management practices specifically apply to legumes fertilized with biosolids. First, they will usually need to be fertilized with nitrogen for the life of the stand. Second, it is best to apply biosolids with a sprinkler system since vehicle traffic injures plants, increases plant diseases and reduces crop yield. Third, legumes require high levels of potassium — a nutrient not supplied in large quantities by biosolids. Supplemental potassium fertilization may be required.

Because of these special management considerations, legumes are best used where light applications of liquid biosolids can be applied via sprinkler immediately after each hay or silage harvest.

Grain and Grass Seed Crops

Grain and grass seed crops are well suited for biosolids applications since the harvested portion of the crop does not contact biosolids. Biosolids are applied before seeding for all grain and grass seed crops.

For fall-seeded crops (for example, winter wheat and winter barley), biosolids can be applied anytime prior to seed bed preparation, when the soil is dry enough to apply biosolids without undue risk of runoff, leaching, or soil compaction.

For spring-seeded grains (for example, corn, spring wheat, barley or oats), the time interval for applying biosolids can be fairly short. In many areas the soil does not dry out enough to support traffic until planting time. In these cases, biosolids may need to be applied and incorporated into the soil, immediately followed by planting. In dryland cropping areas, the time interval for applications is longer — biosolids can be applied in the fall when soils are drier.

Some spring-seeded crops may need supplemental (starter) fertilizers. The nitrogen in the starter fertilizer (usually 10 to 30 lb nitrogen per acre) is more immediately available to the crop and decreases the total amount of nitrogen needed from the biosolids.

Non-Food Crops

These crops include turf, ornamental plants, and fiber crops. Some of these crops may be used in a situation that has a high potential for public exposure (see Table 4.11B). It may be necessary to restrict the sale of products such as sod for one year after applying Class B biosolids. Contact your regulatory authority for more information about harvest restrictions for these crops.

Transportation and Accessibility

It is rare for a biosolids generator to have land near the treatment plant where biosolids can be applied. Transportation is therefore an important part of a land application program.

In Washington, the most common way of transporting biosolids to a land application site is by truck. There are several requirements that must be followed:

- Haulers must always comply with state and federal transportation regulations.
- Trucks, farm vehicles and application equipment must be thoroughly cleaned before being used for other purposes.

When evaluating biosolids haul routes, important considerations are:

- Cost
- Acceptable transport corridors
- Access to receiving lands
- Spill potential

Cost

The farther the application site is from the treatment plant, the higher the hauling costs will be. In these cases, it is often more cost-effective to undertake volume and weight reduction processes (for example, dewatering) before transporting.

Transport Corridors

To determine how suitable the roads are, biosolids managers should check with local planning and transportation officials. Load restrictions, either permanent or seasonal, can eliminate access along certain routes. There may be public objections to trucks driving through some neighborhoods.

Access to the Site

Trucks also need safe access from a public all-weather road to and from the site. Again, seasonal conditions may restrict this access. When biosolids will be delivered faster than they can be applied, storage areas must be identified and authorized in a site permit.

Spills

Biosolids haulers should have an emergency response plan in case of a vehicle accident or spill. Transport routes that avoid watercourses and rough terrain will reduce the risk of contamination if there is a spill.

Chapter 5

Worksheet for Calculating Biosolids Application Rates in Agriculture

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Calculating Biosolids Application Rates Based on Nitrogen

The worksheet beginning on page 5-2 will walk you through the calculations that yield the biosolids agronomic rate. This rate is based on biosolids quality (determined by analytical results), site and crop nitrogen requirements, and regulatory limits for trace element application. In almost all cases, nitrogen controls the biosolids application rate. By calculating the agronomic rate, managers can match the plant-available N supplied by biosolids to crop N needs.

The calculations consist of 6 steps:

1. Collect information on the site and crop, including crop N requirement.
2. Estimate the plant-available N needed from the biosolids application.
3. Collect biosolids nutrient data.
4. Estimate plant-available N per dry ton of biosolids.
5. Calculate the agronomic biosolids application rate on a dry ton basis.
6. Convert the application rate to an as-is basis.

Under Federal and state regulations, managers must maintain records on cumulative loading of trace elements *only* when bulk biosolids do not meet EPA Table-3 standards for trace elements (see Tables 3.9 and 3.10 of this document).

Worksheet

Step 1. Collect Site Information

Soil and crop information:

Line No.		Your Information	Example
1.1	Soil series and texture (NRCS soil survey)		Puyallup sandy loam
1.2	Yield goal (grower, agronomist) (units / acre*)		5 tons / acre / yr
1.3	Crop rotation (grower; e.g., wheat / fallow / wheat)		perennial grass
1.4	Plant-available N needed to produce yield goal (fertilizer guide; agronomist) (lb N / acre / yr)		200

Plant-available N provided by other sources:

Line No.		Your Calculation	Example	Units
	Pre-application testing			
1.5	Nitrate-N applied in irrigation water		10	lb N / acre
1.6	Preplant nitrate-N in root zone (east of Cascades)**		—	lb N / acre
	Adjustments to typical soil N mineralization			
1.7	Plowdown of cover or green manure crop**		—	lb N / acre
1.8	Previous biosolids applications (Table 5.1)		30	lb N / acre
1.9	Previous manure applications		—	lb N / acre
	Grower information			
1.10	N applied at seeding (starter fertilizer)		—	lb N / acre
1.11	**Total plant-available N from other sources** (sum of lines 1.5 through 1.10)		40	lb N / acre

*Yield goals may be expressed as a weight (tons, lb, etc.) or as a volume (bushels).

**Do not list here if these N sources were accounted for in the nitrogen fertilizer recommendation from a university fertilizer guide.

Step 2. Estimate Plant-Available N Needed from Biosolids

Line No.		Your Calculation	Example	Units
2.1	Plant-available N needed to produce yield goal (from line 1.4)		200	lb N / acre
2.2	Plant-available N from other sources (from line 1.11)		40	lb N / acre
2.3	Amount of plant-available N needed from biosolids (line 2.1 – line 2.2)		160	lb N / acre

Step 3. Collect Biosolids Data

Application Information:

Line No.		Your Information	Example
3.1	Moisture content of biosolids (liquid or solid; see Table 5.3)		liquid
3.2	Biosolids processing method (see Table 5.3)		anaerobic
3.3	Method of application (surface or injected)		surface
3.4	Number of days to incorporation of biosolids		no incorporation
3.5	Expected application season		Mar. – Sept.

Laboratory Biosolids Analysis (dry weight basis):

If your biosolids analysis is on an as-is or wet weight basis, you will need to divide your analysis by the percent solids (line 3.10) and multiply the result by 100 to convert to a dry weight basis.

Line No.		Your Calculation	Example	Units
3.6	Total Kjeldahl N (TKN)*		50,000	mg / kg
3.7	Ammonium N		10,000	mg / kg
3.8	Nitrate N **		not analyzed	mg / kg
3.9	Organic N*** (line 3.6 – line 3.7)		40,000	mg / kg
3.10	Total solids		2.5	percent

*If TKN, ammonium N, and nitrate N analyses are in per cent, multiply by 10,000 to convert to mg / kg.

**Nitrate-N analysis required for composted or aerobically-digested biosolids, but not for anaerobically-digested biosolids.

***Organic N = total Kjeldahl N – ammonium

Step 4. Estimate Plant-Available N Per Dry Ton of Biosolids

Convert biosolids N analysis to lb per dry ton:

Line No.		Your Calculation	Example	Units
4.1	Total Kjeldahl N (TKN) (line 3.6 x .002)		100	lb N / dry ton
4.2	Ammonium N (line 3.7 x .002)		20	lb N / dry ton
4.3	Nitrate N (line 3.8 x .002)		not analyzed	lb N / dry ton
4.4	Organic N (line 4.1 – line 4.2)		80	lb N / dry ton

Estimate Inorganic N Retained:

4.5	Percent of ammonium-N retained after application (Table 5.2)		60	percent
4.6	Ammonium-N retained after application (line 4.2 x line 4.5 / 100)		12	lb N / dry ton
4.7	Calculate biosolids inorganic N retained (line 4.3 + line 4.6)		12	lb N / dry ton

Estimate Organic N Mineralized:

4.8	Percent of organic N that is plant-available in Year 1 (Table 5.3)		30	percent
4.9	First year plant-available organic N (line 4.4 x line 4.8 / 100)		24	lb N / dry ton

Plant-available N:

4.10	**Estimated plant-available N** Add available inorganic N and available organic N (line 4.7 + line 4.9)		36	lb N / dry ton

Step 5. Calculate the Agronomic Biosolids Application Rate

Line No.		Your Calculation	Example	Units
5.1	Amount of plant-available N needed from biosolids (from line 2.3)		160	lb N / acre
5.2	Estimated plant-available N in biosolids (from line 4.10)		36	lb N / dry ton
5.3	Agronomic biosolids application rate (line 5.1 / line 5.2)		4.4	dry ton / acre

Step 6. Convert to As-is Biosolids Basis

Desired Units		Your Calculation	Example
Gallons per acre =	(line 5.3 / line 3.10) x 24,000		42,240
Acre-inches per acre =	(line 5.3 / line 3.10) x 0.88		1.55
Wet tons per acre =	(line 5.3 / line 3.10) x 100		176

How to Use the Worksheet

Step 1. Collect Site Information.

Soil Series and Surface Soil Texture (Line 1.1)

Find the location on the county NRCS soil survey. Record the series name and surface texture of the predominant soil.

Crop Yield Goal (Line 1.2)

Field records are the best source for crop yield estimates. You can find proven yields for most grain farms from the local Farm Service Agency office. For most other cropping systems, grower records are the only source available. Be sure to note whether the yield records are on an as-is or dry matter basis. Where field records are not available, you can make first-year estimates for a project using NRCS soil surveys, county production averages, or other local data sources.

A site used repeatedly for biosolids application should have yield data collected each year. Use this accumulated data for determining crop nitrogen requirement. If crop yield data is not kept, you may need to conduct additional monitoring (e.g., post-harvest soil nitrate testing) to be sure biosolids are applied at an agronomic rate.

Yield data is typically not available for grazed pastures because grazing animals consume the crop directly in the field. In these cases omit the yield goal, and go directly to Line 1.4. Estimate plant nitrogen needs from the appropriate pasture fertilizer guide recommendation, based on the level of pasture management.

Crop Rotation (Line 1.3)

Consult with the grower and discuss the range of possible crop rotations. Rotations that include root crops or other crops with a long post-application waiting period are not suitable for Class B biosolids applications.

Plant-Available N Needed to Produce Yield Goal (Line 1.4)

You can estimate plant-available-N needs by referring to university fertilizer guides or consulting a qualified agronomist.

University Fertilizer Guides

Land grant universities (Washington State University, Oregon State University, or University of Idaho) publish fertilizer guides that estimate crop nitrogen requirements. Use the fertilizer guide most appropriate for the site and crop. For major crops, guides may cover irrigated or rainfed (dryland) cropping and different geographic areas. Don't use guides produced for irrigated sites when evaluating dryland sites. When appropriate guides do not exist, consult the local Cooperative Extension or Natural Resources Conservation Service office, or a qualified agronomist for assistance.

Nitrogen fertilizer application rates listed in the fertilizer guides are based on field growth trials under the specified climate and cultural conditions. Growth trial results are averaged over a variety of soil types and years. Note that fertilizer guide recommendations are not the same as crop uptake. This is because the fertilizer guides account for N available from mineralization of soil organic matter and the efficiency of N removal by the crop.

The N rate recommended in fertilizer guides assumes average yields, good management practices, and removal of N from the field through crop harvest or grazing. In terms of satisfying crop N needs, plant-available N from biosolids application is considered equal to fertilizer N.

Agronomist Calculations

Because of the general nature of university fertilizer guides, it may be worthwhile to have a qualified agronomist calculate how much plant-available N is needed for a specific field. You will need to document your reasons for using agronomist calculations instead of the university fertilizer guide.

Plant-Available N Provided by Other Sources (Lines 1.5–1.11)

To make sure there isn't too much nitrogen applied to a crop, you must determine how much nitrogen comes from sources other than biosolids and soil organic matter.

These sources of N are grouped into three categories in the worksheet.

- Plant-available N estimated by pre-application testing,
- Adjustments to typical soil organic N mineralization (usually obtained from an agronomist),
- Information supplied by the grower.

N Estimated by Pre-application Testing (Lines 1.5-1.6)

Irrigation Water

Since the amount of nitrate-N in irrigation water varies, it should be determined by water testing. Irrigation water containing 5 mg nitrate-N per liter will contribute 1.1 pounds of nitrogen per acre-inch applied; irrigation water containing 10 mg nitrate-N per liter will contribute 2.3 pounds of N per acre inch.

Preplant Nitrate-N in the Root Zone (east of Cascades)

You can estimate the preplant nitrate-N in the root zone by testing the soil in early spring. Sample in one-foot increments to a depth of at least two feet. University of Idaho Cooperative Extension Service Bulletin No. 704, *Soil Sampling*, is a good reference for soil sampling procedures.

Some fertilizer guides use preplant soil nitrate-N when calculating N fertilizer application rates. If you use these guides, don't count soil test nitrate-N in our worksheet. It has already been accounted for in the recommended fertilizer N rate prescribed in the guide.

Adjustments to Typical Soil N Mineralization (Lines 1.7-1.9)

Nitrogen mineralization is the release of nitrogen from organic forms to plant-available inorganic forms (ammonium and nitrate). Soil organic matter supplies plant-available N through mineralization, but this is accounted for in the fertilizer guides. Sites with a history of cover crops, biosolids applications, or manure applications supply more plant-available N than do sites without a history of these inputs, and biosolids recommendations must be adjusted based on this additional supply of N.

Plowdown of Cover or Green Manure Crops

Green manures and cover crops are not removed from the field, but are recycled back into the soil by tillage. You can get an estimate of the N contributed from this plowdown by referring to the university fertilizer guides, or by estimating the yield and nitrogen concentration of the cover crop. Recovery of green manure N by the next crop ranges from 10–50% of the total N added to the soil by the cover crop. Estimates of plant-available N contributed by green manure crops should be made by a qualified agronomist.

Previous Biosolids Applications

Previous biosolids applications contribute to plant-available nitrogen in the years after the initial application. In the worksheet, they are considered as *N from other sources*. We estimate that 8, 3, 1 and 1 percent of the organic N *originally applied* mineralizes in Years 2, 3, 4 and 5 after application (Table 5.1). After Year 5, biosolids N is considered part of stable soil organic matter and is not included in calculations.

Table 5.1 Estimated nitrogen credits for previous biosolids applications at a site.

	Years After Biosolids Application			
	Year 2	**Year 3**	**Year 4 and 5**	**Cumulative Years 2, 3, 4 and 5**
Biosolids Organic N	Percent of Year 1 Organic N that Becomes Available			
as Applied	8	3	1	13
Mg/kg (dry wt basis)	Plant-available N released, lb N per dry ton			
10000	1.6	0.6	0.2	2.6
20000	3.2	1.2	0.4	5.2
30000	4.8	1.8	0.6	7.8
40000	6.4	2.4	0.8	10.4
50000	8.0	3.0	1.0	13.0
60000	9.6	3.6	1.2	15.6

In using Table 5.1, consider the following example. Suppose:

- You applied biosolids with an average organic N content of 30,000 mg / kg.
- Applications were made the previous 2 years.
- The application rate was 4 dry tons per acre.

Table 5.1 gives estimates of nitrogen credits *in terms of the organic N originally applied.* Look up 30,000 mg / kg under Year 2 and Year 3 columns in the table. The table estimates 4.8 lb plant-available N per dry ton for year 2, and 1.8 lb plant-available N for year 3 (two-year credit of 6.6 lb N per dry ton). To calculate the N credit in units of lb / acre, multiply your application rate (4 dry ton / acre) by the N credit per ton (6.6 lb N / dry ton). The N credit is 26.4 lb plant-available N per acre.

Previous Manure Applications

Previous manure applications contribute to plant-available nitrogen in a similar manner to previous biosolids applications. To estimate this contribution, consult an agronomist.

Information Supplied by the Grower (Line 1.10)

N Applied at Seeding

For best growth, some crops depend on starter fertilizers (N applied at seeding). These fertilizers usually supply N, P and S. Examples are 16-20-0, 10-34-0. Starters are usually applied at rates that supply 10–30 lb N per acre. Enter all of the N supplied by starter fertilizer on line 1.10 in the worksheet.

Step 2. Estimate Plant-Available N Needed from Biosolids.

Next you will estimate the amount of plant-available N the biosolids must provide. This is the difference between the total plant-available N needed to produce the yield goal and the plant-available N from other sources.

Step. 3. Collect Biosolids Data.

To make the calculation, managers will need the following analyses:

- Total Kjeldahl N (TKN).
- Ammonium-N (NH_4-N).
- Nitrate-N (NO_3-N; composted or aerobically digested biosolids only).
- Percent total solids.

If your laboratory results are on an as-is or wet weight basis, you must convert them to a dry weight basis. To convert from an as-is to a dry weight basis, divide your analysis by the percent solids in the sample and multiply the result by 100.

Total Kjeldahl N includes more than 95% of the total nitrogen in biosolids. In using the worksheet, we will assume that total Kjeldahl N equals total N.

Ammonium-N usually makes up more than 95% of the total inorganic N in most biosolids. The laboratory analysis for ammonium-N includes both ammonia (NH_3) and ammonium (NH_4^+). Depending on your laboratory, results for ammonium-N may be expressed as either ammonia-N or ammonium-N.

Nitrate-N analyses also include small amounts of nitrite. Nitrite concentrations are negligible in biosolids. There may be significant amounts of nitrate in aerobically-digested biosolids or in composts. There is little nitrate in anaerobically-digested biosolids; therefore nitrate analysis is usually not required for these materials.

Determine biosolids organic N by subtracting ammonium-N from total Kjeldahl N (line 3.6 – line 3.7). Percent total solids analyses are used to calculate application rates. Biosolids applications are calculated as the dry weight of solids applied per acre (e.g., dry tons per acre).

Step 4. Estimate Plant-Available N Per Dry Ton of Biosolids.

The estimate of plant-available N per dry ton of biosolids includes:

- Some of the ammonium-N.
- All of the nitrate-N.
- Some of the organic N.

Inorganic N Retained (Lines 4.5–4.7)

Ammonium-N (Lines 4.5–4.6)

Under some conditions, ammonium is readily transformed to ammonia and lost as a gas. This gaseous ammonia loss reduces the amount of plant-available N supplied by biosolids. The following section explains the factors used to estimate ammonia-N retained in plant-available form after application.

Biosolids Processing

Some types of biosolids processing cause most of the ammonia-N to be lost as ammonia gas or converted to organic forms before application:

- Drying beds.
- Alkaline stabilization at pH 12.
- Composting.

Application Method

Ammonia loss occurs only with surface application. Injecting liquid biosolids eliminates ammonia loss, since the injected liquid is not exposed to the air. Surface applications of liquid biosolids lose less ammonia than do dewatered biosolids. For liquid biosolids, the ammonia is less concentrated and is held as NH_4^+ on negatively-charged soil surfaces after the liquid contacts the soil.

Ammonia loss is fastest just after application to the field. As ammonia is lost, the remaining biosolids are acidified — that is, each molecule of NH_3 lost generates one molecule of H^+ (acidity). Acidification gradually slows ammonia loss. Biosolids that remain on the soil surface will eventually reach a pH near 7, and further ammonia losses will be small. Losses of ammonia after six days on the soil surface are very close to zero.

Days to Soil Incorporation

Tillage to cover biosolids can reduce ammonia loss by adsorption of ammonium-N onto soil particles.

Table 5.2 estimates the amount of ammonium-N retained after field application. To use this table, you will need information on biosolids stabilization processes, method of application (surface or injected), and the number of days to soil incorporation.

Table 5.2 Estimates of ammonium-N retained after biosolids application.

Days to Incorporation by Tillage	Surface-applied				Injected
	Liquid Biosolids	Dewatered Biosolids	Alkaline-stabilized Biosolids*	Composted or Drying Bed Biosolids	All Biosolids
	----------------Ammonium-N retained, percent of applied---------------				
0 to 2	80	60	10	100	100
3 to 6	70	50	10	100	100
over 6†	60	40	10	100	100

*For alkaline-stabilized biosolids analyzed for ammonium-N before lime addition.

†If biosolids will *not* be incorporated by tillage, use over 6 days to incorporation.

Nitrate-N (Line 4.3)

We assume 100% availability of biosolids nitrate-N.

