Ontario Forest
Industries Association

GUIDELINES FOR THE UTILIZATION OF PULP AND PAPER MILL BIOSOLIDS IN SILVICULTURE AND LAND RECLAMATION

In Association with:

DR. THOMAS E. BATES
and
LAFLEUR DE LA CAPITALE INC.

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WATER & EARTH SCIENCE ASSOCIATES LTD.

GUIDELINES FOR THE UTILIZATION OF PULP AND PAPER MILL BIOSOLIDS IN SILVICULTURE AND LAND RECLAMATION

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PREFACE

This report, entitled "Guidelines for Utilization of Pulp and Paper Biosolids in Silviculture and Land Reclamation," and its technical annex, were prepared for the Ontario Forest Industries Association by Water and Earth Sciences Associates Ltd., in conjunction with Dr. Thomas E. Bates and Lafleur de la Capital Inc.

The purpose of the report is to provide guidance for the development of pulp and paper biosolids application programs, and for the development of associated requests for Ministry of Environment (certificates of) approval.

The MOE and the MNR supported and encouraged development of pulp and paper biosolids guidelines, with the understanding that the guidelines may be in part or in whole incorporated into MOE policy. However, while the guidelines have been made consistent with Ministry policy, it should be noted that at this point the guidelines have not been adopted by MOE.

Craig Gammie
OFIA

January, 2000

1.0 INTRODUCTION

Pulp and paper mills in Ontario generate approximately 350,000 dry metric tonnes of pulp and paper mill biosolids (PPMB) annually. In Ontario, as in most jurisdictions, the majority of PPMB are managed by landfilling at private facilities or by combustion. Biosolids are also sent to municipal landfills and increasingly greater amounts are being managed by land application on agricultural, silvicultural and land reclamation sites.

Pulp and paper mill biosolids are the solid residues from the treatment of wastewater from pulping, paper making and paper recycling operations. These materials are primarily composed of organic matter and contain some macro- and micro-nutrients that are beneficial to land application programs. PPMB are also relatively free of potential contaminants and pose a limited risk to the environment when applied in a controlled, well managed operation.

Because of the beneficial properties of PPMB, they should be considered as a potential resource to be utilized and not wasted. The advantages of using PPMB in a land application program include the following:

- increased productivity for agricultural crops and trees
- improved soil quality through the addition of organic matter
- improved soil structure
- reduced reliance on commercial fertilizers and herbicides
- reduced reliance on landfill disposal for materials with other uses
- economic development (ie., job creation)

1.1 PURPOSE

The purpose of these guidelines and the accompanying technical annex is to provide documents that establish a set of standards and management practices specific to the use of PPMB in silviculture and land reclamation sites in Ontario. It is intended that these guidelines will facilitate future approvals for land application sites from the Ontario Ministry of Environment.

1.2 SCOPE

The scope of these guidelines is limited to consideration of primary, secondary and combined (primary plus secondary) biosolids from pulp and paper mill wastewater treatment systems, and biosolids from de-inking processes. These guidelines do not consider other solid residues from pulp and paper mills (eg., lime rejects, wood waste, bark, etc.). Some of these residues, such as wood wastes, although designated as wastes, meet the criteria for exemption from the requirements of Part V of the *Environmental Protection Act* and Ontario Regulation 347.

These guidelines are also limited to the use of PPMB in silviculture and land reclamation applications. Agricultural land application of PPMB is being covered in a separate document currently in preparation.

The guidelines reflect considerations in the following areas:

- land productivity (soil quality, vegetation growth)
- protection of human and animal health
- protection of environmental quality

To be sustainable, an application program must provide benefits to the soil and vegetation on the land that the residuals are being applied to, and must not degrade the physical environment. The fundamental approach taken in developing these guidelines is that an application program should be designed to optimize the benefits to the soil and vegetation, rather than to maximize the disposal of unwanted solid residues. If PPMB are to be viewed as a valuable resource, the resource must be used wisely and in an environmentally sustainable manner.