Organic N Mineralized (Lines 4.8–4.9)

Biosolids organic N, which includes proteins, amino acids and other organic N compounds, is not available to plants at the time of application. Plant-available N is released from organic N through microbial activity in soil — called mineralization. Mineralization is more rapid in soils that are warm and moist, and is slower in soils that are cold or dry. Biosolids organic N mineralization rates in soil also depend on the treatment plant processes that produced the biosolids.

Use Table 5.3 to estimate biosolids mineralization rates based on processing. Use the middle of the range presented, unless you have information specific to the site or biosolids that justifies using higher or lower values within the range.

Table 5.3 First year mineralization estimates for organic N in biosolids.

Processing	Moisture Content	First-year Organic-N Mineralization Rate
		percent of organic N
Anaerobic digestion	liquid	20-40
Aerobic digestion	liquid	30-45
Aerobic or anaerobic digestion and storage in lagoon > 6 months	liquid	15-30
Anaerobic digestion and dewatering	semi-solid	20-40
Drying bed	solid	15-30
Heat-drying	solid	20-40
Composting	solid	0-20

Step 5. Calculate the Agronomic Biosolids Application Rate.

Perform this calculation using the results of the previous sections, as shown in lines 5.1 through 5.3.

Step 6. Convert Agronomic Biosolids Application Rate to As-is Basis.

Use the appropriate conversion factors (given Step 6) to convert to gallons, acre-inches, or wet tons per acre.

Other Considerations for Calculations

- **Small acreage sites without a reliable yield history**. Some communities apply biosolids to small acreages managed by hobby farmers. In many of these cases, there is no reliable yield history for the site, and the goal of management is not to make the highest economic returns. You can be sure of maintaining agronomic use of biosolids nitrogen on these sites by applying at a rate substantially below that estimated for maximum yield.

- **Equipment limitations at low application rates.** At some low-rainfall dryland cropping locations east of the Cascades, the agronomic rate calculated with the worksheet (Table 1) will be lower than can be spread with manure spreaders (usually about 3 dry tons per acre). At these locations, you may be able to apply the dewatered biosolids at the equipment limit, but check with your permitting agency for local requirements.

- **Unavailable soil nitrate (dryland cropping, east of Cascades).** Not all of the nitrate-N determined by testing dryland soils (line 1.6) is available to the crop, because chemical extraction of nitrate is more efficient than plant root extraction. This difference becomes significant when soil nitrate concentrations are low (less than 10 mg nitrate N / kg soil) and sampling is done to greater than two feet.

  Recent research has shown that the amount of unavailable nitrate-N increases with soil clay content. Use the following formula if you estimate unavailable nitrate-N based on soil clay content.

  Unavailable nitrate-N (mg / kg) = percent clay x 0.1

- **Denitrification and immobilization.** Denitrification (the loss of nitrate as gaseous N_2 or N_2O) and immobilization (the loss of nitrate or ammonium by incorporation into organic compounds) can occur following biosolids application. At agricultural sites these losses usually are not included in biosolids loading rate calculations because university fertilizer guides account for average losses due to these processes. Check with your local permitting agency before including denitrification or immobilization losses in the loading rate calculations.

- **Site Specific Inputs.** Biosolids application rates can also be calculated using a more detailed N budget method found in Washington State Department of Ecology Publication No. 99-508, *Managing Nitrogen from Biosolids*. The N budget method allows for more site-specific inputs into the calculation. It will be most valuable when budget components are based on actual site monitoring data. If you do not have detailed site nitrogen data, use the worksheet presented above.

Calculating Cumulative Loading of Trace Elements

Under Federal and state regulations, managers must maintain records on cumulative loading of trace elements *only* when bulk biosolids do not meet EPA Table-3 standards for trace elements (Table 3.9).

When required, the steps in tracking trace metals are:

- Obtain biosolids trace element analyses from the wastewater treatment plant database (Table 3.14).
- Compute pounds of element per dry ton of biosolids. Multiply mg/kg (dry weight basis) by 0.002.
- Keep records of the amount of biosolids applied to the site each year (in dry tons per acre).
- Compute pounds of element applied per acre. Multiply pounds of element per dry ton by dry tons applied.
- Compare cumulative pounds of element applied with the cumulative loading rate limit (Table 3.10)

Chapter 6

Agricultural Site Management

Table of Contents

Introduction

For a land application program to be successful, biosolids managers, contractors, landowners and farmers must work together as a team. A successful program requires proper management practices for soil conservation, irrigation and drainage water, nutrients, crops and livestock. Site managers must remember that biosolids are nutrients. The basics of good fertilizer management apply to all biosolids applications.

This chapter focuses on management practices for:

- Soil conservation
- Water management
- Winter biosolids applications in western Washington

Other aspects of a successful agricultural land application program are addressed elsewhere:

- Nutrients (Chapters 1, 5 and 9)
- Crops and livestock (Chapter 4)
- Management practices for overcoming soil limitations (Table 4.8)

Soil Conservation

To manage land application of biosolids properly, runoff and erosion must be controlled. Erosion decreases soil productivity, increases sediment loads in streams, and could carry biosolids into surface waters.

Soil conservation practices help control erosion by improving infiltration and slowing the velocity of water that flows over the surface. A well-managed permanent cover, such as pasture and hay crops, has the lowest potential runoff and erosion. To reduce soil erosion in row crops, tillage operations must be managed carefully.

Properly managed biosolids applications also help reduce soil erosion. The organic matter in the biosolids helps form stable soil aggregates, which increases the porosity and infiltration rate of the surface soil. Also, where crop yield increases because of biosolids, there is more crop residue to protect the soil surface.

In eastern Washington, surface biosolids applications have reduced wind erosion immediately after application, probably because of increased soil surface roughness. If left on the surface to dry, liquid or dewatered biosolids form large chunks (about the size of a quarter) that do not move with the wind.

Tillage

For cultivated crops, particularly grain crops, conservation tillage can help control erosion. Unlike conventional tillage (i.e., using a moldboard plow), conservation tillage does not turn the soil over. Instead, the soil is mixed with a chisel or sweep plow to partially incorporate crop residues, loosen the soil, break up compacted layers and leave a rough soil surface. The number of tillage operations is also reduced. Although it buries crop residue, moldboard plowing is acceptable when the soil surface is left rough (no additional tillage) during the winter months.

Other Conservation Practices

Effective erosion control may require additional conservation practices. For example, cross-slope farming — i.e., planting crop rows along the contour instead of up and down hills — is one effective practice. Appropriate conservation practices vary widely depending on crop, soil, landscape, climate, etc. Consult with your local Natural Resources Conservation Service (NRCS) office to discuss appropriate conservation practices for your site.

Highly Erodible Land

In certain parts of Washington state, the NRCS has classified much of the farmland as highly erodible. Farmers who participate in government farm programs must use an approved conservation plan on these lands to meet the conservation compliance provisions of the federal 1995 Farm Bill.

Biosolids applications could come in conflict with the conservation plan if biosolids incorporation requires additional tillage operations beyond normal. Before applying biosolids, growers should contact their local NRCS office to review their plan and avoid reducing surface crop residue levels below the requirement. Conflicts between biosolids application and conservation compliance are most likely in the drier areas (below 16 inches annual precipitation) that use a winter wheat-summer fallow system.

The following management practices help to maintain surface residues on highly erodible sites:

- In dryland grain rotations, apply biosolids to standing stubble after grain harvest and before the first tillage operation. This is the time during the fallow season when fields can best support vehicle traffic.
- Do not apply biosolids to powder-dry soils after the soils have been tilled. Preferably, wait for rainfall to moisten the surface soil and the straw. When moist, the straw will bend rather than break when vehicles drive over it. Moist soil will greatly reduce dust problems during application.
- Incorporate biosolids only when absolutely necessary to control odor.
- Use tillage practices that maintain surface residues throughout the fallow cycle.
- Use herbicides instead of tillage to control broadleaf weeds after grain harvest and grassy weeds in late winter and early spring.

Vehicle Traffic Pattern

Biosolids contractors and growers are learning to manage traffic on different soils to cause the least damage. One choice is to spread vehicle traffic as evenly as possible over the whole field, rather than using the same path repeatedly. Another choice is to use the same lane for all traffic, which reduces the area compacted, but probably requires remediation (such as subsoiling) on the lane itself. Where wind erosion is a problem, vehicle traffic should be kept away from the edge of the field to avoid dust problems.

Water Management

Many agricultural areas face problems because of too much or too little water in the soil. To manage these problems, farmers drain or irrigate their farmlands. Therefore, both of these practices must be considered when planning biosolids applications.

Irrigation

Irrigation affects biosolids management in two ways. First, crop yields are higher on irrigated land than on dryland, which increases the amount of nutrients that may be added with biosolids. Second, irrigation increases the potential for both leaching and runoff. Farmers can reduce leaching and runoff with an irrigation system that is properly designed and managed.

Practices that can reduce leaching and runoff include:

- Scheduling irrigations based on crop need.
- Diverting irrigation runoff water into re-use systems.
- Monitoring soil salinity and sodium levels to maintain water infiltration and crop yields.

With sprinkler irrigation, the rate can be controlled, producing little, if any, surface runoff. Sprinkler irrigation immediately after a biosolids application can help reduce ammonia loss and wash biosolids off forage plants. To prevent runoff, don't over-irrigate.

For information on irrigation management, you can contact WSU Cooperative Extension agents, NRCS personnel and qualified agronomists.

Biosolids Application via Sprinklers

Liquid biosolids can be applied via sprinkler irrigation. It is important to use an appropriate liquid application rate (inches of as-is biosolids applied per hour). Runoff will occur if:

- Biosolids are applied at a rate above the soil's infiltration capacity, *and*
- Slope and vegetation conditions at the site permit runoff.

Several factors are responsible for reduced surface soil infiltration rates with liquid biosolids applications:

- Slurries containing fine particles clog some of the small soil pores.
- A layer of wet biosolids accumulates at the soil surface, conducting water more slowly than the soil beneath it.

Surface soil texture, the solids content of the biosolids, and the amount of liquid applied are the key factors determining infiltration rates. The maximum sprinkler application rates in Tables 6.1A and 6.1B are adapted from tables developed by the NRCS for use with animal manure slurries. These application rates do not exceed the infiltration rate of the soil.

Consider an example where you want to apply 0.5 inches of liquid biosolids with a 5% total solids content to a silt loam soil. In Table 6.1A (for applications up to 0.5 inches), find the column titled *5% Total Solids*. Find the surface soil texture *Silt loam* in the left column. The maximum sprinkler application rate is 1.2 inches per hour.

Soils are listed in Tables 6.1A and 6.1B with clay content increasing as you go down the page. Soils high in clay (clay loams and clays), have very low maximum application rates (inches per hour). For these soils, sprinkler irrigation should be used for biosolids application only if:

- Application amounts are low (below the maximum application rate in Table 6.1B), or
- The site is flat or nearly flat.

Table 6.1A Maximum sprinkler application rates for light (up to 0.5 inch) applications of liquid biosolids.

	% Total Solids		
	1	**2**	**5**
Surface Soil Texture	**Maximum Sprinkler Application Rate (inches per hour)**		
Sand	3.3	1.9	0.8
Loamy sand	3.2	2.2	1.1
Sandy loam	2.3	1.9	1.2
Loam	1.6	1.5	1.3
Silt loam	1.4	1.3	1.2
Sandy clay loam	0.9	0.9	0.8
Clay loam	0.6	0.6	0.6
Silty clay loam	0.6	0.6	0.6
Sandy clay	0.3	0.3	0.3
Silty Clay	0.4	0.4	0.4
Clay	0.2	0.2	0.2

Table 6.1B Maximum sprinkler application rates for heavier (0.5 to 1 inch) applications of liquid biosolids.

	% Total Solids		
	1	2	5
Surface Soil Texture	**Maximum Sprinkler Application Rate (inches per hour)**		
Sand	3.3	1.9	0.8
Loamy sand	2.6	1.8	0.9
Sandy loam	1.8	1.5	0.9
Loam	1.1	1.1	0.9
Silt loam	1.0	0.9	0.8
Sandy clay loam	0.7	0.7	0.6
Clay loam	0.5	0.5	0.4
Silty clay loam	0.4	0.4	0.4
Sandy clay	0.2	0.2	0.2
Silty Clay	0.3	0.3	0.3
Clay	0.1	0.1	0.1

These tables identify the infiltration rate when there is full vegetative cover and when initial soil moisture content is 50% of the available water capacity. Exceeding these rates may cause runoff. Source: Agricultural Waste Management Field Handbook AWMFH-1, Part 651. Soil Conservation Service, 1992. Check this source for appropriate rates for heavier applications of biosolids.

Poor Drainage and Wetlands

It is usually not legal to drain wetlands because of state, federal and local laws protecting those areas. Any biosolids application near a wetland should be handled with care. If wetlands are present, or if you are considering drainage, obtain a bona fide wetlands determination for the site and consult with the permitting authority.

In areas with poor natural soil drainage, soils that are already drained can grow a wider range of suitable crops. Soils that have been drained have higher yields, nutrient requirements and biosolids applications rates. Drainage also allows earlier biosolids application in the spring because the water table recedes more rapidly.

Artificially drained soils require careful management. While surface ditches may lower the water table, the ditches drain into natural streams, which must not be harmed by biosolids applications. To protect the streams, limit applications to the dry times of year when water tables are already low and ditches are empty, and use buffer zones along drainage ditches. Groundwater should be at least two feet below the soil surface and static or receding before biosolids are applied.

Winter Biosolids Application in Western Washington

Winter biosolids applications in western Washington require careful site selection and management. Factors that influence site suitability and management include:

- Potential for flooding
- Potential for leaching and runoff
- Type of crop
    - Annual
    - Cover crop
    - Perennial grass
- Residual soil nitrate-N (report card method, see Chapter 9)
- Biosolids application method

Potential for Flooding

The flooding hazard is listed by month in NRCS soil surveys as frequent, occasional or none. At low-lying sites in western Washington, flooding can take place from November through April. Flooding is a problem at biosolids application sites because nutrients and pathogens may contaminate surface waters. Sites that occasionally flood may be acceptable, however, provided that:

- Biosolids are applied at least 60 days before the onset of flood season, which allows enough time for nutrient utilization and pathogen die-off. This will usually limit biosolids applications to May through August.
- Perennial grass cover maintained on the site.
- Biosolids are not applied to draws that carry water at high velocity.

- There are no conflicts with wetlands regulations.

Potential for Runoff and Leaching

Soil hydrologic groups can be used to identify suitable soils for winter biosolids application. Soil hydrologic groups (A, B, C and D) are classified according to the runoff-producing characteristics of the soil, independent of slope and crop cover. The chief consideration is the rate of water infiltration into bare soil. Sandy, well-drained soils are in hydrologic groups A or B. Soils higher in clay with poor drainage are in hydrologic groups C and D.

Soil hydrologic groups are included in recent soil surveys. For areas with older soil surveys, obtain the hydrologic group classification from your local NRCS office.

Table 6.2 illustrates the leaching and runoff characteristics of four western Washington soils.

Table 6.2 Example of average water table depth, potential leaching and runoff for NRCS soil hydrologic groups A, B, C and D in western Washington.

Location: Whatcom County

Soil Hydrologic Group	Example Soil Series	Soil Drainage Class*	Water Table Depth Feb.	Apr.	Oct.	Nov.	Leaching Potential	Runoff Potential
			-----------Feet----------					
A	Lynnwood	SWED	>6	>6	>6	>6	High	Very Low
B	Puyallup	WD	>6	>6	>6	>6	Moderate	Low
C	Birchbay	MWD	2	3	6	6	Low	Moderate
D	Briscot	PD	1	2	6	2	Low	High

*SWED = Somewhat excessively drained MWD = Moderately well-drained
WD = Well-drained PD = Poorly drained

Soil groups C and D are generally not suitable as winter biosolids application sites because of seasonal high water tables, high runoff potential and possible winter flooding. Groups A and B have fewer problems with flooding and runoff, and are usually the most desirable sites for winter application. They do not have seasonal high water tables. Biosolids applications on group A soils should be scheduled to minimize leaching. Apply biosolids several times a year instead of as a single heavy application. If A and B soils are not irrigated, they can best use nutrients applied in late winter or early spring (February or March). Crop growth on non-irrigated A and B soils is limited by drought from July until fall rains.

Table 6.3 is an example of scheduling a biosolids application based on soil hydrologic groups. The factors included in the example are:

- Crop nitrogen use
- Seasonal flooding
- Seasonal water tables
- Leaching potential
- Runoff potential

For the example:

- A grass crop is grown on each of the four soil groups in the Whatcom County (Bellingham) area.
- The crop requires 200 lb N per acre per year of plant-available nitrogen.
- Irrigation maintains active growth throughout the summer.

The limits in Table 6.3 are adapted from manure application schedules developed by the NRCS Western Washington District Office for applying dairy slurry (about 2% total solids). For biosolids, winter applications are not recommended (Table 6.3) if potential runoff exceeds one inch per month. Spring biosolids application rates are lowest for soils with the highest leaching potential (Group A and B).

*Table 6.3 Example of western Washington biosolids application scheduling based on potential runoff, leaching and crop N use. **

Location:	Whatcom County
Crop:	perennial grass (irrigated)
Example Annual N Requirement:	200 lb plant-available N per acre

	Most Limiting Factor				Maximum Application Rate			
	Soil Group				Soil Group			
Month	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
					lb. plant-available N / A / month			
October	N**	N	N	R	40	40	40	0
November	N	N	R	R	40	40	0	0
December	N	N	R	F	40	40	0	0
January	N	N	R	F	40	40	0	0
February	N	N	R	F	40	40	0	0
March	L	L	R	R	60	80	0	0
Winter (October – March) Max. Application Rate†					**60**	**80**	**40**	**0**
April	L	L	N	R	60	120	200	0
May	L	N	N	N	120	200	200	200
June	N	N	N	N	180	180	180	180
July	N	N	N	N	120	120	120	120
August	N	N	N	N	80	80	80	80
September	N	N	N	N	40	40	40	40
Annual Maximum Application Rate†					**200**	**200**	**200**	**200**

*Adapted from NRCS liquid manure application guides developed by NRCS western Washington district office (Olympia).

**Limiting Factor Legend:

N:	Crop N use	L:	Nitrate leaching
R:	Surface runoff	F:	Flood

†Do not exceed the yearly maximum application rate (200 lb N / A for this example) or the October through March max. application rate.

Example soils (map units with <8% slope):

Hydrologic Group A:	Lynnwood series	Hydrologic Group C:	Birchbay Series
Hydrologic Group B:	Puyallup Series	Hydrologic Group D:	Briscot Series

In the example in Table 6.3, the most limiting of the three maximums (month, winter or year) controls the allowable application rate. The schedule allows some flexibility in site management. For example, for soil Group B, some of the alternatives are:

- Apply all 200 lb N per acre in May.
- Apply 40 lb N per acre in October and February. Apply the remainder (120 lb N) in May.
- Apply 40 lb N per acre in October, February, May, June, July and August.

The application schedule (Table 6.3) is designed so biosolids application will take place well before seasonal high water tables for hydrologic groups C and D. For groups A and B, winter application rates are determined by crop use. Lower application rates are used during winter months to match the slow growth of the grass. Maximum application rates for groups A and B are lower than groups C and D in spring because of a higher risk of leaching. Progressively lower rates are applied in July, August and September on all soils to match the N required by the crop for the remainder of the growing season.

To design an application schedule to fit the soils, management and precipitation at your site, contact your local NRCS office or a qualified soil scientist or agronomist.

Type of Crop

Crops at winter application sites must be able to:

- Use the winter-applied nitrogen
- Support vehicle traffic
- Filter runoff from the site

The ability of different crops to use winter-applied nitrogen in western Washington is shown in Table 6.4. This table was developed using field research done at the WSU Puyallup Research Center. The ranges in Table 6.4 reflect variability due to weather, crop species, soils and crop management. Fallow ground and legume cover crops do not use nitrogen and are not suitable for winter biosolids application. Grass or cereal cover crops (e.g., rye planted in September after corn harvest) do not need fertilizer N in order to become established in the fall. They can, however, use nitrogen applied in late winter (February). Established perennial grasses provide the most options for winter application: they can use conservative amounts of nitrogen applied throughout the winter period.

Table 6.4 Estimates of fertilizer nitrogen uptake capacity of crops during winter months in western Washington.

		Winter Nitrogen Uptake Capacity		
Crop	**Examples**	**Oct. 1 to Nov. 15**	**Nov. 15 to Feb. 15**	**Feb. 15 to Apr. 1**
		--------------------- lb N / A		-------------------
Annual	Corn	None	None	None
Legume Cover Crop	Austrian winter pea, vetch	None	None	None
Grass Cover Crop	Fall seeded annual ryegrass, winter wheat, winter rye	None	None	20–50
Perennial Grass	Established orchardgrass, tall fescue, perennial or annual ryegrass	20–60	0–20	20–50

Residual (Report Card) Nitrate-N

Perennial grass sites scheduled for biosolids application after October 15 should be tested for residual soil (report card) nitrate-N. Samples should be collected between August 15 and September 30 (see Chapter 9). Use the test results to determine whether a fall nitrogen application is needed:

Report Card Soil Nitrate-N lb /A, 0 to 2 ft.	Need for N? (Oct. thru Jan.)	Need for N? (Feb. thru Mar.)
0 to 60	yes	yes
above 60	no	yes

Because residual nitrate levels are usually low at all sites in late winter (February through March), grasses at all sites can use applied N.

Biosolids Application Method

The suitable application methods for winter applications are:

- Sprinkler application.
- Application from spray trucks operating on all-weather, access roads.
- Application via spray trucks or manure spreaders on well-drained soils (NRCS hydrologic group A, sometimes B).

During heavy rainfall, it is best not to apply biosolids, even on soils in hydrologic group A.

Summary

Winter application sites in western Washington require careful management. Sites with perennial grasses on well drained soils (hydrologic groups A and B) offer the most options for winter application. Winter applications must be at a low rate to match the limited uptake capacity of the perennial grass or cover crop. Biosolids application equipment must not compact wet soils, and must be able to apply the biosolids at low rates.

Chapter 7
Forest Site Design and Management

Table of Contents

Introduction

There are a number of reasons to consider forested sites for biosolids application:

1. Many forest soils are not very productive because they have few nutrients. Biosolids can supply these nutrients, especially nitrogen (N) and phosphorus (P).
2. Forest soils are usually well suited to receive biosolids. These soils have:
   - A great deal of organic carbon, which can store available nitrogen.
   - A forest floor with organic residue, irregular surfaces and good soil structure that enhance infiltration and decrease the potential for surface runoff.
   - A perennial root system, which may allow year-round uptake of available nutrients.
3. In Washington, extensive areas of forestland are suitable for applying biosolids.

Benefits

The three main benefits of applying biosolids to forested ecosystems are improving soils, increasing timber production, and promoting understory vegetation.

Improving Soils

Biosolids can enhance the soil by adding nutrients and improving structure. The biosolids provide virtually every nutrient needed for plant growth. Nitrogen is the most important of these nutrients. Additionally, the fine particles and organic matter in biosolids can enhance soil moisture and nutrient-holding characteristics — immediately and permanently. As the organics in the biosolids decompose, a slow release of nutrients continues for many years.

Increasing Timber Production

Research has documented growth responses ranging from 2 to 100% for Douglas fir stands treated with biosolids. Other tree species, such as hybrid cottonwood, have also shown good growth responses. How growth will be affected depends on site characteristics and stand ages:

- Site class — Growth is most improved in stands where trees are doing poorly due to lack of nutrients.
- Thinned versus unthinned stands — The total wood produced is similar in both unthinned and thinned stands. However, in thinned stands, there is more growth in trees with bigger diameters, and therefore, higher value.
- Response by species — Most tree species grow faster when biosolids are applied. Some respond dramatically, while others show only a slight response.

Currently, most biosolids applications are done on existing stands. Biosolids can also be applied to disturbed sites where establishment of a forest stand is desired (see Chapter 8) or to Christmas tree plantations prior to planting. In past research, dramatic growth response has occurred in reclamation of disturbed sites, but special management techniques are required to reduce the potential for excessive nitrate leaching.

It is difficult to estimate the value added to a forest site when biosolids are applied. A conservative estimate would be the value of the nitrogen fertilizer potential alone, which is approximately $30 / dry ton. Research in western Washington, however, shows trees often grow better when treated with biosolids instead of chemical nitrogen fertilizer. Also, the effect appears to last much longer; some studies show improved growth eight years after application.

Promoting Understory Vegetation

Within six months of application, understory growth is often much more vigorous. It is typically higher in nutrients and provides better habitat for wildlife. Several wildlife studies have found higher populations of animals on treated sites than on nearby untreated sites. The more vigorous understory can also be of commercial value to brush pickers, who harvest ferns and other plants for floral arrangements. To satisfy waiting periods for pathogen destruction, however, brush picking must be restricted until 12 months after application of Class B biosolids.

Effect of Biosolids on Soil and Vegetation

When biosolids are applied to a site, chemical, physical and biological reactions take place within the soil and vegetation.

Chemical

Initially, chemical reactions remove most of the soluble substances (both positive and negative ions) from solution. While some of these reactions only temporarily store ions, others can permanently remove them.

Negative ions (anions) travel through the soil much more rapidly than do positive ions (cations). This process is called leaching. Most soil and organic particles have negative charges; therefore they attract cations. The ability to hold cations is called cation exchange capacity.

Anions, however, are generally repelled. In high enough concentrations, nitrate (NO_3^-) and chloride (Cl^-), will leach rapidly. In contrast, cations such as cadmium (Cd^{2+}), lead (Pb^{2+}) and other trace metals will be held by cation exchange reactions. Although phosphorus (P), a major constituent in biosolids, is an anion, it usually combines with calcium or iron (precipitates) and becomes insoluble. Research on Washington forest soils has shown that these soils can remove high levels of P (Grey, 1999); therefore P is seldom a problem in forest land application systems in Washington. Phosphorus mobility can increase, however, in soils that receive high levels of P for a number of years.

Ammonium (NH_4^+) is also removed from biosolids leachate by cation exchange reactions. However, NH_4^+ not taken up by plants will quickly be changed to NO_3^-.

Physical

The physical process of filtering slows down the rate of percolation, allowing more time for chemical and biological reactions to take place. This filtering process also removes microorganisms and organic matter. Stable organic matter is retained in the soil surface and does not leach through the soil profile. In the forest, most filtering takes place on the surface. A good forest floor with irregular surfaces and vegetation helps maintain good infiltration. Smooth surfaces may be sealed temporarily with liquid application of biosolids.

Biological

Biological processes cause the uptake of nutrients by plants as well as the relatively quick dieoff of disease-causing organisms (pathogens). Forest soils, especially those with a well-developed forest floor, are also excellent systems for decomposing organic matter.

Uptake of Nutrients

The uptake and storage of nutrients — especially nitrogen — by forests can be as great as that of agriculture crops. Reported uptake and storage rates have been impressive:

- More than 270 lb / ac / yr for 3 to 5-year-old poplars.
- As much as 110 lb / ac for the trees and 100 lb / ac for the understory for 6 to 10-year-old Douglas fir ecosystems.

Site Evaluation Criteria

General Conditions

When evaluating potential application sites, there are three basic objectives: enhanced tree growth, no environmental contamination and low cost of operation. In light of these objectives, consider the following physical factors:

- Topography
- Transportation and forest access
- Soils and geology
- Vegetation (characteristics of the stand and understory)
- Water resources
- Climate

Table 7.1 identifies considerations for evaluating these factors. These numbers are suggested only for ranking sites in the order of their desirability for applications. A ranking of 0 for *any* of the factors means the site is generally not acceptable. A ranking of 1 to 3 indicates there may be some problems with the site. To consider this site, other factors must be able to offset the low ranking.

There are no absolute total values that specify whether a site is acceptable; that is, if you add up all the values, they will not fall within good or poor ranges. This system is best used when comparing two sites.

Table 7.1 Ranking system for forest application site evaluation.

Factor	Relative Numeric Rank
Topography	
Slope:	
Less than 10%	10
10-20%	5-8
20-30%	3-6
30%-60%	0-4[1]
Site continuity:	
No draws, streams, etc., to buffer	10
1 or 2 requiring buffers	6
Numerous discontinuities	0-3
Transportation	
Distance	1-10
Condition of the roads	1-10
Travel through sensitive areas	1-10
Forest Access	
Percent of access trail system in place	0-10
Ease of new construction:	
Easy (good soils, little slope, young trees)	7-10
Difficult	1-5
Erosion hazard:	
Little (good soils, little slope)	7-10
Great	1-5
Soil	
Soil type:	
Sandy gravel (outwash, Soil Class I)	10
Sandy (alluvial, Soil Class II)	8
Well graded loam (ablation till, Soil Class IV)	5-6
Silty (residual, Soil Class V)	3-6
Clayey (lacustrine, Soil Class IV)	1-3
Organic (bogs)	0
Depth of soil:	
Deeper than 10 feet	10
3-10 feet	8
1-3 feet	4
Less than 1 foot	0

[1] Suitable for dewatered or dried biosolids only. See Table 7.5.

Table 7.1 (cont'd). Ranking system for forest application site evaluation.

Factor	Relative Numeric Rank
Vegetation	
Tree species:	
Hybrid cottonwood (highest N uptake rates)	10
Douglas fir	9
Other conifers	7
Other mixed hardwoods	4
Red alder	0
Stand age:	
Hardwoods: Less than 4 years	10
Hardwoods: 4 years or greater	8
Conifers: Greater than 30 years	7-10
Conifers: Greater than 4 feet high to 10 years	7-10
Conifers: 10-20 years (high N uptake)	6-8
Conifers: 20-30 years (may be hard to apply to)	0-6
Conifers: Less than 4 feet high	0-3
Stand condition:	
Applying over the tree tops: Well stocked	10
Applying over the tree tops: Poorly stocked	2-6
Applying under the tree tops: Well thinned	10
Applying under the tree tops: Poorly thinned or dense	2-8
Understory:	
Average 6" high or more over 90% of site	10
Average 2" high over 70% of site	7
Partial vegetative cover	2-7

Table 7.1 (cont'd). Ranking system for forest application site evaluation.

Factor	**Relative Numeric Rank**
Water Resources	
Ground water — depth to average seasonal water table:	
More than 15 feet	10
5-15 feet	7
3-5 feet	4
Less than 2 feet	0
Ground water flow:	
Away from usable aquifer	10
Significant contribution to usable aquifer	2-5
Time to contribute to surface water:	
Greater than 1 hour	7-10
Immediate	3
Surface water channels:	
Easily to define and buffer	7-10
Difficult to define and buffer	1-5
Domestic use of surface water:	
Not used	10
Some single family uses far downstream	5
Used by municipality (depending upon distance)	0-5
Climate (i.e., rainfall, temperature)	1-10

Topography

Evaluating topography will quickly tell you whether a site is usable. As shown in Table 7.1, the focus is on slopes and site continuity.

- Slopes — The steeper the slope, the less desirable the site.
- Site Continuity — Land that is not broken up by waterways, cliffs, steep slopes and so on. These types of discontinuities require buffers, which can drastically reduce usable acreage and complicate applications.

Transportation and Forest Access

Transporting biosolids can be the most expensive part of an application program. When evaluating a site, consider distance, road class, routing and access.

- Distance — A shorter haul is cheaper, saving fuel and labor costs.
- Road class — The class of roads also affect hauling costs.
- Routing — Weight limits for roads and bridges may restrict hauling, as will routing through cities and residential areas.
- Access — Constructing access roads and trails is expensive. Many forest sites — especially those that are managed — already have access roads.

Soils

As shown in Table 7.1, you can evaluate soils in terms of texture, parent material or soil class (which is used in septic tank design) and depth. Often, sites that are most suitable for heavy vehicle access (such as the gravelly, sandy soils) are ones that have low productivity — and can benefit the most from biosolids application. They are also better drained.

Vegetation

The condition of vegetation at the application site influences which method to use and how successful the application will be. Table 7.1 ranks species, stand age, stand condition and amount of understory.

- Species — Species such as hybrid cottonwood and Douglas fir are more suitable than mixed hardwoods, due to high N uptake rates. Red alder is not acceptable because it fixes its own N from the atmosphere in excess of what it uses.
- Stand age and condition — Young, vigorous forests that include both trees and understory can handle a higher application rate. Age also affects type and ease of application. When the trees are young, biosolids are applied over the top; when trees are older, biosolids are applied underneath the canopy. However, in between these ages there are times that interference from tree limbs and foliage may hamper application of biosolids. It is better to apply biosolids to well stocked or well thinned trees than to those that are poorly stocked or poorly thinned.

- Understory — A well-established understory increases nutrient uptake in a forest, and decreases the potential for runoff compared with bare soil.

Water Resources

Water resource issues include depth to the water table, distance to aquifers, relationship to surface water and whether or not the watershed supplies public water. These issues are ranked in Table 7.1.

The primary concern for ground water is leaching of nitrate. Biosolids applications are designed to have low enough amounts of N to avoid this problem. Since nutrient uptake and other transformations take place in the top layers of soil, it is best to maintain a distance of at least 2 feet to the water table throughout the year. Sites with standing water or flooding potential may not be suitable or may require special management practices. In cases where a seasonal high groundwater table is within three feet of the surface, a groundwater protection plan is required under the statewide general permit for biosolids management (see section 8.3 of the permit).

If a site is near a waterway, buffers are required to protect water bodies from contaminated runoff or erosion. This reduces the usable area of the site. If there are several drainage ways within or near the site, each reduces the area that can be used for application.

Climate

This ranking is somewhat subjective. Consider the temperature and precipitation at the site. This affects the number of days during the year when snow, freezing conditions or rain might interrupt operations. Elevation will affect the number of days that snow or freezing conditions will make a site unsuitable for applications. Aspect is an important part of the microclimate, because it influences how much sunlight an area receives. South and southwest facing aspects get the most sunlight and have the warmest temperatures. Therefore, biosolids dry faster and the ground isn't frozen or snow-covered as long.

Design Philosophy

Despite the benefits biosolids offer for tree growth, they also contain contaminants and nutrients that, if not managed properly, could degrade the environment. For this reason it is important to understand the characteristics of a forest site when designing the application plan. You may even have to conduct site-specific studies to fine-tune application rates. These studies would focus on nutrient transformations, uptake and losses.

This section presents information you need to understand when designing a forest application plan:

- Nutrient loading (primarily nitrogen)
- Contaminant loading
- Pathogens
- Slopes
- Buffers

Nutrient Loading

The biosolids application must supply enough nutrients to fulfill the uptake requirements of plants on the site, but not so much that the environment will suffer as those nutrients leave the site. The three most significant macronutrients are nitrogen (N), phosphorus (P) and potassium (K).

Nitrogen

Nitrogen is usually considered the most important nutrient when setting application rates for fertilizer or biosolids. A larger quantity of N is needed as a soil supplement than either P or K. Also, nitrogen is typically the limiting nutrient because too much of it can cause nitrate leaching. Many studies at Pack Forest (the University of Washington's experimental forest near Eatonville, Washington) have confirmed this; heavy applications resulted in substantial increases of nitrate in the ground water.

Anaerobic biosolids contain nitrogen in two main forms: organic N (typically about 80% of the total N) and mineral (as ammonium-N, typically about 19% of the total N; and nitrate-N, <1% of the total N). Several things can happen to N that is available immediately after adding biosolids (i.e., in the ammonium form) and shortly after applying biosolids (through mineralization, which transforms organic N to ammonium). This pool of available N can be:

- Lost through ammonia ($NH3$) escaping to the atmosphere (volatilization).
- Taken up by the trees and understory and used as a nutrient.
- Temporarily held as ammonium by the cation exchange capacity of the soil.

- Transformed into organic N by the soil microbes (immobilization).
- Microbially transformed into nitrate (nitrification), which can be taken up by plants or leached into ground water. When there isn't much oxygen in the soil, some of the nitrate can be lost as atmospheric N2 or N2O through the process of denitrification.

Mineralization

Nitrogen mineralizes when the organics in biosolids decompose, releasing NH_4^+. Typical design values for N mineralization for the first year range from 10% (for composted and lagoon biosolids) to 40% (for some aerobically digested biosolids).

Volatilization

Volatilization losses (ammonia escaping to the atmosphere) from biosolids applied to agricultural soils range from 10 to 60% of the initial NH_3. A typical design number is 50%. Forest environments probably lose considerably less than this for several reasons: The forest floor has a low pH, wind speed in forest stands is low, and there is less radiation. Measurements from fairly open forests in western and eastern Washington showed that only about 10% was lost.

Taken Up by Trees and Understory

The trees and understory use the available N from biosolids, and show an increase in growth. Nitrogen uptake can be as high as 300 lb N per acre per year for fast-growing cottonwood, and as much as 110 lb/ac for the trees and 100 lb/ac for the understory in 6 to 10 year-old Douglas fir ecosystems. In old Douglas fir stands, uptake can be as low as 25 lb-N per acre per year.

Immobilization

Because forest soils include an organic layer containing decaying litterfall, twigs and branches, the soil may have excess organic carbon. When this carbon decomposes, it uses some of the available N (immobilization). This immobilization is long-term soil storage of nitrogen, which will be re-released (mineralized) very slowly. A young stand with a good forest floor will probably immobilize about 175 lb N/ac following a biosolids application. When biosolids are re-applied, there won't be much more N immobilized unless the previous application was made many years earlier.

Nitrification

Excess NH_4^+ not taken up by the vegetation or immobilized by the soil will usually be transformed into nitrate. Depending on soil conditions, some denitrification losses — perhaps up to 25% of the total — can occur (EPA, 1983). Measurements from a dry eastern Washington forest showed no denitrification, while about 10% denitrification was measured in a well-drained western forest.

Because most of the transformations are caused by microbial action, they are slowed down considerably in the winter when temperatures are low. At about 40°F, microbial action stops. Through much of the winter, the average temperature of the soil is 40°F or lower under forest stands in Washington. This means that mineralization, nitrification and denitrification essentially stop. Thus, the nutrients from applications made during the winter will be stored in the forest floor and soil layers until temperatures increase.

Table 7.2 presents some typical values to use when designing application rates for the nitrogen budget. Assuming typical values, Table 7.3 shows calculations that can be made for different types of Douglas fir stands. These calculations show the great effect site characteristics can have on application rates.

Phosphorus

The concentration of phosphorus (P) in biosolids is usually about two-thirds that of nitrogen (N). However, the concentration needed by plants is only about 20 to 50% that of N. Therefore, application rates that are set based on nitrogen needs will seldom limit plant growth. Some P may accumulate in the soil, but the amount of P added usually will be small compared with the soil's capacity to bind P. Loss of P to surface water will be negligible as long as application buffers are maintained.

Potassium

The concentration of potassium (K) in biosolids is usually about one-tenth that of N. Plants can take up K at similar levels as N. It is not likely that potassium can accumulate from a biosolids application. Also, since many soils naturally have sufficient concentrations of K, it is seldom a limiting factor for growth.

Table 7.2 Ranges of values and suggested design values for nitrogen transformations and losses from biosolids applied to forest environments.

Transformation/Loss	Range	Suggested Design Value[1]
Nitrogen mineralization		
Anaerobically digested	20% - 40%	30%
Lagooned:	10% - 20%	10%
Composted:	0 – 30%	10%
Ammonia volatilization	0% - 25%	
Open stand - dewatered		25%
Open stand - liquid		10%
Closed stand - dewatered		15%
Closed stand - liquid		5%
Denitrification		
Moist soils most of year		10%
Dry soils		0%
Uptake by trees		
Hybrid cottonwood, established stand		300 lb / ac
Young Douglas fir, 100% of site occupied		110 lb / ac
Older Douglas fir (> 40 years)		25 lb / ac
Uptake by understory		
First application (adjust by % of site covered)		100 lb / ac
Reapplications		0 lb / ac
Immobilization		
Highly productive site		0 lb / ac
Medium to low productivity		
First application:		175 lb / ac
Reapplications (< 3 years apart)		0 lb / ac
Reapplications (3-4 years apart)		50 lb / ac
Reapplications (more than 5 years apart)		100 lb / ac
Old stand (more than 40 years, closed canopy)		0 lb / ac

[1]If calculations for application rates are based on numbers other than the suggested design values, additional supporting documentation may be needed.

Table 7.3 Examples of calculation of first-year biosolids application rates for Douglas-fir stands of three different ages.