1.3 LEGISLATIVE FRAMEWORK

In Ontario, PPMB are regulated as "processed organic wastes" in accordance with Ontario Regulation 347, made under the *Environmental Protection Act (EPA).* The biosolids can be utilized at "organic soil conditioning sites", which require approval under section 27 (Part V) of the EPA as waste disposal sites. Standards for the location, maintenance and operation of organic soil conditioning sites are specified in Ontario Regulation 347.

Prior to the use of an organic soil conditioning site, a Certificate of Approval (C of A) must be issued by the Ontario Ministry of Environment (MOE) upon application by a proponent and review of the application and supporting technical information by the MOE. The C of A usually contains specific conditions applicable to the site and its environs.

Processed organic wastes must be transported from the generator's facility to the land application site by a hauler who holds a valid Organic Waste Management System Certificate for the specific waste materials. These certificates are issued by the MOE under the provisions of the EPA.

Guidance regarding the characterization of biosolids (including sewage biosolids and other organic wastes), the assessment of receiving sites, and site operations is provided in the document entitled, *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land*, which was issued in March 1996 by the MOE and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Pulp and paper mill biosolids are considered as "other wastes" in the document.

An extensive knowledge base has been acquired for the utilization of PPMB in agricultural land applications, and the approval of organic soil conditioning sites for agricultural usage has now become fairly routine in Ontario and other jurisdictions. Considerable research and development effort has been expended by several forestry products companies regarding the use of PPMB in silviculture and land reclamation projects, particularly in Ontario (ie., the Niagara and Cornwall areas) and British Columbia, as well as in the United States (Maine, Washington and Wisconsin). However, such applications are not yet routine practice in Ontario.

2.0 BENEFICIAL USE OF PULP AND PAPER MILL BIOSOLIDS TO FORESTRY AND LAND RECLAMATION SITES

2.1 BENEFICIAL CHARACTERISTICS OF PULP AND PAPER MILL BIOSOLIDS

It has been demonstrated that, when properly managed, the application of PPMB to forest systems and land reclamation sites can provide benefits through improved production and soil health without adverse effects on the environment. Pulp and paper mill biosolids are rich in organic matter and contain moderate levels of nutrients suitable for plant fertilization. The materials also have the potential to improve soil properties, such as the organic matter content,

structure, water retention capacity, erosion control, and support for microbial populations. Primary clarifier fibre and other forestry residuals with high C:N ratios are also effective as mulches for weed and erosion control. As described in the following sections, PPMB may also contribute macro-, and micro-nutrients at levels that can provide long-term benefits to soil and plant productivity.

Pulp and paper mill biosolids can be produced and/or processed in the forms and quantities that are amenable to transportation, storage, and application at forestry and land reclamation sites. The PPMB can be dewatered and/or blended with other materials to a relatively high solids content (from 25-30% and greater), which make them suitable for conventional or easily modified haulage and spreading technologies.

2.1.1 Opportunities for the Beneficial Use of PPMB

The opportunities for the use of PPMB in forestry applications and land reclamation sites lie primarily in their ability to supply organic matter and nutrients to the soil and plants. Some examples of the various functions of PPMB at application sites include the following:

Soil Improvement

- increased organic matter
- improved water infiltration and retention capacity
- improved soil structure
- improved erosion control
- improved storage and cycling of nutrients
- support for a diverse microbial community

Plant Growth and Productivity

- better root penetration
- better air supply to roots
- better moisture supply
- supply of nutrients, with some in slow release, organic form
- pH adjustment

Weed Control

- reduced competition for tree growth
- reduced dependence on commercial herbicides

2.2 PLANT NUTRIENTS OF POTENTIAL BENEFIT AND ELEMENTS OF POTENTIAL CONCERN

Pulp and paper mill biosolids include a wide range of products with varying characteristics and composition. Detailed descriptions of the parameters of interest for forestry and land reclamation applications, as well as those parameters that could be of potential concern to the environment or plant growth, are presented in the accompanying technical support document. A brief summary of the parameters is provided in Table 2-1.

Table 2-1: Summary of Nutrients and Elements of Potential Concern

Parameter	Important Characteristics
Organic Matter	Soil quality
pH	Metals solubility and nutrient availability
Nitrogen	Macronutrient; Potential for leaching
C:N Ratio	Soil fertility; Ability to mineralize organic matter
Phosphorus	Macronutrient; Potential for runoff
Potassium	Macronutrient
Calcium	Macronutrient
Magnesium	Macronutrient
Sulfur	Macronutrient
Sodium	Soil salinity potential
Arsenic	Potential toxicity to plants & animals
Boron	Miconutrient; potential toxicity to plants
Copper, Zinc & Nickel	Micronutrients; potential toxicity to plants & animals
Molybdenum	Micronutrient; potential toxicity to plants & animals
Cadmium & Mercury	Potential toxicity to plants & animals
Lead & Chromium	Potential toxicity to plants & animals
Manganese	Micronutrient; potential toxicity to plants in acid soils
Aluminum	Potential toxicity and leaching from acid soils
Trace Organic Chemicals	Potential leaching

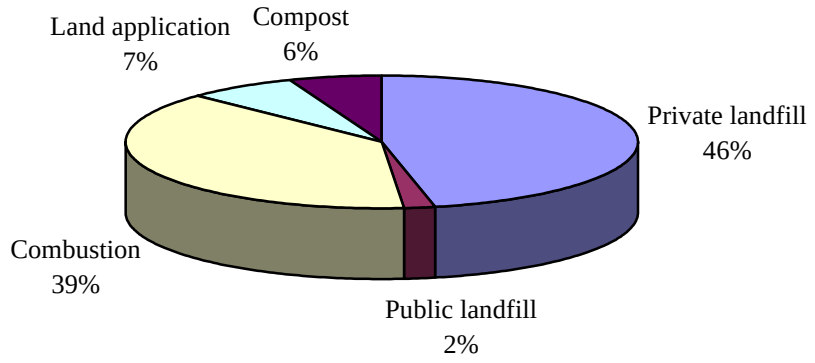
2.3 ALTERNATIVE MANAGEMENT PRACTICES

Pulp and paper mills in Ontario (35 mills in total) generate approximately 350,000 dry tonnes of PPMB annually, which represents 20% of the estimated annual PPMB generation of 1.7 million dry tonnes in Canada (OFIA, 1996; Reid, 1997). From information gathered in two 1996 surveys, the approximate distribution of PPMB generated in Ontario is as follows:

- Primary 25 – 45 %
- Secondary 16 % (the OFIA survey did not distinguish secondary biosolids)
- Combined 29 – 71 %
- De-inking 4 – 10 %

The majority of PPMB generated in Ontario are disposed at landfills (primarily privately-owned, with a small percentage sent to public sites), or by combustion as fuel in boilers at the mill sites. A small proportion of the biosolids are land applied; however, the percentage of land application appears to be increasing from year to year as the practice becomes more widely accepted. Recent data from 55 Canadian forestry product mills (Reid, 1997) indicate the distribution of selected management options for biosolids as shown below in Figure 2-1.

Figure 2-1: Selected PPMB Management Options in Canada (1996)



The data for Canada are believed to be fairly representative of Ontario conditions, except that the amounts of PPMB being land applied may be slightly higher, and the proportion being combusted may be smaller than the national average. The ultimate usage of the composted material is not described in the referenced report; however, it is assumed that the material will be land applied at various scales.

The reliance on landfilling as the predominant means of biosolids management reflects a continued perception of biosolids as unwanted residues that require disposal, rather than materials with intrinsic value to forestry and agricultural production. Certainly, the economics of land application versus landfill disposal play a critical role in the selection of residue management options. However, it has been demonstrated that land applications of biosolids to forests and land reclamation sites can be economically viable and environmentally sustainable when properly managed.