	1-Year old stand	15-Year old stand	55-Year old stand
Plant N requirements (lb/acre)			
1.1 Uptake for understory	10 0	100	20
1.2 Uptake for trees	0	110	25
1.3 Estimated soil N immobilized	17 5	75	0
1.4 Total (1.1+1.2+1.3)	275	385	45
N available from other sources (lb/acre)			
2.1 N from previous applications	0	0	0
2.2 Residual soil nitrate	0	0	0
2.3 Other	0	0	0
2.4 Total (2.1+2.1+2.3)	0	0	0
2.5 Net N requirement (2.4 - 1.4)	275	385	45
Plant available N from biosolids (lb/ dry ton)			
3.1 Ammonium N (%)	0.7	0.7	0.7
3.2 Ammonium N (lb / ton) (3.1 x 20[1])	14	14	14
3.3 Ammonium N volatilized (%)	35	35	10
3.4 Ammonium N volatilized (lb / ton) (-3.2 x 3.3)	-5	-5	-1
3.5 Biosolids organic N (%)	3.9	3.9	3.9
3.6 Organic N mineralized (%)	25	25	25
3.7 Organic N mineralized (lb / ton) (3.5 x 20[1] x 3.6)	20	20	20
3.8 Plant-available N (PAN) (lb / ton) (3.2+3.4+3.7)	29	29	33
3.9 Denitrification loss (% of PAN)	10	10	5
3.10 Denitrification loss (lb / ton) (-3.8 x 3.9)	-3	-3	-2
3.11 Net plant available N (lb / ton) (3.8 + 3.10)	26	26	31
Application rate (dry tons/acre) (2.5 / 3.11)	10.7	15.0	1.5

[1] Multiply percent by 20 to convert from percent to lb / ton.

Contaminant Loading

Applying biosolids to forestlands has a low risk because of contaminant loading limits and established management practices. As shown in Table 7.4, the Environmental Protection Agency (EPA) has set limits for contaminant loading for forest applications. These limits are the same as those for agriculture.

Table 7.4 Limits for trace metal loading for forest applications.

Contaminant	Limit (lb/ac)	Limit (kg/ha)
Arsenic	37	41
Cadmium	35	39
Copper	1300	1500
Lead	270	300
Mercury	15	17
Molybdenum	*	*
Nickel	370	420
Selenium	89	100
Zinc	2500	2800

*Molybdenum level is under reconsideration by the EPA

Pathogens and Vector Attraction Reduction

As established by the EPA, there are two classes of pathogen reduction in biosolids: Class A and Class B. Both are acceptable for forest application. Biosolids applied to forest land must also meet vector attraction reduction requirements outlined in Chapter 3.

Class A biosolids have no public access restrictions. For Class B biosolids, public access must be restricted from 30 days to one year, depending upon whether the site has a high or low potential for public exposure. Sites with high potential for public exposure include those that are used for recreation, such as hiking or hunting, and those that are used for brush-picking. Public access at those sites must be restricted for a full year. Judgments on public access restriction are somewhat subjective and you should consult with your regulatory authority for guidance.

Slopes

Applying biosolids to steep slopes increases the risk of runoff. Table 7.5 lists the maximum recommended slope for different conditions, as determined from field studies at Pack Forest.

Table 7.5 Maximum recommended slopes for biosolids applications to forested sites.

Conditions	**Maximum recommended slope**	
	Liquid	**Dried or dewatered**
Dry Season		
Good vegetative cover	30%	60%
Poor vegetative cover[1]	15%	30%
Wet season		
Good vegetative cover	15%	30%
Poor vegetative cover[1]	8%	8%

[1]In special circumstances, the limits for good vegetative cover may be used where vegetative cover is poor, such as in reclamation or restoration sites where the goal is to establish vegetation to reduce erosion. In these cases, special management techniques may be required to intercept any downslope movement of biosolids.

Buffers

Buffers are those areas adjacent to waterways, property boundaries, and other features that are not intended to receive biosolids applications (Chapter 4). Buffers are wide enough to:

- Protect the environment in case there are oversprays or other errors during application
- Absorb contaminants and filter runoff.

The condition of the ground is critical. For filtering, bare soil is not effective, a grassed surface is fair, and a porous forest floor is excellent.

The width of the buffer depends on the type of water body and the condition of the buffer area. Table 7.6 lists recommended buffers from various types of waterways. For purposes other than surface water protection, the designation of buffers is based on local considerations, such as property lines, wells, and adjacent land use. See Chapter 4 for more information on buffers.

Table 7.6 Buffer recommendations (in feet) depending on type of water body.

	Type of Water Body		
Application Method	**River, Lake, or Stream**	**Seasonal**	**Ditches**
Surface applied:			
Undisturbed buffer	100	50	33
Disturbed buffer	200	100	50
Injected or incorporated	100	50	33

Note: The goal of these buffers is to protect receiving waters. In all cases, good management practices must be used.

Application Procedure

For forestlands, there are two options for applying biosolids:

- Over the canopy of a young plantation
- Under the canopy of an older stand
- Application to disturbed sites is discussed in Chapter 8.

Young Plantations

Biosolids are often applied from a tanker/sprayer vehicle, or a biosolids *throw-spreader* mechanism. Application vehicles spraying liquid or semi-solid biosolids can apply material containing up to 18% solids over the tops of the trees (the canopy) to a distance of 125 feet. Throw-spreaders can apply biosolids containing 15-90% solids up to 200 feet into a plantation. To do this, trails must be spaced appropriately.

The best age and size for trees is more than five years old, or more than about four feet high. This cuts down on the required maintenance (disking, herbicide, etc.) because the trees are well established.

If possible, application to young plantations should take place during the rainy, non-growing season. This helps wash the biosolids from the foliage. It also keeps the biosolids off new foliage, which could retard the current year's growth. Avoid extreme weather, especially with saturated soil conditions, during rainy-season biosolids applications, because the risk of runoff increases.

Another application method is the sprinkler irrigation system. This system has been successful for applying liquid biosolids. The major drawback has been clogged nozzles.

Manure spreaders can also apply ("fling") dewatered or dried biosolids, similar to the throw-spreaders. As their range is typically limited, application trails may need to be at closer intervals than with other methods.

Because the recommended time for applications occurs during the time that growth is reduced, uptake of nutrients is also reduced. When biosolids are first applied to the soil, the available N is in the ammonium form. As explained earlier, this form doesn't leach. Secondly, during this time soil temperatures are low and neither N mineralization (transformation of organic N to ammonium) nor nitrification (transformation of ammonium to nitrate) occurs significantly, so the nutrients are effectively stored until the next growing season.

Older Stands

For older stands, application takes place under the canopy. Since foliage is not affected, biosolids can be applied year-round. Application methods are similar to those for young plantations. However, since older stands usually are not in rows, some of the alternatives for plantations may not be available (for instance, there may not be straight trails, or there might not be many trails).

Application Rate and Timing

Applications to forested sites can be made either annually or once every several years.

Annual Applications

Annual applications supply only enough N for the annual uptake requirements of trees, considering volatilization and denitrification losses, and mineralization from current and previous years. Annual applications are preferred if the biosolids are quite liquid (less than 5% solids). A heavy application of this type could exceed the soil's infiltration rate. Instead, annual light applications avoid the problems of surface sealing, increased potential for runoff, and anaerobic conditions that cause odor problems and plant stress.

Less Frequent Applications

Forest applications are often made at three to five year intervals. As forest floors contain a significant amount of organic matter and perennial vegetation, immobilization by the soil microbes and by plants can temporarily store significant amounts of N. In following years, plants and microbes die and decompose, releasing the immobilized N for plant growth.

Additional advantages to less-than-annual applications include a longer period for the forest floor and vegetation to return to normal conditions, and a greater time for public access.

Liquid applications that are of significant depth (>1/2 inch) should be made in a series of three or more partial applications, depending on the percent solids. In this way, applications will be more even and there will be time for the biosolids to stabilize or dry, which decreases runoff. The interval between partial applications ranges from 2–14 days, depending on weather conditions.

Application Equipment and Operation

Biosolids Transfer Equipment

Biosolids are delivered from the wastewater treatment plant in an over-the-road vehicle. At the site, they are usually stored temporarily before being transferred to an application vehicle. A multi-purpose vehicle, which delivers and applies the biosolids, is often used by smaller facilities or where applications are close to the treatment plant.

Transferring biosolids between vehicles and storage is by gravity or pumping, depending on the solids content of the biosolids and the position and configuration of the storage vessel.

Unloading via Gravity

The easiest way to unload a trailer from the treatment plant is by gravity. For gravity transfer:

- The storage facility must be either in-ground or have a ramp the truck can be driven onto.
- The biosolids must be dilute enough to flow from the trailer (<8% solids) or pressurized tank (<15% solids), or the trailer bed must be tilted.
- Dewatered biosolids containing up to 24% solids can be emptied via gravity from a tilting bed or bottom-unloading dump, provided there is enough clearance for operation.

Unloading via Pumping

Biosolids can be pumped if they are liquid enough — below 10 to 15% solids. With a higher percentage of solids, the flow of biosolids to the pump will be restricted. Centrifugal pumps can be used on dilute biosolids (<10–13% solids). Chopper-type centrifugal pumps may be able to pump up to 15% solids. Dewatered biosolids may need to be diluted with water before pumping.

Biosolids Application Systems

Methods

There are three general methods for applying biosolids to forests: 1) *spray irrigation* with either a set system or a traveling gun, 2) *spray application* by an application vehicle with a spray cannon, and 3) *application by a throw-spreader or manure-type spreader*. In the Pacific Northwest, the most common methods for forest applications are the throw-spreader or a vehicle-mounted cannon. Table 7.7 lists these application methods, their range, relative costs, advantages and disadvantages, and their suitability for biosolids of different solids contents.

Table 7.7 Comparison of different application systems.

System and Range	Relative Costs	Advantages	Disadvantages
Set irrigation system. Range = 30'- 200'.	High capital Low operations Low maintenance	Simple to operate. 2–8% solids.	Frequent clogging. Use only low percent solids. Brush interferes.
Traveling big gun. Range = 200'.	Moderate capital Low operations Low maintenance	Simple to operate on appropriate sites. 2–8% solids.	Frequent clogging. Use only low percent solids. Brush interferes. Need even terrain.
Application vehicle with mounted cannon. Range = 125'.	Low to moderate capital High operations High maintenance	Any terrain. Biosolids up to 18% solids.	May need special trails.
Throw-spreader mounted on an ATV chassis	Moderate-high capital Low operations Low maintenance	Can apply dewatered biosolids with >20% total solids. Fast and good throw distance	Limited to >15% solids.
Manure spreader. Range = 10-50'	Low capital Low operations Low maintenance	Can apply dewatered biosolids with >20% total solids.	Limited to high percent solids. Trails may need to be close together.

Application Vehicles

Many application vehicles have been designed for agricultural applications. Most can be modified for forest use by mounting a spray nozzle and pump on the tank.

Application vehicles can also be custom-made. Depending on site needs, options include a specially designed all-terrain vehicle or a heavy-duty truck chassis with rear-mounted tank. Liquid application vehicles can be filled by a traveling tanker, directly from on-site storage, or may itself be an over-the-road multi-purpose vehicle that is filled at the wastewater treatment plant. Throw-spreaders or manure spreaders can be filled by loaders, or may be custom-fit with self-loading clamshells.

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Chapter 8

Other Beneficial Uses of Biosolids

Table of Contents

Introduction

Biosolids have other potential beneficial uses, including

- Disturbed and mined-land reclamation
- Improving poor condition rangeland
- Home lawns and gardens
- Public contact sites
- Intermediate and final landfill cover

Regardless of how they are used, all land-applied biosolids must meet federal and state requirements for trace element concentrations, pathogen reduction, and vector attraction reduction (see Chapter 3 for details). The pathogen and vector attraction reduction standards that apply to a variety of land application sites are shown in Table 8.1.

Table 8.1 Operational standards for land application of biosolids.

	Standards*	
Biosolids Application Site	**Pathogen Reduction**	**Vector Attraction Reduction**
Agriculture	Class B or A	1 to 10**
Forest	Class B or A	1 to 10
Rangeland	Class B or A	1 to 10
Public Contact	Class B or A	1 to 10
Reclamation	Class B or A	1 to 10
Lawn or garden	Class A	1 to 8

*See Chapter 3 for details on pathogen and vector attraction reduction requirements.

**See Table 3.6 for details and references to Chapter 173-308 WAC

Land Reclamation

Biosolids provide organic matter and slow-release nutrients that help establish vegetative cover and restore productivity on drastically disturbed land. Examples of potential reclamation projects include strip mines, borrow pits, cut and fill sites, construction sites, areas where topsoil mining has occurred, some contaminated sites, and areas where severe wind or water erosion has occurred.

Biosolids have been used successfully at reclamation projects in the Northwest, and can be an important component of a land reclamation project. Biosolids should only be used in land reclamation projects that are carefully planned and managed, so that the goals of the project, the management practices, and the expected benefits of using biosolids are clear. Applying biosolids to a degraded piece of land with no management plan for site renovation is not consistent with beneficial reuse. It is important to consider future potential uses of any reclaimed site, since there are restrictions on public access and crop harvest for a period of time following application of Class B biosolids. See Chapter 4 for details on harvest and access restrictions.

The agronomic biosolids rate for nutrients on a drastically disturbed site is usually much less than the amount of organic matter needed to restore productivity. Therefore, to have the desired level of soil organic matter, biosolids applications for land reclamation are usually greater than the agronomic rate.

When agronomic rates are exceeded, the site evaluation must :

- Assess whether the biosolids application poses a risk to the environment and to public health [see WAC 173-308-190(1) and (5), WAC 173-308-240(5) and WAC 173-200-080 (Groundwater Quality regulations)].
- Describe why biosolids are the preferred reclamation alternative.
- Assess whether the activity provides a greater benefit to the environment as a whole.
- Describe control technologies to keep contamination to a minimum.

Balancing Carbon and Nitrogen

One technology to reduce potential nitrate loss from land reclamation sites is carbon and nitrogen balancing. Its purpose is to provide enough organic matter to restore soil productivity without producing excess nitrate that could leach into ground water.

The principle behind C:N balancing is combining a carbon-rich, nitrogen-deficient source of organic matter with the nitrogen-rich biosolids. It is similar to balancing the raw materials for composting, except that decomposition occurs in the soil rather than in a compost pile. Ideally, microbes will be able to break down the carbon source and biosolids simultaneously, using biosolids N to balance their nutrient needs and create stable organic matter. This would allow application of large amounts of organic matter without exceeding the capacity of the site (crop and soil) to assimilate nitrogen.

C:N balancing is a promising technique for land reclamation, but it is still in a developmental stage. Research has shown that the type of carbon source is important. If the carbon source contains too much N, such as grass-rich yard debris, it will not tie up biosolids N, and large nitrate loss may occur. If the carbon source is difficult for microorganisms to break down, such as wood chips, the biosolids will break down faster than the carbon source. This will result in a short-term excess of N, but a long-term N deficiency. Research results indicate that materials such as hardwood leaves, woody yard debris, straw, compost, and paper mill fines are the most suitable carbon sources.

A mine reclamation project might involve amending the soil to a depth of 12 inches using biosolids combined with a woody carbon source. A typical rate for such an application would be in the range of 10 to 25 dry tons of biosolids and 100 to 150 dry tons of carbon source per acre. The amount of each material used will vary depending on the characteristics of the biosolids, carbon source, soil, and depth of amendment. Applications must be calculated on a site- and material-specific basis, and projects will likely require monitoring.

For guidance in calculating biosolids and carbon source application rates for C:N balancing, refer to *Managing Nitrogen from Biosolids*, Department of Ecology publication No. 99-508. This document also contains more background information on C:N balancing.

Regulatory Requirements

It is very important to consult with Ecology before developing a land reclamation proposal. Those who plan to reclaim land by applying biosolids at greater-than-agronomic rates must have the application rates approved in a site-specific plan submitted to the department (See Chapters 2 and 11). The plan must show that the rates are necessary to remediate the site and that site reclamation with biosolids is the best reclamation alternative available. Also, all other regulations regarding biosolids quality, waiting periods, buffers, etc. apply to land reclamation projects.

Rangeland

Rangeland is a type of natural land area that supports grasses and shrubs, but is neither forested nor cultivated for crop production. It is commonly managed for grazing livestock, principally cattle and sheep, but it also provides habitat and forage for wildlife, and outdoor recreation for people.

Rangelands offer a potential beneficial use for biosolids. In some cases, suitable range sites are more accessible than agricultural areas yet, typically, they are more isolated from houses and other sensitive land uses. More importantly, biosolids can improve the productivity of rangelands.

Range conditions tend to be harsh. The climate of rangelands in the inland Northwest is predominantly arid or semi-arid with cold winters and hot summers. Precipitation is seasonal, falling mostly during the winter, and highly variable from year to year. Native vegetation (grasses, forbs, shrubs), is adapted to these conditions, and supplies forage and habitat for livestock and wildlife. However, the ecology of rangeland is fragile and environmental changes can alter its character and quality. During the late 19th and early 20th centuries, unrestricted grazing degraded much of the range in the western U.S. The resulting effects - reduced forage value, undesired plant species, and erosion - are still apparent in many areas today.

Benefits of Biosolids to Rangelands

Although it is not a common practice, fertilization can enhance the quantity and quality of range forage. Organic sources of nutrients, such as biosolids, provide fertility for several years with the gradual release of nutrients as organic matter decomposes. In addition, biosolids serve as a soil amendment, improving the tilth and water retention capacity of the soil. Research studies have shown that surface applications of biosolids to arid and semi-arid rangelands can yield the following benefits:

- Increase vegetative growth and cover.
- Increase water infiltration and soil moisture retention, thereby decreasing runoff and erosion.

- Reduce wind erosion.
- Improve forage quality and palatability with higher concentrations of nutrients in plant tissues.
- Help restore degraded rangelands.

The application of biosolids to rangelands also has possible drawbacks, such as undesired changes in plant species composition, movement of nitrate and other compounds with soil water or surface runoff, and overgrazing of areas fertilized with biosolids. Because of potential changes in species composition, rangeland sites that are already in peak condition or include critical wildlife and plant habitats are not good candidates for biosolids applications.

Research indicates that these drawbacks can be avoided with appropriate site selection and management. On balance, application of biosolids to rangelands can be a beneficial and safe practice.

Effects of Biosolids on Range Vegetation

In contrast to agriculture, rangeland is characterized by a mixed assortment of perennial and annual plants; no harvest, tillage or cultivation; and reliance on seasonal natural precipitation. To reduce disturbance to the soil and plants, biosolids are applied to the surface of range soils without incorporation.

For semi-arid and arid rangelands, lack of water usually limits plant growth. Vegetative growth fluctuates through the year and from year to year, depending on temperatures and the amount of moisture available from precipitation. When water is abundant, availability of nutrients, particularly N and P, determine plant growth. Biosolids increase range productivity by increasing infiltration of moisture into the soil, retaining more moisture from rain and melting snow, and by supplying nutrients when moisture is available.

The nutrients and soil-amending properties of biosolids will last for several years. Research suggests that the effects of biosolids continue for five years or more after an application to rangeland. Given the long-term benefits, and the variable growth of range vegetation, it is more practical to make one biosolids application every several years, rather than apply biosolids annually.

Different range plant species respond differently to the biosolids-altered conditions. Therefore, applications can affect the botanical composition of the site. Generally, biosolids application favors grasses and forbs (non-grass herbaceous plants) over legumes. Shrub response is species-specific.

Site Selection

The following characteristics are important in selecting a range application site:

- Potential sites should be responsive to fertilization.
- If the site is not currently productive it should be a good candidate for renovation.
- Adequate acreage to apply biosolids after buffers have been taken into consideration.
- Site is accessible for biosolids application vehicles, and application can be done with minimal effect on rangeland.

Because biosolids can alter the composition of the plant species, a range specialist should be consulted in selecting the biosolids application site, as well as determining application rate and management practices. Plant species changes may harm rangelands that are in pristine condition, or rangelands that are critical wildlife and plant habitats, and these areas should be avoided for biosolids use.

Other site selection criteria include buffers to water sources and neighboring property, transportation, topography, and accessibility. More information on these criteria is found in Chapter 4 (Agricultural Site Design) and Chapter 7 (Forest Site Design and Management).

Determining the Biosolids Application Rate

Unlike agriculture, range production does not involve the harvest of a specific crop with an expected yield and well-documented nutrient requirements. The concept of an agronomic application rate loses significance in range situations, especially if single applications are intended to produce multi-year effects. Therefore, other approaches are used to determine biosolids application rates to rangeland. Two such approaches include:

- Recommendations for fertilizing rangelands.
- A target application rate, intended to improve range quality and/or productivity without producing negative environmental effects. In this case, the target rate can be determined from research findings, or experience coupled with site monitoring

Recommendations for Fertilizing Local Rangelands

If available, recommended application rates for fertilizing rangelands can provide the basis for calculating a biosolids application rate. The fertilizer recommendation represents the plant nitrogen requirement. The biosolids application rate can be determined by dividing the N requirement (fertilizer recommendation) by the amount of N available from the biosolids for the first year of the application, after accounting for N losses and mineralization.