3.0 APPLICATION CRITERIA FOR FORESTRY AND LAND RECLAMATION SITES

The application of PPMB to forestry and land reclamation sites must provide benefits to soil quality and plant growth, without causing adverse effects to human and animal health, and the environment. The purpose of this section is to provide appropriate criteria for PPMB applications to forestry and land reclamation sites in order to achieve these objectives. A brief overview of forest productivity principles and land reclamation is presented first, followed by recommended application rates and management practices.

3.1 FOREST PRODUCTIVITY PRINCIPLES

As the demand for natural resources increases, there is an increasing need to carefully manage these resources to ensure that they are sufficient for future generations. In the case of a forest, it not only provides a source of lumber and pulpwood, it also provides wildlife habitat, recreational opportunities, and water retention, along with many aesthetic and psychological benefits.

Forests, whether natural or manmade plantations, require the same basic elements in order to grow and survive; adequate water, productive soil and sunlight. Climate also plays an important role in determining what tree grows where. In the case of a natural forest, these elements dictate the composition of tree and plant species within that environment. Natural forests consist of a variety of different species. It is this diversity that helps to protect the forest from insects and diseases.

In tree plantations, even though the same basic elements for growth apply, there are a number of factors which are quite different from the natural forest. Tree production in plantations follows many of the same principles as the production of an agricultural crop. The right tree planted in good soil, supplied with water and nutrients and protected from competing plants, insects and diseases will be healthy and produce vigorous new growth. The intent behind plantation tree farming is to maximize economic returns by encouraging trees to produce maximum biomass in the shortest amount of time on a given land area.

In a plantation, the trees have generally been planted in rows to facilitate efficient maintenance and harvesting. Competition from weeds and grasses is controlled either by chemical, mechanical, natural, or organic methods. Soil nutrients are sometimes augmented by applying fertilizers. Soil moisture is sometime conserved by amending the soil with organic matter and using mulches.

Plantations of trees differ from the natural forest in that they are usually intensively-managed, even-aged monocultures. Monocultures, unlike natural mixed-wood forests, can be more susceptible to insect and disease outbreaks and may require frequent applications of pesticides. However, with careful monitoring and sound maintenance practices, trees grown in plantations will usually outperform trees growing in the natural forest. As with any plant, if provided the necessary ingredients for healthy growth, it will have a stronger ability to resist attacks from harmful insects and diseases.

Trees grown in plantations, allow for efficient use of space, offer high quality fibre and wood, and simplify harvesting. Plantations also allow for experimentation with new fast-growing, disease resistant hybrids. Again, the goal is to reduce the time between planting and harvesting, thereby increasing the yield per hectare. It is shown throughout this guideline how the use of pulp and paper mill biosolids can aid in the production of plantation and nursery grown plant material.

3.2 LAND RECLAMATION

The disturbed land and mineral soil remaining after the extraction of aggregates or other surface mining or excavation activities is generally non-productive, highly erodable and unsightly. Current legislation in Ontario under the *Aggregate Resources Act* and the *Mining Act* requires the rehabilitation of surface openings following extraction of aggregates and minerals in order to return the land to some productive use. However, many historical gravel pits, quarries and surface mines have been left in a non-rehabilitated condition. These sites can benefit from applications of PPMB to return organic matter to the soil, supply the nutrients necessary for plant growth and control erosion. Other areas that can benefit from revegetation and stabilization using PPMB and other biosolids include construction sites, former roadways and landfill sites (Sopper, 1993; Macyk, 1998).

The potential for successful land reclamation using PPMB is largely related to its organic matter content, and the need for soils to increase their organic matter in order to achieve full ecosystem recovery after surface extraction. The long-term productivity of reclaimed land is dependent upon achieving an improved soil structure, stable carbon and nitrogen cycles, microbial diversity, fertility, and nutrient cycling (Sopper, 1993). In order to support vegetative growth, a minimum organic matter content in soils of 2% or greater is generally required.