Application rate (dry tons / acre) = Fertilizer recommendation (lb. N / acre) / Available N from biosolids (lb. N / dry ton)

The worksheet for calculating agricultural application rates in Chapter 5 can be used for estimating biosolids application rates for rangeland. The worksheet is a useful format for documenting how application rates were estimated. Several considerations are important to keep in mind when using the worksheet:

- Some of the information requested in the worksheet, such as a specific yield goal for a crop, is not relevant for range applications, where the goal is long-term improvement of range conditions.
- Background N inputs (from manure, irrigation water, legume plowdown etc.) are usually negligible for rangeland. The only exception is if biosolids or manure have been applied in the recent past. If you suspect this is the case, you should have a soil sample analyzed for nitrate (see Chapter 9) and / or estimate the amount of N provided by previous applications of biosolids or manure (see Chapter 5).
- In range environments, N losses via ammonia volatilization can be large. The conventional assumption is that 50% of the ammonia present is volatilized if the application is made during the cool wet season and 100% is volatilized if biosolids are applied in the hot dry season.
- Finally, the N fertilization recommendation used should be specific to local range conditions. Nutrient requirements depend on climate and plant species. As a result, suggested range fertilizer rates found in publications vary greatly, from roughly 20 to 200 lbs of N per acre. If local range fertilizer guidelines are not available, either consult with a range specialist or select a safe target application rate as described below.

Target Application Rates

In the absence of estimated nutrient requirements, it is reasonable to estimate a safe target application rate and then monitor the site to assess the effects of the application. Depending on the range management goals (e.g. increase forage quality or range restoration), site monitoring might evaluate the effect on forage production and quality, changes in plant species composition, soil organic matter, nitrate in the soil profile, or runoff volume and quality. The rate for subsequent applications can be adjusted according to the site monitoring results.

Target application rates are for multi-year applications and assume storage of N in the root zone from year to year with little leaching loss (because of the arid to semi-arid environment). To estimate an appropriate target application rate, you can refer to research results or experience from other rangeland applications, and consult a range specialist familiar with local conditions.

Research findings can form the basis for selecting a target biosolids application rate that improves range productivity and condition without causing environmental damage. In interpreting research findings, differences in the nature of the biosolids, climate, range ecology, and research focus should be taken into account.

For specific references to research studies, refer to the Rangeland chapter in *Managing Nitrogen from Biosolids* (Washington State Department of Ecology publication No. 99-508).

Experience can also supply guidance for choosing a target application rate. On ranches that apply biosolids to rangelands, application rates of 2 to 5 dry tons per acre are common. These are lower than the maximum rates that research projects have found to be effective and environmentally safe. Since low application rates appear to be beneficial, and range acreage is abundant, it seems prudent and reasonable to begin with a low target application rate, within the level of 2 to 5 dry ton per acre. Strips with higher application rates could be incorporated into the site, and monitored to determine short and long-term effects of the higher rates on range quality and risk of leaching and runoff.

Management Practices

As with any biosolids application, conditions that may lead to contamination of ground and surface water should be avoided. This includes application of biosolids to steep slopes, riparian areas, wetlands, and on snow-covered or frozen ground near surface water.

If Class B biosolids are used, a 30-day waiting period must be observed between biosolids application and resumption of grazing. In general, grazing should be monitored on range fertilized with biosolids. It is possible that animals will overgraze fertilized areas because of the improved forage quality and palatability.

Research has shown that fall and winter applications can be beneficial for rangeland. Studies conducted in west Texas found plants responded better to biosolids applied in the dormant season compared to applications made just before and during the growing season. Leaching of nitrate-nitrogen from biosolids over the winter and early spring is less of a concern in range environments because of the limited amount and movement of water in the soil. We do not yet have research experience with winter applications in the Northwest, however.

Summary

Biosolids applied to rangelands can increase the production and quality of forage and/or make a positive change in the plant community. In either case, the application of biosolids should complement the management goals for the range, rather than using the range simply as an outlet for the biosolids.

Since the status and ecology of the site can be altered, it is very important that a range specialist be involved with the planning, management, and evaluation of the application. Pristine rangeland, sites that are already in peak condition, land adjacent to riparian areas, or sites that include critical wildlife and plant habitats are likely not good candidates for biosolids applications.

Lawn and Garden Use

Biosolids that are applied to a lawn or home garden must meet all exceptional quality (EQ) standards:

- Class A for pathogens (Table 3.1)
- Vector attraction reduction alternatives 1 to 8 (Table 3.6)
- Table 3 trace element concentration limits (Table 3.9)

If you distribute biosolids for lawn or garden use you must provide a label or information sheet that has the basic information, certification, and instructions shown in Table 8.2 below.

Table 8.2 Requirements for labels and information sheets for biosolids.

Label or Information Sheet Requirement	Notes and Applicability	Example
Name, address and phone. WAC 173-308-260(4)(a)(I).	All products. Information about the person who prepares the biosolids product.	City of Cascadia 4212 Clear Creek Lane Cascadia, WA 99999 (360) 555-1234
Statement of compliance. WAC 173-308-260(4)(a)(ii).	All products. May cite actual regulatory requirements or be a statement of general compliance.	This product has been prepared to meet all applicable federal and state regulations for biosolids.
Statement encouraging proper use of the product, protection of the health and the environment. WAC 173-308-260(4)(a)(iii).	Applies to all products.	Use this product in accordance with the manufacturer's directions. Protect water quality. Do not exceed recommended rates of application and do not apply in close proximity to surface waters. Store in a cool, dry place. As with all such products, wash hands after use.
Agronomic rate – unpackaged products*. WAC 173-308-260(4)(a)(iv).	"Unpackaged biosolids" means biosolids distributed in a loose, unpackaged form such as, but not limited to, tote bags, tote tanks, bins, tanks, trailers, spreader trucks, railcars, and pick-up truckloads or other container provided by the final purchaser solely for transport of the material. Can be site or crop specific. Can be actual rate or instructions on how to determine rate.	Consult the producer for a proper agronomic rate for your crop. - *or*- See the Department of Ecology's Biosolids Management Guidelines (WDOE 93-80) for guidance on determining agronomic rates.

Table 8.2 Requirements for labels and information sheets for biosolids. Cont'd.

Label or Information Sheet Requirement	Notes and Applicability	Example
Agronomic rate – packaged products *. WAC 173-308-260(4)(a)(iv).	"Packaged biosolids" means biosolids distributed in a container provided by the distributor of the material. Packaged products may provide application rate information where the product is used as a soil amendment. Packaged products that make nutrient claims must comply with Department of Agriculture regulations for commercial fertilizers.	Do not exceed five bags per one hundred square feet of garden.
Statement regarding origin of material. WAC 173-308-260(4)(a)(v).	Statement must make clear that the product is derived from biosolids.	This product contains biosolids produced from the treatment of wastewater.
Any additional product specific instructions	Information at the producer's discretion or per special permit requirement.	
Disclaimer	For products that are not intended to compete with commercial fertilizers or be regulated by the Washington State Department of Agriculture (most unpackaged products and any packaged products that are not making nutrient claims).	This product is not a commercial fertilizer. All nutrient claims are estimates or averages and are not guaranteed.
For all products that claim to be a fertilizer.	See State Department of Agriculture regulations for commercial fertilizers.	

Public Contact Sites

Biosolids can be used on sites that have a higher amount of public contact than typical agricultural or forest sites. These public contact sites include parks, ball fields, golf courses, cemeteries, and other sites with high public use. Because of the high potential for public exposure on these sites, public access must be restricted for 12 months following application of Class B biosolids, to allow for complete die-off of pathogens. Septage may not be applied to a public contact site. Turfgrass sod grown using class B biosolids has the same restrictions, when the sod is used for home lawns, parks, or other high public contact sites. There are no access restrictions for any site when Class A biosolids are used. Other site design and management requirements are much the same as for agricultural sites, although a site specific land application plan will not usually be required where EQ products are applied to the land (see Chapters 3 and 4).

Dewatered or liquid biosolids can be used during the development phase of a site to condition the soil and get plant growth started. To reduce odors, the biosolids can be tilled or injected into the soil. When biosolids are applied to grass and landscapes in public contact areas, they should be processed to reduce odor and make it easier to spread them evenly. In summary, managers have more choices for public contact areas with Class A biosolids. If public access is controlled, for example, during development or renovation of a site, Class B biosolids can also be used.

Landfill Cover

Biosolids are not suited for use as a daily cover material in a landfill, and such use is considered disposal under state regulations. But, biosolids can be used beneficially at landfills to help establish plants on intermediate or final landfill cover. Biosolids are either mixed with the cover material (usually sand or topsoil) or applied to the surface after the cover is in place. Mixing the biosolids with the cover material is the best way to improve the rooting environment because it increases the amount of organic matter and nutrients throughout the root zone. Mixing also reduces the risk of biosolids runoff.

Both surface application and mixing before application have been used successfully in Washington. The City of Tacoma applied liquid biosolids on top of the cover material, while Richland and Spokane mixed biosolids with the cover material before application. At these landfills, wind erosion decreased and plant cover became better established.

Chapter 9
Site Monitoring

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Application Monitoring

Calibrating Application Equipment

Calibrating application equipment is an essential part of biosolids application and recordkeeping. Because of the nature of the material and limitations of the application equipment, it is difficult to deliver the exact application rate planned. In most circumstances it is reasonable to expect actual application rates to be within 15% of the planned rate.

Calibrate biosolids spreaders by determining the area applied per load. The worksheet in Table 9.1 calculates the feet-of-travel for a full spreader load. It works for solid or liquid biosolids applicators. You will need to determine how to adjust your spreader to meet the feet-of-travel calculated in the worksheet. You can adjust either the ground speed of the spreader vehicle or the biosolids discharge rate.

The worksheet calculations assume a rectangular spreading area using a truck or tractor-mounted applicator. You will need truck scales to determine the weight of biosolids in the spreader, and a measuring wheel to measure the actual length and width of the application area in the field.

If you are applying liquid biosolids that vary in percent total solids, you will need to recalibrate the spreader as the solids content changes. Material with 4% total solids should be applied at half the rate of material with 2% total solids to maintain the same application rate in dry tons per acre. This recalibration is very important at low solids content, because a small error in calibration can result in a large error in the application rate.

At the end of each day you should verify the calibration by measuring the total area spread, and comparing the actual number of loads applied with the projected number based on area covered (Table 9.1, Step 4).

How to Use the Worksheet:

1. **Determine the weight of biosolids the application vehicle will hold.** Use truck scales to weigh an empty application vehicle; then weigh it when full. (Table 9.1, Steps 1.1-1.3). Convert the result to dry weight, based on the solids content of the biosolids (Steps 1.4-1.5).

2. **Calculate the target biosolids application rate on an as-is basis.** Divide the target biosolids application rate (usually based on the worksheet in Chapter 5) by the solids content of the biosolids. You don’t need the as-is rate to complete this worksheet, but it will be useful to the spreader operator for making an initial choice of ground speed and discharge rate.

3. **Calculate feet-of-travel for a full spreader load.** Calculate the target area to cover with a spreader load, based on the capacity of the spreader and the target application rate (Step 3.1). Then measure the width of the application swath (Step 3.2) and divide into the target area to calculate the target feet-of-travel (Step 3.3). Use a measuring wheel to determine the actual feet-of-travel in the field, and adjust the spreader ground speed or discharge rate as necessary to meet the target rate.

4. **Calculate the number of spreader loads to apply per field.** Determine the net application area of the field (excluding buffers), and divide by the target area covered per spreader load. When applying biosolids, keep a log of the number of loads and compare with the calculated number at the end of each field. Recalibrate the equipment as needed.

Table 9.1 Example worksheet for biosolids spreader calibration using the spreader load method.

Operator Information

	Your operation	Example
Date		23-Aug-02
Operator		Mike Brown
Site		12-E
Spreader ID		Manure spreader 2
Speed		3 mph
Gear, rpm, etc.		

Table 9.1 Example worksheet for biosolids spreader calibration using the spreader load method (continued).

Step 1. Calculate spreader capacity

Line no.		Your calibration	Example
1.1	Weight of empty spreader (lb)		12000
1.2	Weight of spreader loaded with biosolids (lb)		30000
1.3	Net weight of biosolids in spreader (lb) (line 1.2 – line 1.1)		18000
1.4	Total solids analysis of biosolids (percent)		20
1.5 W	Dry weight of biosolids in spreader (dry tons) (line 1.4 / 100) x line 1.3 / 2000		1.8

Step 2. Calculate biosolids rate on an as-is basis

2.1	Target biosolids application rate (dry tons / acre) (based on Chapter 5 calculations)		3.0
2.2	Biosolids application rate, as-is (wet tons / acre) (line 2.1 x 100 / line 1.4)		15

Step 3. Calculate feet-of-travel for a full spreader load

3.1	Target area to cover per spreader load (ft^2) (line 1.5 / line 2.1) x 43560		26136
3.2	Width of spreader application swath (ft)		20
3.3	Calculated feet-of-travel per spreader load (ft) (line 3.1 / line 3.2)		1307

Step 4. Calculate the number of spreader loads to apply per field

4.1	Net area of field available for biosolids application (acres / field)		30
4.2	Number of spreader loads to apply per field (line 4.1 x 43560) / line 3.1		50

Biosolids Application Records

You must document the biosolids applied to a site, and keep daily records of field applications. These records should be in a simple, legible, reproducible format. Include the application date, percent total solids, quantity applied (dry tons per acre) and acreage applied. For reports, calculate biosolids applied on a field-by-field basis (e.g., 3 dry tons per acre on field 1).

When biosolids are stockpiled before they are applied, keep records of the quantity of biosolids delivered and the quantity of biosolids applied to the field. For examples of these records, see Tables 9.2 and 9.3. Measure the solids content of stockpiled biosolids at the time of application because it can change during storage.

Table 9.2 Example of a record of biosolids delivery to a stockpile or lagoon.

Grower/land manager: Earl Q. Black

Stockpile or lagoon identification: 1-B

Date of Delivery	Wet Tons Delivered	Percent Total Solids as Delivered	Dry Tons Delivered
08-Aug-02	200	21	42
09-Aug-02	300	20	60
10-Aug-02	300	19	57
11-Aug-02	375	20	75
12-Aug-02	400	19	76
13-Aug-02	450	21	95
Cumulative Site Total	2025	20	405

Table 9.3 Example of a biosolids application record for a land application site.

Date of report	11-Aug-02
Grower/land manager	Erin Green
Site or field number	14-C
Target application rate (dry tons/acre)	3.2
Total site acreage (acres)	48.6
Target application rate (dry tons/site)	155.5
Actual application rate (dry tons/site)	147.8
Percent of target rate applied (%)	95

	Daily					Cumulative	
Date of Application	**Wet Tons Applied**	**Percent Total Solids as Applied**	**Dry Tons Applied**	**Acreage Applied**	**Dry Tons per Acre Applied**	**Dry Tons Applied**	**Dry Tons per Acre Applied**
08-Aug -02	180	18.2	32.8	12.0	2.7	32.8	2.7
09-Aug -02	280	20.8	58.2	18.0	3.2	91.0	3.0
10-Aug -02	290	19.6	56.8	18.6	3.1	147.8	3.0

Environmental and Public Health Monitoring

You may be required to develop a sampling and analysis plan for your land application sites as part of the approval process for coverage under the statewide General Permit for Biosolids Management (Chapter 2). Monitoring requirements will depend on the sensitivity of the site and the approach proposed in your land application plan. A site with a conservative application plan (e.g., wide buffers, low application rates, dry season applications) will need little monitoring. A site plan that has minimum buffers or a longer season of application, sites with a greater risk of leaching or runoff, or sites with nearby neighbors are likely to need more monitoring. An incentive for conservative management is that you will have fewer monitoring requirements.

Monitoring Protocol

Monitoring protocol depends on the medium (soil, ground water, surface water, plant tissue) and purpose of the monitoring. Conditions at the site also affect monitoring protocol. This section is a general introduction to monitoring, and does not discuss specific methods for each situation.

Each site will have a specific monitoring protocol. Refer to publications such as those listed below, and consult with experienced professionals to make sure that all aspects of your monitoring program will meet regulatory and management needs.

Publications for Guidance on Monitoring

- **Groundwater and surface water:**

  Standard Methods for the Examination of Water and Wastewater. American Public Health Association. This book provides general procedures for water sampling and sample handling, as well as specific methods for analysis.

- **Soil:**

  Principles of Soil Sampling for Northwest Agriculture. WREP 0009. Washington State University Cooperative Extension. This bulletin discusses procedures for sampling for nutrients.

  Soil Sampling. Bulletin 704. University of Idaho Cooperative Extension System. Good background on agricultural soil sampling.

  Soil Sampling for Nitrate Analysis. Oregon State University Extension Service. (Available in 2001). This bulletin is focused on sampling for soil nitrate.

  Managing Nitrogen from Biosolids. Publication # 99-508. Washington State Department of Ecology and Northwest Biosolids Management Association. This publication has a chapter on nitrogen analysis.

General Monitoring Considerations

All monitoring plans must address the following considerations:

Representative Sampling

The samples you collect must be representative of the medium you are monitoring (a stream at a specific location, soil in a field unit, etc.). To obtain a representative soil sample, for example, you need to define the sample area, and then collect multiple (15 or more) subsamples on a grid or in a more random pattern, avoiding atypical areas. The samples are then combined and fully homogenized to represent the field unit. A representative ground water sample may come from a single well, but the well needs to be pumped for a specified period of time to ensure collecting water that represents the aquifer at that location. Surface water samples must be paired; up and downstream samples must be taken at the same time to provide a basis for comparison.

Specific sampling instructions depend on the site and medium sampled. Be sure to consult with your regulatory authority to determine whether your site requires a sampling plan, and if so, what type of design is expected.

Timing

The timing of sampling is often critical. For example, post-harvest soil nitrate sampling must be done in the late summer or fall after plant uptake of N has slowed or ceased, but before fall rains leach nitrate through the profile. Stream sampling may focus on specific flow periods during the year.

Tools

Sampling tools must be capable of collecting a representative sample without contamination. For example, a representative sample for a 0 to 12-inch soil depth has the same amount of soil from the soil surface (0 to 6 inches) as from the bottom of the sampling depth (6 to 12 inches). A shovel is not an acceptable sampling tool, because it will skew the sample toward the shallower portion of the depth. Use a cylindrical soil probe, which is designed to collect a soil sample that is uniform with depth.

Containers

Containers must protect samples, and be inert to components in the samples. Appropriate containers vary, depending on the medium sampled and the purpose of the analysis (See Table 3-12 as an example). A bag may be a suitable container for a soil sample for nutrient analysis, while a water sample for coliform analysis will require a sterilized glass or plastic bottle. The laboratory providing the analytical service can provide guidance on container requirements, and may provide the containers as well.

Preserving, Handling, Storing, and Shipping Samples

In general, samples should be analyzed as quickly as possible. Appropriate handling, preservation, and storage methods and holding times vary widely depending on the specific type of sample. Consult your laboratory or refer to appropriate publications for specific recommendations. *Standard Methods for the Examination of Water and Wastewater*, for example, outlines methods for preserving, holding, and handling water samples for a variety of analyses.

Choosing a Laboratory

Choose laboratories that have experience with the types of samples that you are collecting. For example, use an agricultural lab for basic soil nutrient or soil nitrate analyses. A lab that does not run your type of samples routinely may not be set up to do the appropriate analyses. Ask the lab about their quality assurance / quality control program. Some labs participate in external quality assurance programs, such as the Western States Proficiency Testing Program for agricultural samples. Find out how the lab reports results, to see if they are consistent with any permit requirements or management needs. If you aren't familiar with the lab, it's a good idea to obtain a copy of a sample laboratory report. Some laboratories also have sampling and consulting services, which can be hired to help design and carry out a monitoring plan. Contact your local cooperative extension office for a list of laboratories serving agriculture.

Pre-application Monitoring

Pre-application soil and water sampling is seldom required as a matter of regulation, but is strongly recommended. Sampling before application can help to identify sites with high contaminant levels before biosolids are applied. It may be best to avoid these sites, unless biosolids are being used as part of a remediation project.

The following monitoring is suggested to document existing site conditions before biosolids application.

Soil: Trace Elements

Analyze the surface soil (0 to 1 foot) for trace elements: total arsenic, cadmium, copper, lead, mercury, nickel and zinc. Molybdenum and selenium analyses are expensive and are recommended only when site use in the past has been unusual (e.g., industrial site, chemical storage site) or when there are high levels of other trace elements.

Soil: Nitrate-Nitrogen

Test for soil profile nitrate-N to identify the amount of nitrate-N present from previous fertilizer applications (central and eastern Washington farmland only). Collect samples, in 1-foot depth increments, to the root-restricting layer (e.g., hardpan). Sampling depth will range from 1 to 6 feet, depending on soil type. Refer to the section on post-harvest (report-card) nitrate testing later in this chapter for guidance on sampling procedures.

The sampling depth used for pre-application nitrate monitoring is deeper than for post-harvest testing (described later in this chapter). The deeper sampling is needed to identify long-term accumulation of nitrate-N, due to pre-existing N management practices (e.g., application of too much fertilizer N, over-irrigation). If more N is applied over the years than is needed by the crop, and if there is not enough precipitation to move it out of the soil profile, it will accumulate deeper in the soil where roots are scarce.

Soil: Phosphorus

Testing for phosphorus can screen sites for those with excessive levels of plant-available phosphorus. Soils with excessive P levels pose a greater risk of surface water contamination from P in runoff and erosion. They are most likely to be found at sites with a history of manure application.

Sampling the 0 to 12-inch depth will give P levels that can be compared with agricultural soil test standards. Sampling the 0 to 2-inch depth may be the best for environmental testing, however, since it is the P in the uppermost layer of soil that is most likely to be lost through runoff or erosion.

Phosphorus testing protocols are likely to be included in nutrient management guidelines that are being developed by the Natural Resources Conservation Service (NRCS). These guidelines are for organic sources of nutrients, including biosolids, and will be available in 2001.

Some states use a P index to screen sites for potential environmental P risk. This index includes site and management factors in addition to soil test levels. Washington may adopt a P index as part of its nutrient management guidelines.

Contact the NRCS or WSU Cooperative Extension to find out the latest information on the P index and P testing.

Surface Water

Surface water is usually monitored only after biosolids application. Comparing pre- and post-application surface water samples is usually not valid because there are wide variations in water quality due to seasonal or other factors.

Groundwater

When possible, analyze domestic supply wells on or near the project site for nitrate-nitrogen and fecal coliform bacteria.

Monitoring Active Projects

Little monitoring is needed after application if there is a well-designed operations plan, thorough recordkeeping of biosolids application rates, and good management of the site.

Surface Water

To prevent contamination by biosolids, maintain adequate buffers between application areas and surface waters. In sensitive areas, surface water monitoring may be advised or required to demonstrate that biosolids applications are not affecting water quality.

A good monitoring system for surface water provides an estimate of how off-site factors affect water quality. The usual approach is to monitor points both upstream and downstream from the biosolids application site. Surface water contaminants can originate from domestic and wild animal waste and from failing on-site septic systems.

Basic measurements for surface water include ammonium-N, temperature, pH, and fecal coliforms. Ammonia is the most toxic form of nitrogen in surface water. Ammonia levels are derived from measurements of ammonium, pH and temperature.

Groundwater

Contaminants in groundwater reflect past activities, even activities from off-site. Therefore, groundwater monitoring may not tell you much about current activities.

Biosolids applied at agronomic rates should not affect groundwater quality. When required, monitor nitrate-nitrogen and fecal coliform bacteria in domestic water supply wells. If a detailed investigation of groundwater quality is necessary, a professional hydrogeologist should evaluate the site and design the sampling program.

Sometimes nitrate monitoring in and beneath the crop root zone is desirable to demonstrate that nitrate leaching is not degrading water quality. Nitrate monitoring may be appropriate on sites with high biosolids application rates. Soil sampling can be used at most locations (see the next section for details).

Use suction lysimeters for water sampling beneath the root zone on sites where soils are too rocky for routine soil testing. Only qualified personnel should install lysimeters, collect samples and interpret the data. The lysimeters must be located accurately to represent the site. Because of site variability, you may need many lysimeters to characterize water quality. Periodic sampling gives only snapshots of nitrate levels. The quantity of nitrate leached (lb nitrate-N per acre) cannot be calculated without an estimate of the volume of water moving through the soil.

Trace Elements

It is not necessary to monitor soils during the active life of a site for the trace elements regulated under the EPA 40 CFR Part 503. Variability in sampling and analysis usually obscures the small changes in soil concentration of trace elements.

As an example, consider a site where biosolids having 1000 mg/kg zinc is applied at 5 dry tons per acre and incorporated to a depth of six inches. This application adds 10 pounds of zinc per acre, and increases soil zinc concentration by about 5 mg/kg. Background soil zinc levels for most soils are about 50 mg/kg. It is almost impossible to detect a change of soil zinc from 50 to 55 mg/kg, because of sampling and analysis variability. Extensive risk assessments were conducted by EPA for all of the trace elements, and incorporated into the trace element limits in 40 CFR Part 503 (see Chapter 3). These assessments are more important for determining environmental or public health risk than are small changes in soil concentration over time. If needed, cumulative trace element amounts applied at a site can be calculated from records of biosolids application rate and biosolids trace element analyses.

Post-Harvest Nitrate-Nitrogen Soil Testing

Post-harvest soil testing is also called *report-card* testing. It helps evaluate how well the biosolids application rate matched the nitrogen needs of the crop. The report-card test identifies when excess nitrate-N is present, but it cannot determine the cause of the nitrate excess.

Use the test results as a tool in adjusting future biosolids applications and nutrient management at the site. The test is for agricultural sites only; it was not developed for forest sites.

Sampling Timing

The timing of this soil test is the key to its usefulness. Most of the release of available N from biosolids occurs within a few weeks of application, unless soils are cold or dry. The available N is then taken up by crops, with the most rapid uptake occurring in mid-season when the crops put on the most growth. As crops mature, they redistribute N internally and the uptake of soil N declines rapidly. At this point both the release of N by biosolids and the uptake of N by plants is low. Unused nitrate will remain in the soil until it is leached or denitrified by fall and winter precipitation (west of the Cascades). Where precipitation is low (east of the Cascades), much of the soil nitrate will carry over to the next cropping season, although it will leach deeper into the profile.

It is important to collect samples during the window between uptake and leaching. The best sampling time is from August 15 to September 30. Sample annual crops (e.g., silage corn) as soon as possible after harvest. For dryland sites harvested every two years, sample only in crop harvest years. Modify the biosolids application program based on test results.

Sample Depth

In many cases sampling the 0 to 12-inch depth is enough, but you will need to sample deeper in some situations. Basing interpretations on a shallow (12-inch) sample assumes that most of the nitrate is in the 0 to 12-inch depth, or that the shallow sample is a good predictor of nitrate in the rest of the profile.

The assumptions will not be valid if fall and winter rains leach nitrate deeper into the soil profile. If you delay collecting post-harvest report-card samples until October in most areas west of the Cascades, then you should sample in 12-inch increments at least to the 2-ft depth. Sampling later in the fall is not recommended because typical winter rainfall will leach nitrate out of the profile. Even if you collect report-card samples before much leaching occurs, it may be worthwhile to sample to 2 or 3 feet, to see how the distribution of nitrate in the profile compares with assumptions. This is most useful when a field has not been sampled previously below the 0 to12-inch depth.

In dryland areas east of the Cascades, winter precipitation leaches nitrate into the soil profile, but often much of the nitrate remains in the root zone, available for the next crop. In these cases sample the entire root zone (typically 3 to 6 feet) in 12-inch increments to determine pre-plant nitrate.

Refer to *Soil Sampling for Nitrate Analysis* (available in 2001), for more information on soil nitrate sampling and analyses.

Should Soils Be Tested for Other Forms of Nitrogen?

Other nitrogen tests include total N and ammonium N. You do not need to test for them routinely. Total N does not change much with time, and is not very sensitive to management. An initial sample may be useful for pre-application monitoring, but otherwise there is no need to measure total N.

Ammonium is converted rapidly to nitrate in warm, moist soils. Analyze for ammonium only if you have applied N to the field within the last 30 days, or if the soil has remained dry since application.

Converting Laboratory Analyses to lb/acre

Laboratory analyses for nitrate usually are reported in mg N / kg soil (parts per million). Converting mg / kg to lb / acre depends on soil bulk density. A typical bulk density for a loamy soil is 1.3 g / cm^3 (about 80 lb per cubic foot), and an acre-foot of this soil weighs about 3.5 million pounds. To convert from the nitrate-N content from mg / kg to lb / acre for a 12-inch soil sample, multiply by 3.5. Conversion factors for soils with other bulk densities are shown in Table 9.4. If you don’t know the bulk density of the soil, use 3.5 as a conversion factor. Table 9.5 shows a sample calculation.

Table 9.4. Bulk density conversion factors for determining soil nitrate N in lb/acre.

Estimated soil bulk density (g/cm^3)	Conversion from mg/kg to lb/a (for a 12-inch sample)
1.0	2.8
1.1	3.0
1.2	3.3
1.3	3.5
1.4	3.8
1.5	4.1

Table 9.5. Calculation example: How much nitrate-N in lb/acre is in the sampled depth of the following soil?

Depth (ft)	Bulk Density (g/cm^3)	NO_3-N (mg/kg)	Conversion (from Table 9.5)	NO_3-N (lb/acre)
0-1	1.1	15	3.0	45
1-2	1.3	4	3.5	14
2-3	1.3	3	3.5	11
Total				70

Here's a step-by-step description of the calculation that was made for one depth (0 to 12 inches) in Table 9.5. In the example, soil test nitrate-N (NO_3-N) for the 0 to 12-inch depth was 15 mg / kg (ppm), and soil bulk density is estimated at 1.1 g/cm^3. The calculated quantity of nitrate-N present (0 to 12-inch depth) is 45 lb / acre (15 x 3.0). The conversion factor (3.0) is for a soil bulk density of 1.1 g/cm^3 (from Table 9.4).

To calculate nitrate for a deeper sample (0 to 36-inch depth in Table 9.6), repeat the calculation process for each depth (0 to 12, 12 to 24, and 24 to 36 inches). Then sum the nitrate in each depth (45 + 14 + 11 = 70 lb nitrate-N per acre).

Guidance for Interpreting Report-card Nitrate Tests

Tables 9.6 and 9.7 contain interpretive information for evaluating report-card nitrate-N data. This information is based on a limited number of cropping systems. Comparing data with other report-card data from similar cropping systems can aid in interpretation. A number of variables affect soil nitrate levels, and the report-card test does not identify the cause of high or low nitrate levels in the soil.

Table 9.6 Suggested ranges for report-card soil nitrate-nitrogen analyses (sampled August 15 to September 30).

Range*	Nitrate-N for 1-ft sample (lb/acre)	Nitrate-N for 2-ft sample (lb/acre)
Low	0-15	0-25
Medium	15-55	25-75
High	55-105	75-150
Very High	>105	>150

*These ranges are based on a 1-ft nitrate-N content of <5 mg/kg for low, 5-15 mg/kg for medium, 15-30 mg/kg for high, and >30 mg/kg for very high. The ranges become wider as the nitrate-N level increases because variability increases with increasing nitrate content.

Table 9.7 Guidance for interpreting report-card ranges.

Range	Interpretation Guidance
Low	• Evaluate crop performance (actual yield vs. yield goal). If yield is below the goal, insufficient N may have limited yield. • Higher N application rates will not improve yields where pests, diseases, nutrient deficiencies or other limiting factors control crop productivity. • To improve yields, review and modify N management practices (rate, timing, placement) and irrigation water management. • If yields are adequate and irrigation is not excessive, the low nitrate levels reflect excellent management.
Medium	• Nitrogen application rate was adequate for the yield goal with little to moderate nitrate accumulation. • Continue current nitrogen application program next year.
High	• Considerable N was not utilized by the crop at the end of the growing season. • Evaluate N inputs and application calculations (biosolids, fertilizer, irrigation water, etc.). • Decrease N application rates or improve management of other nutrients, pests etc. to increase crop N removal.
Very high	• Major management changes may be needed. • Biosolids applications should not continue at the site during the next growing season. • Check agronomic rate assumptions and calculations.

Other Soil and Nutrient Analyses

Why Test for Unregulated Plant Nutrients?

Besides the soil nitrogen analyses needed to determine biosolids application rates (see Chapter 5), you should also consider crop and soil nutrient analyses to:

- Identify soil fertility problems that limit crop yield.
- Document benefits of biosolids applications.
- Compare treated and untreated areas.
- Evaluate soil phosphorus levels.

Soil Fertility Problems

Additional analyses may help identify soil fertility problems that limit crop yield. Examples include salinity, unfavorable pH and potassium deficiency. Biosolids will not correct these problems; rather, they must be remedied by management and/or other soil amendments.

Documenting Benefits

Sometimes pre- and post-application monitoring is used to document biosolids benefits. Soil tests will show changes in plant-available soil nutrients. Plant tissue tests show changes in crop nutrient content.

Making Comparisons

Soil and plant tests can be used to compare biosolids-treated and untreated areas within the same field. This is the best way to demonstrate the beneficial use of biosolids.

Evaluate Soil Phosphorus Levels

Repeated biosolids applications can increase soil phosphorus to excessive levels. A soil test program is a tool to help avoid excessive phosphorus applications, and apply biosolids P to sites where it is most needed.

Choosing Nutrient Tests

Before choosing a nutrient test, you should ask several questions:

- What does the test measure?
- Do data exist to interpret the results of the test?
- Are there specific sampling instructions?

What Does the Test Measure?

For a single nutrient, there are a variety of soil and plant tests, which can yield different results subject to different ways of interpretation. For example, different phosphorus soil tests can vary in many ways: (1) the composition of the extraction solution (water, salt, acid or base); (2) the concentration of the extraction solution (weak acid, strong acid, etc.); (3) temperature (room temperature, high temperature) and (4) extraction time (minutes or hours).

Each test will recover varying amounts of the total soil phosphorus. Individual test methods may be designed for specific situations, such as the separate P tests recommended for acid versus alkaline soils. There are also different analytical procedures for nitrogen, potassium, sulfur and the micronutrients in soils and plants.

Do Data Exist to Interpret the Results of the Test?

In cooperation with private industry agronomists, WSU Cooperative Extension has developed reliable soil and plant tissue testing methods for Washington crops. Growth trials have analyzed the relationship between the measured soil (or plant nutrient content) and crop yield; this is known as test calibration. These trials are conducted over many years and on many soil types.

Some private agronomists have developed valid soil and plant tissue test calibration data for specific crops in specific geographic areas of the state. Tests that lack calibration data are difficult to interpret and should not be used.

Are There Specific Sampling Instructions?

Soil Sampling

Soil sampling methods affect how results are analyzed. For instance, specific soil sampling depths are recommended for certain crops. If comparisons will be made over time, or between treated and untreated areas of a field, the soil sampling depth must be consistent.

Recommended procedures for soil sample collection also vary with the kind of crop (e.g., perennial vs. annual) and with cultural practices (e.g., irrigated vs. dryland). General procedures for soil sampling are outlined in university extension publications (Table 9.8).

Plant Tissue Sampling

When sampling plant tissue, several variables influence nutrient concentrations, including crop, plant part (leaf, petiole, or whole plant) and sampling date. For valid comparisons, sampling methods must again be consistent.

Table 9.8 Examples of university publications on soil testing and plant tissue testing.

Soil Testing	
Bulletin 704	Soil sampling (Idaho)
EC 1478	Soil test interpretation guide (OSU)
PNW xxx	Soil sampling for nitrate analysis (OSU, available 2001)
WREP 0009	Principles of soil sampling for Northwest agriculture (WSU)
Plant Tissue Testing	
WREP 43	Critical nutrient ranges in Northwest crops (WSU)
EB 0757	Critical nutrient ranges in Washington irrigated crops (OSU)
For more information, visit the WSU publications web site at caheinfo.wsu.edu, the OSU web site at eesc.orst.edu or the Idaho web site at info.ag.idaho.edu. Or contact: Bulletin Office, Cooperative Extension, Cooper Publications Building, Washington State University, Pullman, WA 99164-5912; (509) 335-2857. Publication Orders, Extension and Station Communications. Oregon State University, 422 Kerr Administration. Corvallis, OR 97331-2119; Fax (541) 737-0817.	

Recommended Nutrient Tests

Plant Tissue Testing

In the past, plant tissue testing has been used to determine whether in-season N applications were needed for high-value irrigated crops. There is limited data for low-acreage specialty crops (e.g., hops), dryland crops and nutrients other than N. You can obtain interpretive guides for plant tissue testing from WSU Cooperative Extension Publications (Table 9.8).

Soil Testing

Different soil testing laboratories may use different testing procedures, and test results from one lab can change if a new method is adopted. You must know which method was used when comparing test results. Appropriate soil fertility tests for Washington soils are given in Tables 9.9 and 9.10.

Interpreting Tests

There are three ranges for interpreting nutrient test results: low, marginal and adequate.

Low Range

In this range, nutrients are deficient and must be added to reach maximum yield.

Marginal Range

Test values border between low and adequate ranges. You may need to add nutrients to reach maximum yield. Base nutrient application decisions on economics (the cost of fertilizer inputs and the value of the crop). Applying non-mobile nutrients (e.g., phosphorus, potassium, some micronutrients) will usually have a long-term benefit.

Adequate Range

In this range, there are sufficient nutrients. Applying nutrients beyond the crop requirement is not necessary but will probably not reduce crop yield. However, applying nitrogen beyond the crop requirement can reduce crop yield and quality, and increase the risk of nitrate leaching. High surface soil phosphorus levels may increase P in runoff and cause pollution of receiving surface waters.

Table 9.9 Recommended tests for soil pH, nitrogen, phosphorus and potassium analyses.

Name/ Nutrient	Abbr. Name	Soil pH	Extractant Name	Importance/Use	Units	Determination
pH			1:2 soil:water	Log scale. pH 5.5 to 7.5 best for most crops. Affects microbial activity, nutrient solubility.	none	pH meter
Nitrate-N	NO_3-N		Potassium chloride	Plant-available nitrogen	mg/kg	Distillation or colorimetry
Ammonium + Ammonia-N	NH_4-N + NH_3-N		Potassium chloride	Plant-available nitrogen.	mg/kg	Distillation or colorimetry
Phosphorus*	P	below 7	Bray 1 (dilute-acid fluoride)	Index of plant available P. Must have field calibration data to interpret.	mg/kg	Colorimetry
Phosphorus*	P	below 7	Morgan (sodium acetate)	Index of plant available P. Must have field calibration data to interpret.	mg/kg	Colorimetry
Phosphorus*	P	above 7	Olsen (sodium bicarbonate)	Index of plant available P. Must have field calibration data to interpret.	mg/kg	Colorimetry
Potassium	K		Ammonium acetate	Exchangeable or plant-available K. Must have field calibration data to interpret.	mg/kg	AA or ICP

Determination: AA = atomic absorption spectrophotometry, ICP = inductively coupled plasma.

*Use a P soil test calibrated for local crops and soils. Consult university fertilizer guides or qualified agronomists for guidance.

Table 9.10 Recommended tests for other soil analyses. Request these analyses only when necessary. Professional assistance may be required for test interpretation.

Name/ Nutrient	Chemical Name	Soil pH	Extractant Name	Importance/ Use	Units	Determination
Cation exchange capacity	CEC		Ammonium acetate pH 7	Soil capacity to hold cations	meq / 100g	AA or ICP
Exchange-able bases calcium, magnesium, potassium, sodium	Ca, Mg, K, Na		Ammonium acetate pH 7	Same procedure as for CEC above. Need for Mg and Ca on acid soils. Sodium hazard on irrigated soils.	mg / kg or meq / 100 g	AA or ICP
Organic matter	OM		Walkley-Black (oxidation by dichromate) or loss on ignition	Used to estimate annual plant-available N released from organic matter. Indicator of general soil condition.	percent by weight or mg / kg	Colorimetry or weight loss
Lime requirement		< 6.5	SMP buffer	Quantity of lime to apply on acid soils to grow crops sensitive to soil acidity.	tons pure calcium carbon-ate per acre	pH meter
Electrical conductivity			Saturated paste	Salinity hazard on irrigated soils	mmhos / cm	Conductivity
Micro-nutrients	Zn, Cu, Fe, Mn	> 7.0	DTPA, pH 7.3	Need for micronutrients on sensitive crops. Must have field calibration data to interpret.	mg / kg	AA or ICP
Boron	B		Hot water Azomethine-H	Need for B for legume crops. Must have field calibration data to interpret.	mg / kg	Colorimetry
Sulfate sulfur	SO_4-S		Calcium phosphate	Need for S fertilization. Must have field calibration data to interpret.	mg / kg	Ion chromato-graph, turbidimetric

Determination: AA = atomic absorption spectrophotometry, ICP = inductively coupled plasma.

Chapter 10

Biosolids Composting

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Overview

The goal of biosolids composting is to produce a material that meets Class A pathogen reduction requirements, and is desirable for distribution and marketing.

Composting is a controlled, aerobic process that breaks down organic materials. Just as in the digestion process for biosolids, microorganisms use the organic material for food, changing it to a different chemical form. Composting can generate enough heat to kill pathogens and meet Class A pathogen reduction requirements. State and federal regulations govern composting operations to prevent environmental and health problems at the composting site and from compost use. This chapter outlines:

- Benefits and costs of biosolids composting.
- The composting process.
- Pathogen reduction and vector attraction reduction requirements for biosolids composts.

This chapter is an introduction to issues relevant to regulation and use of biosolids compost. It is not a comprehensive discussion of biosolids composting. It does not discuss siting, planning, or operation of compost facilities. Nor does it discuss control of odors or runoff. Refer to the Washington State Department of Ecology Publication 97-502, *Compost Facility Resource Handbook*, for a detailed discussion of regulations and guidance for compost facilities in Washington State. For information on compost quality, refer to the Washington State Department Ecology Publication 94-38, *Interim Guidelines for Compost Quality*.

Benefits and Costs

When evaluating biosolids composting, consider the benefits and costs listed in Table 10.1.

Benefits

After composting, the final product is more stable, releasing nutrients more slowly than biosolids. The compost can be stored for long periods of time and will retain its quality, if protected from the weather. In some cases, extended storage of the product by the producer (but not purchasers or users) may result in a regulatory requirement for retesting the material. Consult the Department of Ecology if in doubt. The composting process also reduces odors, resulting in a product with a pleasant earthy smell.

Table 10.1 Benefits and Costs of Composting

Benefits	Costs
Composting Process	
• Can meet Class A requirements for pathogen reduction. • An alternative to land application of biosolids during winter months. • Can provide an alternative for recycling other solid wastes used for bulking or feedstocks (e.g., yard debris).	• Potential for odor complaints at compost facility. • Site acquisition and development. • Bulking agent • Compliance with solid waste regulations (due to use of feedstocks and bulking agents such as yard debris). • Facility operation.
Compost Product	
• Revenue from product marketing. • Less odor in finished product. • Excellent soil conditioner. • Can provide a tangible benefit to local taxpayers. • Educational tool to raise public awareness of biosolids reuse.	• Cost of marketing and production. • Transportation costs.

Class A compost has a wide range of horticultural and landscaping uses. It can be distributed to the public, and it has no access restrictions when used in public contact areas such as parks. Biosolids compost also is an excellent material for land reclamation projects, but it may command a higher price in urban markets. Recent research shows that compost can suppress certain soilborne plant diseases, another selling point for the product.

Costs

Composting costs include site acquisition and development, facility operations, regulatory compliance, and marketing of the finished product. The facility must be approved by the local health department. Additional requirements may include land for buffers around the compost facility, site preparation, and handling equipment such as shredders, screens, conveyers, and turners. Facilities and practices to control odors, leachate, and runoff are a critical part of any compost operation.

Do not underestimate the amount of planning and effort needed to produce high quality compost. Successful composting requires active hands-on management. Improperly planned or managed operations may not produce a Class A material, and they are more likely to cause odors that are offensive to neighbors.

The Composting Process

Composting involves several phases, including feedstock preparation and mixing, high-rate decomposition, stabilization, curing, screening, storing, and marketing. The success of a composting process depends on managing the following factors and keeping them in a desirable range for each phase of the process.

- C:N ratio
- Particle size and porosity of feedstocks
- Moisture
- Aeration
- pH
- Temperature

Refer to the following publications for details on the biology of composting and how to manage each phase of the composting process.

Compost Facility Resource Handbook. Washington State Department of Ecology Publication # 97-502. 1998.

Composting Facility Operating Guide. The Composting Council. Alexandria, VA. 1994.

The On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service. Cornell University. Ithaca, NY. 1992.

Feedstocks for Biosolids Compost

Liquid and dewatered biosolids are too wet for composting alone. They are mixed with bulking agents such as wood chips, straw or yard debris (ground tree and shrub trimmings) to reduce moisture, increase porosity, and provide a more desirable C:N ratio for composting. A mixture of digested biosolids and wood chips may not have enough of the easily degradable carbon compounds (volatile solids) that act as an energy source for composting. Higher energy materials such as yard debris or manure may need to be added. Adding these materials, however, may affect the C:N ratio, porosity, or moisture content. Operators should anticipate the need to experiment with different feedstocks and management strategies before finding the one that works best for their case.

Composting Methods

Following is a brief introduction to the composting methods most commonly used for biosolids. Any of these methods can produce a compost that meets Class A pathogen reduction standards as a Process to Further Reduce Pathogens (See Tables 3.1 and 3.3, and the section on Pathogen Reduction below).

Windrow Method

This is the simplest method with the lowest start-up costs. Raw materials are blended and formed into long, linear mounds (windrows) that are up to 9 feet high and 18 feet wide at the base. To meet pathogen reduction standards, the compost must be turned (see Pathogen Reduction Requirements below). The size of the mounds depends on the raw materials and the type of turning equipment used — for example, front-end loaders, tractor-pulled turners or large self-propelled turners. Material on the outer layer is eventually mixed into the center where it will be exposed to high temperatures. The active composting stage lasts from three to nine weeks.

Some windrows are aerated using a blower system with aeration ports embedded in the pad. This keeps the windrow supplied with oxygen and can reduce odors. Time, temperature, and turning requirements for pathogen reduction are the same for simple windrows and aerated windrows.

Aerated Static Pile Method

This method also uses piles but does not require turning. Instead, the pile is built over a base of porous materials such as wood chips. A perforated pipe in this base is attached to a blower, which pushes or pulls air through the pile for aeration. Some facilities have aeration pipes and ports built into the underlying concrete pad. The piles are typically five to eight feet high, and ten to sixteen feet wide. The length of the pile depends on blower capacity. The blower should maintain even air flow through the pile.

Since the pile is not turned, you must be sure the initial mixing of the materials is thorough. Covering piles with finished compost or another insulating material is essential to achieve the required minimum temperatures throughout the pile. When air is pulled through the pile, odors can be controlled by venting the system through a pile of cured compost, which acts as a biofilter. Operating the blower intermittently leads to more uniform composting because air and moisture will equilibrate in the pile when the blower is off. You should monitor temperature and oxygen throughout the composting process and adjust the aeration schedules accordingly. The same principles apply for aerating a windrow. Although pathogen reduction can occur within a few days, it takes much longer to produce a finished compost. The active composting period is from three to five weeks.

In-vessel Composting

These are enclosed, aerated containers that allow composting under controlled conditions of temperature and aeration. Large vessels were once used, but during the 1990s the technology has shifted to smaller vessels (typically 30 to 100 yard volume).

Other Methods

The U.S. EPA has established specific time, temperature, and operating requirements for producing Class A biosolids compost (see below). You can produce Class A compost using methods other than those described above. Any variations, however, must be approved as part of the permit review, through a special process called Pathogen Equivalency Determination. You must provide a thorough justification of any alternative proposal to Ecology and the local health department, and gain written approval through the permit process to proceed. A determination of equivalency is made by the U.S. EPA, and can be a time-consuming and costly task for the producer.

Pathogen Reduction and Vector Attraction Reduction

Pathogen Reduction Requirements

Composting can be used to meet the Environmental Protection Agency's Class A or B pathogen reduction requirements. The cost of the composting process, however, will not justify the production of a Class B product. A Class B compost should be viewed as a failed batch and be reprocessed to achieve Class A standards. Following are Class A requirements for biosolids compost produced by the standard composting methods (static aerated pile, windrow, or in-vessel).

Time and Temperature Requirement (PFRP: Table 3.3)

Using either the in-vessel composting method or the static aerated pile composting method, maintain the temperature of the biosolids at 55^{o}C or higher for three days.

Using the windrow composting method, maintain the temperature of the biosolids at 55^{o}C or higher for 15 or more days. During the period when the temperature is maintained at 55^{o}C or higher, turn the windrow at least five times.

Testing Of Finished Compost

Fecal coliform levels must be below 1000 most probable number (MPN) per gram of total solids; or salmonella levels must be below 3 MPN per 4 grams of total solids. As part of obtaining permit coverage, you must develop a sampling program to demonstrate that your facility meets these standards. Sampling must be representative of the finished product and should be done close to the time of sale or distribution. Several samples will be required. Remember, the goal is not simply to meet a regulatory standard, but to demonstrate to your customers – the public – that the product you market is safe for use where people will be in close contact with it.

Vector Attraction Reduction Requirement

As described in Chapter 3, vector attraction is the attraction of rodents, flies, mosquitoes or other organisms that can transport pathogens. Vector attraction reduction must be achieved during the composting process. Following are the requirements for vector attraction reduction during composting:

Time and Temperature Requirement (Table 3.6)

Maintain at least fourteen consecutive days residence time at temperatures greater than 40^{o}C, with average temperature greater than 45^{o}C. Pathogen reduction must occur at the same time as or before vector attraction reduction is complete.

Summary

Composting is a good alternative for processing biosolids from small or large wastewater treatment plants. The compost site must meet facility standards, and the compost process must meet requirements for pathogen reduction and vector attraction reduction. Several methods can be adapted for biosolids composting. Composting is more expensive than some alternatives, but the product has a higher market value and is more versatile than biosolids liquid or cake.

Chapter 11

Land Application Plans

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Introduction

The purpose of planning is to ensure that biosolids application programs are designed and managed properly. Plans help anticipate costs and problems, avoid pitfalls, improve efficiency, stay on top of regulatory requirements, and provide guidance for project managers and workers.

Written land application plans are part of the General Permit requirements for all projects using biosolids that do not meet exceptional quality standards (WAC 173-308-310). Plans are not generally required for projects using exceptional quality biosolids, but formal planning may still be valuable. For exceptional quality biosolids, managers may want to develop internal plans that focus on the key elements of their projects.

This chapter provides guidance for preparing written plans. It includes information required for the General Permit as well as planning guidance that goes beyond the minimum regulatory requirements. For the specific minimum regulatory requirements, see WAC 173-308-310.

Site Specific Land Application Plan

The biosolids management regulations (Chapter 173-308 WAC) require site-specific land application plans as part of a complete application for coverage under the statewide General Permit for all sites where non-exceptional quality biosolids will be applied. If specific sites have not yet been identified, then you must submit a general land application plan (described in Chapter 2).

Key elements of the site-specific plan are:

- Past biosolids applications
- Crop management
- Agronomic rate calculation
- Method and timing of biosolids applications
- Monitoring
- County location and water resource inventory area
- Biosolids storage

- Site maps (with details)
- Groundwater management plan
- Restriction of public access

You should also consider the following additional planning elements:

- Transportation and delivery
- Site management and administration
- Reporting

This section gives guidance for addressing the elements of the land application plan. In some cases this guidance goes beyond the minimum regulatory standards. Although you must address each of the main elements of the plan, the specific approach is flexible, as long as you meet the intent of WAC 173-308-310.

The Department of Ecology or the local health department will review and approve your plans. This review may lead to changes and accommodations necessary to ensure proper management of biosolids at each application site.

Past Biosolids Applications

- Note whether or not biosolids with trace element contents exceeding any value in Table 3 of the federal or state rules (see Chapter 3, Table 3.9) have been applied to the site in the past (if known).
- If so, note the dates and amount of application, trace element content of the biosolids, and area where the biosolids were applied (if known).

Crop Management

- Describe crop rotations, tillage practices, harvest frequency and methods, and intended use of crop.
- Show how the biosolids management plan relates to any other existing Natural Resources Conservation Service farm plans (e.g., organic nutrient management, irrigation water management, or crop residue management plans).

Agronomic Rate Calculation

- Provide an example of your calculation method (worksheets are in Chapters 5 and 7.) If you do not follow the procedures in these worksheets, or modify the factors used in the worksheets, provide justification for your approach.
- Provide documentation to support yield and nitrogen need estimates used in the calculations. When available, include records of past yields at the site.

Method and Timing of Biosolids Application

- Supply a schedule that relates biosolids application to tillage, planting, grazing (if applicable) and harvesting of the crop.
- When possible, identify application equipment (manufacturer and model).
- Estimate the accuracy of the application equipment (percent error) and the range of application rates the equipment can deliver.
- Describe how the biosolids application equipment will be calibrated and how application rates will be verified.
- Soil incorporation: List the incorporation equipment and the planned interval between application and incorporation.
- Explain the expected effects of the application method on soil compaction and erosion by wind and water.

Monitoring

Pre-application Monitoring

- Report any soil, ground water, or surface water monitoring done within the last two years. See Chapter 9 for a discussion of pre-application monitoring.

Site Monitoring

- Describe monitoring to occur during the life of the project. This includes any monitoring required by Ecology or the local health department.

County and Water Resource Inventory Area

- Contact the regional Ecology office or your local health department to determine the water resource inventory area of your proposed site.

Biosolids Storage

The General Permit for biosolids management has only basic requirements for biosolids storage (Section 8.7 of the General Permit). The information below provides additional guidance for making storage plans.

Storage Management Practices

Describe how management practices will:

- Protect surface water and groundwater.
- Keep odors and other nuisances to a minimum.

Planned Storage Facility

These are guidelines for describing the storage facility and plans, including:

- Solids content of the stored biosolids.
- When it will be used, and for how long.
- Distance to residential and commercial areas, and major roads.
- Distance from storage to application sites.
- Storage capacity.
- Management practices to control runoff and leaching.
- Control of nuisances such as dust, mud, vectors and odor.
- Method and equipment for removing biosolids.
- Environmental monitoring.

Engineering Plans

Engineering plans may be required, depending on the size of the storage facility and the risk to groundwater and surface water.

Site Maps

Include enough maps so the reader can clearly identify the proposed site. This should include:

- A vicinity map, showing transportation routes, access and the locations of application fields.
- Individual field maps showing storage and application areas, wells, surface water, buffers and other significant features. Note streams, lakes, wetlands and intermittent streams on the map. Note widths of buffers and number of acres to be used for application. Also note location of critical areas in growth management plans (Chapter 36.10A RCW), wellhead protection areas, Shoreline Master Program areas, and critical habitat for endangered species.
- Map showing site topography.
- Property ownership maps, including ownership, zoning, and use of adjacent properties.
- Soil maps for each field (Natural Resources Conservation Service).

Site Characteristics

The following information is useful for supplementing site maps. You can get this information from local well logs, the NRCS soil survey and other local sources.

<u>Summary of Local Soil and Watershed Information</u>

- Summarize your conclusions about site limitations and suitability.
- Describe major surface water drainage patterns, and proposed management practices that will control surface runoff.
- Describe groundwater depth and quality.

<u>Soil Limitations</u>

Examples of soil limitations are slope, infiltration and permeability.

- List the predominant soil mapping units for each site as shown in the NRCS soil survey. Include NRCS soil maps for each field.
- Include map unit descriptions for each mapping unit.
- Note the expected soil limitations.
- Describe the methods used to overcome these limitations.

Irrigation and Drainage systems

Describe these systems and the management practices that will protect surface and groundwater quality.

For irrigation systems, include:

- Type of system (sprinkler, furrow etc.).
- Typical rate and frequency of irrigation.
- Management practices that will control irrigation runoff.

For artificial drainage systems, include:

- Location of major drainage lines.
- Condition and maintenance of the drainage system.
- Location of outlets to surface water.

Groundwater Management Plan

- Note if the seasonal high groundwater level is expected to be within 3 feet of the surface at any time during the year.
- If groundwater is expected to be within 3 feet of the surface, develop a groundwater management plan (General Permit, section 8.3). In the plan, explain how groundwater will be protected. (This can include information on rate and timing of application, type of crop grown, and irrigation and drainage).

Restriction of Public Access

- Describe whether or not it is likely the public will have access to the site.
- Include a drawing of signs that will be posted at the site (See WAC 173-308-275).
- Describe the size and location of signs.
- If signs will not be used, describe how access will be restricted.

Transportation and Delivery

Requirements for transporting biosolids are covered in section 8.6 of the general permit. The following section includes planning guidance for transportation and delivery.

Proposed Haul Route

Describe the suitability of the route, in particular:

- Is the road stable enough for truck traffic?
- Is the route accessible during bad weather?
- Is the route close to residential or business areas?
- At what time during the day will the route be used?
- What is the estimated number of trips per day?

Alternate Haul Routes

- If applicable, describe alternative routes and their suitability.

Vehicles

Describe the vehicles that will be used to haul biosolids, including:

- Load capacity.
- Features that control spills.
- Procedures to clean vehicles if they will be used to transport crops.

Spill Response

- Describe the spill response plan and plans for notifying Ecology in case of a spill during transportation.

Site Management and Administration

Biosolids Application Monitoring

- Describe how the biosolids application equipment will be calibrated.
- Note the frequency and method used for determining the percent total solids.

- Describe the record keeping system for biosolids applied per acre.
- List the frequency and person responsible for monitoring site buffers.
- Describe the planned remediation measures if biosolids are applied to buffer areas.

Contingency Plans

- Describe the operations plan for bad weather, accidents, and breakdowns.
- List phone contacts for emergencies.
- Show that the necessary equipment is available to respond to an emergency.

Responsibilities

List name and phone number for those who are responsible for:

- Transportation and delivery of biosolids.
- Biosolids storage.
- Biosolids application, including calibration and adjustment of application procedures.
- Site management and recordkeeping.
- Soil incorporation of biosolids.
- Monitoring site buffers.
- Collection of samples for environmental and public health monitoring.
- Laboratory analyses of environmental samples.
- Reporting to regulatory agencies.

Reporting

- List the regulatory agencies that will receive the reports.
- List required elements of the reports.
- Note the due dates for the reports.

Chapter 12

Record Keeping and Reporting

Table of Contents

Introduction

Records are the documentation necessary to show that biosolids managers are meeting regulatory requirements. Record keeping varies depending on the responsibilities of the biosolids manager (preparing biosolids, applying biosolids to land, distribution and marketing) and the type of biosolids (exceptional quality or not). Large facilities must submit annual reports that include most of the required records. Small facilities may also be required to submit these records in some cases. This chapter summarizes record keeping requirements and provides references to record keeping information in the other chapters of the Biosolids Management Guidelines.

Person Who Prepares Biosolids

Records Tracking How Biosolids Were Used

- Amount of bulk biosolids sold or given away for land application projects not under the direction of the preparer or their agent.
- Amount of biosolids sold or given away in a bag or other container
- Amount of biosolids distributed in the form of compost (this includes only the amount of biosolids used, not the total amount of compost product)
- Amount of bulk biosolids applied to land under the direction of the preparer or their agent
    - Agricultural land
    - Forest land
    - Land reclamation site
    - Public contact site
    - Lawn or home garden
- Amount of biosolids disposed in a landfill
- The amount of bulk biosolids that are sold or given away by the preparer to another person who prepares biosolids for application to the land (such as Class B biosolids delivered to a composting facility, or biosolids transferred from one treatment plant to another).

Biosolids Quality and Treatment Records

Bulk Biosolids

- **Trace elements:**
  Laboratory analysis data to verify that biosolids meet EPA Table 1 or Table 3 limits. See Chapter 3 for information on sampling, analysis, and documentation.

- **Pathogens:**
  Laboratory analysis and / or process monitoring data to show that Class B or Class A criteria were met. See Chapter 3 for information on sampling and documentation for pathogen reduction. A description of the process used to meet pathogen reduction is also required (Chapter 3).

- **Vector attraction reduction:**
  Laboratory analysis and / or process monitoring data to show that vector attraction reduction criteria were met. Vector attraction reduction records also must include a description of the process used to meet the criteria (Chapter 3). When vector attraction reduction is met in the field by tillage or injection, the person who applies the biosolids is responsible for documentation and record keeping.

- **Nitrogen:**
  Laboratory analysis data showing content of total N and ammonium N (and nitrate N if required) in biosolids.

- **Certification statements:**
  Appropriate certification statements in WAC 173-308-290 must accompany records.

Biosolids Distributed in a Bag or Other Container

Requirements are similar to bulk biosolids, except that records must show that the biosolids met Class A pathogen reduction requirements and vector attraction reduction requirements before they were distributed.

Person Who Applies Biosolids

These records are only required for biosolids that do not meet exceptional quality standards, unless specifically requested by the regulatory authority.

- Description of how site and access restrictions were met. This includes waiting periods for harvest of crops and public access, and buffer requirements. See Chapter 4 for details on access and buffer requirements. The information in Chapter 4 is valid for agricultural, forestry, rangeland, land reclamation and public access site applications.
- If vector attraction reduction requirements are met at the time of application (injection or tillage) include a description of how they were met.
- If any trace element concentration is greater than EPA Table 3 limits (see Chapter 3), keep the following records indefinitely:
  - Site location
  - Area of biosolids application
  - Date, rate, and location of biosolids applications
  - Cumulative amount of each element applied

  See Chapter 9 for record keeping for daily biosolids applications and Chapter 5 for calculating cumulative loading rates of trace elements.
- Certification statements:
  Appropriate certification statements in WAC 173-308-290 must accompany records.

Agronomic Rate Records

Maintaining agronomic rate records allows you to document that applications have met agronomic rate requirements. The worksheet in Chapter 5 is useful for keeping calculation records, and Chapter 9 outlines procedures for keeping track of applications on a field by field basis.

Site Monitoring Records

The regulations do not give specific requirements for record keeping for other environmental and public health monitoring. The regulatory authority will determine any additional record keeping requirements on a case-by-case basis. You may be required to monitor soil and/or water and keep additional records, depending on the conditions of your permit coverage (see Chapter 9). Even if there are no additional record keeping requirements, you should retain copies of all laboratory reports for soil and water monitoring taken during the life of the project.

Chapter 13
Septage Management

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Definition of Domestic Septage

Domestic septage is the liquid or solid material removed from a container that receives *only* domestic sewage; e.g., a septic tank, holding tank, portable toilet, Type III marine sanitation device or similar treatment works. Domestic septage can include material from businesses if it is of domestic quality. Septage that is not of domestic quality is not covered by these guidelines.

Class I, II, and III Domestic Septage

The Department of Ecology defines three classes of domestic septage depending on its source and degree of stabilization. Class I domestic septage comes from devices that typically are pumped at long intervals, such as septic tanks. The septage is largely stabilized from its long residency in the tank. Class I septage can contain as much as 25% Class II material, or as much as 25% restaurant grease trap waste.

Class II septage comes from devices that are pumped frequently, such as portable toilets, holding tanks, pit or vault toilets, or Type III marine sanitation devices. This material is only partially stabilized.

Class III septage includes material from septic tanks, cesspools, or similar devices serving businesses, as long as the septage is of domestic quality. This includes septage from businesses producing only domestic quality bathroom and kitchen wastes, or septic tanks receiving only domestic quality wastes. Class III septage does not include other commercial or industrial wastes.

Overview of Septage Regulations

Regulations for land application of domestic septage vary, depending on:

- The type of septage (Class I, II, or III) and how it is treated.
- Where the septage will be applied.
- The design application rate (agronomic vs. standard EPA septage calculation).

This chapter contains guidance for septage applications on sites such as agricultural and forest lands, when application rates are consistent with the standard EPA septage calculation method presented later in this chapter. Most septage applications will fall under these guidelines.

If you apply septage at a rate that exceeds the rate allowed by the standard EPA septage calculation, you must monitor and manage the septage according to regulations for biosolids (not as septage). Refer to the rest of this publication for guidance.

Do not apply domestic septage to a public contact site such as a park, or distribute it for home or garden use, unless it meets all the treatment requirements for exceptional quality biosolids. In those cases it must also be managed and monitored as biosolids.

Comparing Septage with Biosolids

In many ways domestic septage is similar to municipal biosolids: its biological, chemical and physical properties are similar, and it also benefits crops. Land application of both septage and municipal biosolids are covered by the same federal and state regulations. There are, however, some important differences between septage and municipal biosolids, which can affect land application programs.

Dispersed Production

Septage production is widely dispersed. It is pumped from many individual septic tanks across an area, is handled by different pumpers and haulers, and may be treated and applied to the land at many different locations. Careful record keeping and reporting are essential for a successful land application program.

Composition

Septage composition is affected by its source:

- Class I and Class III septage are similar to municipal biosolids. They have been partially broken down and stabilized by the bacteria that live in the septic tank — a process that is similar to biosolids digestion.
- Class II septage usually has had little time to be digested. It is more like raw sewage than municipal biosolids. Stabilization and site requirements are more stringent for this material than for Class I or III septage.

Even Class I septage can vary widely in composition, depending on household habits, appliances and the amount of solids that have accumulated in the tank at the time of pumping. Tables 13.1 and 13.2 show mean and range data for septage composition: Table 13.1 data is from several sources, Table 13.2 data is from a few samples collected at Whidbey Island.

The data show that septage samples can vary by an order of magnitude or more in solids content, BOD and nutrient levels. The mean values are similar across the different data sets. Mean trace element levels in septage (data not shown) are similar to or slightly lower than typical levels found in municipal biosolids.

Table 13.1 Selected physical and chemical characteristics of septage[1,2]

	United States			Europe & Canada	EPA Design Value
	Mean	**Min.**	**Max.**	**Mean**	
	---------------%				
Total Solids	3.4	0.1	13.0	3.4	4.0
	---------------mg/L				
TSS[3]	23,000	350	71,000	31,000	25,000
BOD[3]	6,500	440	79,000	8,300	7,000
Total N	588	66	1,060	1,060	700
NH_3-N	97	3	116	----	150
Total P	210	20	760	155	250
Grease	5,600	200	23,000	----	8,000

[1]Data are reported on a wet basis.

[2]Source: Septage Treatment and Disposal. USEPA 625/6-84-009. US data summarized from 12 references, European and Canadian data from 6 references. Number of samples analyzed was not reported.

[3]TSS is total suspended solids; BOD is biochemical oxygen demand.

Table 13.2 Selected characteristics of Whidbey Island septage[1]

	Mean	Max.	Min.	EPA Design Value[2]
	%			
Total Solids	2.4	5.8	0.4	4.0
	mg/L			
BOD	5,400	12,000	1,200	7,000
Total N	917	1,470	490	700
NH_3-N	308	516	98	150
Total P	218	370	25	250

[1]Based on analyses of six samples, reported on a wet basis.

[2]Source: Septage Treatment and Disposal. USEPA 625/6-84-009.

Regulations

Regulations for the land application of domestic septage are similar to those for municipal biosolids. Both are covered under the same federal and state regulations and guidelines for soil and crop selection, soil criteria, site management, buffers and storage. Refer to the following biosolids guidelines when planning for the land application of septage:

- Overview of regulations (Chapter 2)
- Site selection (Chapter 4)
- Crop selection (Chapter 4)
- Timing of applications (Chapter 6)
- Soil conservation (Chapter 6)
- Site monitoring (Chapter 9)

There are important differences between septage and municipal biosolids regulations. These include:

- Requirements for pathogen reduction and vector attraction reduction
- Monitoring requirements for nutrients and metals
- Physical screening
- Application rate calculations
- Waiting periods and restrictions on public access
- Buffers to surface water

Pathogen and Vector Attraction Reduction

Class I and III Septage

Class I and III septage are considered to be adequately stabilized for land application, when certain management and access restrictions are observed. Vector attraction reduction requirements are met either by alkaline treatment or by injecting or tilling into the soil.

Alkaline treatment reduces the numbers of pathogenic and odor-producing microbes in the septage by subjecting the septage to high pH. *Enough lime must be added to maintain the pH at 12 for at least 30 minutes, and the septage must be tested to check that this pH has been maintained.* If the septage is being managed as municipal biosolids, more stringent alkaline treatment requirements will apply.

Because alkaline treatment destroys only microbes — not organic matter — odors may return after several weeks. Therefore, alkaline treatment may not control odors when septage is stored for more than a short time before land application. Sites receiving alkaline-treated septage must meet all biosolids requirements for waiting periods for food crops (see pg. 13-10 and 13-11).

If Class I or III septage is not lime-treated, it must be injected into the soil or tilled into the soil within 6 hours of application, to provide a barrier to vector attraction. Sites receiving septage treated in this fashion must meet all biosolids requirements for waiting periods for crop production and public contact (see pg. 13-10).

Class II Septage

Class II septage is mostly unstabilized material, and is not considered suitable for direct application to the land. Before land application, Class II septage must be treated to meet at least Class B pathogen reduction standards (digestion, class B alkaline treatment, composting etc.), or be analyzed to demonstrate that it meets Class B standards for fecal coliform density. Vector attraction reduction is accomplished through alkaline treatment, soil injection, or soil incorporation. When batches of Class I septage contain less than 25% Class II material treat the entire batch as Class I. The more stringent requirements for Class II apply when a load or batch contains more than 25% Class II material.

Monitoring

Monitoring Quality

If septage is lime-treated, monitor every batch to make sure that alkaline treatment requirements are met. Those requirements are described on pg. 13-5. Septage managers do not have to measure septage nutrients and metals, as long as they base land application rates on the standard EPA calculation described on pg. 13-8.

If septage is managed as biosolids derived from municipal sewage sludge, then all applicable requirements for monitoring biosolids derived from municipal sewage sludge (including nutrients and trace elements) must be met. This approach will generally not be practical except for relatively sophisticated septage operations. For cases where a septage handler or jurisdiction chooses to measure septage nutrients and trace elements, it is easiest to sample at a treatment or storage facility. This material is a mixture of loads collected over time, which represents overall septage quality better than would individual truckloads. When handling and analyzing septage samples, follow the guidelines for municipal biosolids (see Chapter 3).

Estimating Quantity

If you need to estimate septage production in an area, the EPA has developed a planning formula based on published septage production data:

> Estimated volume = (population using septic systems) x (60 gal / person / year)

This formula provides a starting estimate for septage volume. More accurate estimates can be made by analyzing actual septage pumpouts. By keeping central records on pumpouts, you can determine local annual septage volume, seasonal trends and daily peak volumes. By knowing this information, it will be easier to plan septage treatment and handling facilities, and estimate the needed acreage for land application.

Keeping Records

The person who is responsible for applying domestic septage to land is also responsible for maintaining application records. Required records include:

- Septage source and class. These can be basic business records or receipts documenting the source, volume, and class of septage loads.
- Septage treatment and site management used to meet pathogen reduction and vector attraction reduction requirements. This includes a certification statement as described in the state regulations.
- Site description and application records. This includes the location of the site, acreage of the septage application area, the annual (365-day) nitrogen requirement of the crop grown on the site, the date of each septage application, and the amount of septage applied to the site each year.

Preventing Contamination

Domestic septage can become contaminated if it is mixed with commercial or industrial wastes. Septage from commercial or industrial sources can be applied to land under these guidelines *only* if it is known to come from septic tanks that receive only domestic-quality sewage (Class III septage). It is essential that pumpers and haulers exercise good judgement and discretion when collecting septage from these sources. When in doubt, do not pump the source or accept a load of septage until the quality can be verified.

Physical Screening

Septage must be physically screened or ground before land application. The purpose of this treatment is to remove or pulverize trash and other recognizable materials, so that debris in the septage is not a nuisance or eyesore after it is applied to land. Screening is preferred to grinding because it removes debris such as plastic that should not be disposed on the land.

Application Rate

The EPA has developed a rate calculation for septage applications that can be used without measuring the nutrient content of the septage. The rate calculation is conservative however, and will probably not provide the full N requirement of the crop, especially if pH adjustment is used (which results in a loss of ammonia nitrogen). This is because the EPA considered not only the agronomic rate but also the underlying risk assessment for the federal biosolids rule in developing the septage equation. For this reason, septage applications are more suitable for sites where peak productivity is not a major concern.

Use the following equation to calculate the maximum application rate by the EPA method:

$$AAR = N / 0.0026,$$

where AAR is the annual application in gallons per acre per 365-days, and N is the amount of nitrogen needed by the crop in pounds per acre per 365 days.

Table 13.3 shows the highest annual septage rates calculated from the equation. If you use this table, you do not need to analyze the septage for nutrients or trace elements. Remember that the rates in this table may not supply the full N requirement of the crop.

You can also calculate a site-specific agronomic application rate using the worksheet in Chapter 5. If you choose this method, you will need to analyze the septage for both nitrogen and trace elements, and you will need to meet all other requirements for land application of biosolids. This approach will generally not be practical except for relatively sophisticated septage operations. If you store, or further process septage before land application (such as with alkaline treatment or lagoons), it could be to your advantage to manage the septage to meet all requirements for land application of biosolids. Often this will allow you to apply more material per acre than when using the standard EPA septage equation.

*Table 13.3 Annual application rates of septage based on crop nitrogen requirement. **

Nitrogen Application Requirement	Septage Application Rate	Septage Application Rate
lb N / year	Thousand gal / acre / year	Acre inch / year
20	8	0.3
40	15	0.6
60	23	0.9
80	31	1.1
100	38	1.4
120	46	1.7
140	54	2.0
160	62	2.3

*Source: 40 CFR Part 503.13. This table based on EPA application rate equation for septage *that has not been analyzed:*

$$AAR = N / 0.0026,$$

where AAR is the annual application in gallons per acre per 365-day period; N is the amount of nitrogen in pounds per acre per 365 days needed by the crop

If septage analysis is performed, use the worksheet in Chapter 5 to calculate application rates.

Timing and Storage

Septage applications should be managed to benefit crop production and reduce the risk of leaching and runoff. This becomes a greater challenge when septage is applied during the winter. If winter applications are part of a septage management program, follow the guidelines in Chapter 6, so that they will be done in an environmentally sound manner.

There are times and places when septage cannot be applied because of field conditions. For example, the soil may be frozen or too wet for application, or the timing may not be right to meet crop needs or fit in with field operations. Septage can be stored, composted or taken to a wastewater treatment plant during these periods.

Waiting Periods and Restrictions on Public Access

Harvest restrictions for food crops prevent the spread of pathogens. The following restrictions apply for septage:

- Do not harvest any crop for at least 30 days after application of septage to the land.
- If harvested parts are above the ground and touch the soil (e.g., squash, lettuce or strawberries), crops cannot be harvested until 14 months after septage application.
- If harvested parts are below the ground (e.g. carrots and potatoes), crops cannot be harvested for 38 months after septage application. If the septage remains on the surface for 4 or more months before incorporation, then the harvest restriction is reduced to 20 months.

These additional restrictions apply when alkaline treatment is not used:

- Animals cannot graze for 30 days after septage application to forage.
- Turf cannot be harvested from turf farms for 1 year after septage application when used for home lawns or any area with a high potential for public exposure.
- Public access is restricted for 1 year in areas with a high potential for public exposure, and for 30 days in areas with a low potential for public exposure.

Although these additional restrictions do not apply to septage that has been treated with lime, good management may require waiting periods for these applications. For example, application to forages should take place after harvest or grazing, but before regrowth of the crop. The crop should be allowed to regrow before turning animals into the field again.

Requirements for posting sites to restrict public access are the same as for Class B biosolids (WAC 175-308-275).

Buffers

The minimum buffer distance to surface water for septage applications is 100 feet. All other minimum buffers are the same as for Class B biosolids (Chapter 4). For special situations, buffers may need to be larger; at all sites they must be large enough to protect receiving waters.

Appendix 1

Proposed EPA Regulations for Dioxins

Why Regulate Dioxins?

During the late 1980s and early 1990s, EPA conducted surveys and analyzed data of pollutants in biosolids from treatment works around the country. Data from treatment works across the U.S. and information on several hundreds of potential pollutants were evaluated, resulting in regulation of nine metals in biosolids under the Part 503 rules. This is often referred to as Round I of the 503 rule.

During the 1990s EPA did additional screening of 31 pollutants that they had identified for further evaluation. Through this Round II screening they pared the list to polychlorinated dibenzo-p-dioxins / dibenzofurans (collectively referred to as dioxins or dioxins and furans), and dioxin-like coplanar polychlorinated biphenyls (PCBs). The EPA then completed a risk assessment for these compounds and developed the proposed regulation described below.

What Are Dioxins?

Chlorinated dioxins are by-products of certain manufacturing processes and incomplete combustion of organic waste. Small amounts of dioxins enter the wastewater stream from a number of diffuse background sources. Toxic chronic effects from dioxins have been observed at very low doses compared with other materials.

For the purpose of the proposed regulation, dioxins include 29 compounds, consisting of 7 polychlorinated dibenzo-p-dioxins, 10 polychlorinated dibenzofurans, and 12 coplanar polychlorinated biphenyl compounds. These compounds are similar in that they all have a multi-ring structure, a planar (flat) shape, and the lateral positions on the multi-ring structure are substituted with chlorine atoms. The planar shape and chlorine substitution make these compounds biologically potent at low concentrations.

Toxic effects include both cancer and non-cancer effects. The effects are generally chronic, meaning they result from long term exposure over years and decades.

What Is the Proposed Regulation?

Based on risk assessment studies, EPA has proposed a numeric limit of 300 ng toxic equivalency (TEQ) per kg dry biosolids. (One ng/kg is one part per trillion.) The TEQ is calculated by multiplying the concentration of each of the 29 compounds by its toxic equivalency factor, and summing the result. The EPA has proposed that the 300 ng/kg TEQ be the Ceiling Limit for biosolids (EPA Table 1). Material that contains more than 300 ng/kg TEQ will not meet biosolids criteria, and will not be suitable for land application.

The acceptable level of dioxins in the environment has become a subject of intense national debate. The numeric limit for biosolids will likely be evaluated further, and may change from the proposed level described here.

Who Has to Monitor for Dioxins, and How Often?

Under the proposed regulation, wastewater treatment plants with a wastewater flow of more than one million gallons per day, and biosolids production facilities that prepare more than 290 dry metric tons per year of biosolids must analyze their biosolids for dioxins. Annual analysis will be required initially. If dioxin levels are less than 30 ng TEQ/kg biosolids for two consecutive years (10% of the Ceiling Limit), plants will only need to analyze for dioxins once every five years. Because dioxins come from diffuse sources, large variations in concentration are unlikely, and analyses can be done less frequently when levels are low.

Wastewater treatment plants with flows of one million gallons per day or less, and biosolids production facilities that produce 290 metric tons per year dry solids or less are proposed to be exempt from dioxin monitoring.

When Will the Regulations Become Effective?

EPA published the draft regulations in December, 1999, and has requested comments on the proposal. The final regulation may differ from the proposal, based on comments received and new information on dioxin risk. EPA plans to have the dioxin regulations incorporated in 40 CFR Part 503 by December 2001.

Appendix 2

Calculating Geometric Means

To demonstrate that biosolids meet class B pathogen reduction standards, biosolids managers must document that fecal coliform densities are less than 2,000,000 most probable number (MPN) or 2,000,000 colony-forming units per gram of total solids. This standard must be achieved by calculating the geometric mean of seven representative samples. Fecal coliform levels can vary by an order of magnitude or more from one sample to the next. A geometric mean is the most reasonable representation of coliform levels when such variability occurs. This appendix explains how to calculate geometric means.

We are all familiar with simple arithmetic means (averages). You begin with a set of measurements (e.g. 2, 4, and 8), add them (sum = 14), and divide by the number of values in the set (14 / 3), giving a mean value of 4.67.

A geometric mean is not much more difficult. It involves determining an arithmetic mean (just like above) *for the logarithms* of your sample values. For those who are familiar with them, logarithms make it easier to work with very large (or very small) numbers.

Logarithms are simply exponents. If we express a number in exponential form (e.g. $100 = 10^2$), then 2 is the common (base 10) log of 100. Similarly the log of 1000 is 3 ($1000 = 10^3$), and the log of 10,000 is 4 ($10000 = 10^4$). The log of 66,271 is 4.8213 ($66{,}271 = 10^{4.8213}$). A scientific calculator or computer spreadsheet will convert a number to its common logarithm.

To calculate a geometric mean, convert each value to its common logarithm and add the logarithms together. Next, compute the mean by dividing the sum of the logarithms by the number of samples. The result is an average logarithmic value.

The last step is to convert the logarithmic value back to the original form. This is called the anti-logarithm and is the reverse of the conversion to a logarithm. Recall from above that the logarithm of 100 is 2. The anti-logarithm of 2 is 100. Scientific calculators or computer spreadsheets will determine anti-logarithms, using an anti-log, power or exponent function.

Example: Calculating the geometric mean of seven fecal coliform measurements.

Sample #	Fecal coliform (MPN/g)	Logarithm
1	700,000	5.8451
2	1,500,000	6.1761
3	400,000	5.6021
4	4,500,000	6.6532
5	6,000,000	6.7782
6	2,200,000	6.3424
7	1,900,000	6.2788
SUM	17,200,000	43.6759

Arithmetic mean of logarithmic values = 43.6759 / 7 = 6.2394

Geometric mean = Anti-logarithm of 6.2394 = 1,735,459

Appendix 3
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