3.3 RECOMMENDED CRITERIA AND PPMB APPLICATION RATES

The purpose of land application of PPMB to forestry and land reclamation sites is to enhance biomass productivity by improving soil quality. In order to be sustainable, applications must provide these benefits without adverse effects to the environment, human and animal health and soil productivity. The following criteria for proper PPMB land application are divided into three categories:

- Receiving soil criteria
- Biosolids criteria and recommended application rates
- Vegetation characteristics (eg., forested sites vs. land reclamation)

Recommended application rates will be controlled by criteria in these categories.

3.3.1 Soil Criteria

The following criteria apply to the forestry soils or land reclamation sites that are to receive PPMB soil amendments.

Soil pH

- Pulp and paper mill biosolids with metal contents exceeding the concentrations specified on Column 3 of Table 3-2 should not be applied to soils with a pH value below 6.0

Traditionally, sewage biosolids have not been allowed on agricultural land with a soil pH of less than 6.0 because most heavy metals are much more soluble and plant available at low soil pH. Agricultural soils are commonly limed to provide a pH of 6.0 or higher. However, many forest soils in the province are quite acidic and liming is rarely practiced.

If the metal concentrations in the PPMB are less than those specified in Column 3 of Table 3-2, they should be acceptable for application to acid soils (ie., pH less than 6.0) at the higher forestry rates because metal availability from these biosolids will not be critical. Pulp and paper mill biosolids with higher metal concentrations should be restricted to soils with pH values of 6.0 or higher. It is also noted that some PPMB have higher than neutral pH values, and may be of use in increasing the soil pH in acid soils.

Heavy Metals

- Pulp and paper mill biosolids with metal concentrations greater than Column 3 of Table 3-2 should not be applied to soils with mean metal contents greater than those listed in Column 3 of Table 3-1.

Metals such as copper, molydenum and zinc are required in small quantities by plants for proper growth and development. However, at certain soil concentrations, these and other metals can be toxic to plants and animals. The levels at which different metals become toxic may vary from site to site, and are not firmly established. Therefore, in order to prevent any toxic effects, the concentrations of metals in the soil must be maintained at acceptable levels, based on current scientific evidence. The metals concentrations presented in Column 3 of Table 3-1 have been established as the maximum acceptable metals concentrations in soil receiving biosolids containing significant concentrations of metals (ie., concentrations above those listed in Column 3 of Table 3-2).

Table 3-1: Criteria for Metal Content in Soils

1	2	3	4	5
Metal	**Mean Metal Content in Uncontaminated Ontario Soils (mg/kg)**	**Maximum Permissible Metal Content in Soils Receiving PPMB (mg/kg)**	**Maximum Permissible Metal Addition to Uncontaminated soil (kg/ha)**	**Maximum Permissible Metal Application per 5 year (kg/ha)**
Arsenic	7	14	14	1.4
Cadmium	0.8	1.6	1.6	0.27
Chromium	15	120	210	23.3
Cobalt	5	20	30	2.7
Copper	25	100	150	13.6
Lead	15	60	90	9
Mercury	0.1	0.5	0.8	0.09
Molybdenum	2	4	4	0.8
Nickel	16	32	32	3.56
Selenium	0.4	1.6	2.4	0.27
Zinc	55	220	330	33

Note: From Table 2 of *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA, 1996).

Organic Soils

- Pulp and paper mill biosolids should be applied to mineral soils, not to organic soils.

The primary benefit of PPMB applications to forest systems is the organic matter these materials supply. Organic soils, which are defined as soils of a minimum of 0.4 metres thickness consisting of 17% or more organic carbon content (approximately 30% organic matter) will not benefit from the addition of organic matter provided by PPMB, and a disruption of the natural nitrogen and carbon cycling patterns may result from PPMB amendments, particularly for high C:N ratio materials.

Phosphorus

- Pulp and paper mill biosolids high in phosphorus should not be applied to soils with an Olsen sodium bicarbonate extractable phosphorus concentration greater than 60 mg/L.

Phosphorus is an important plant nutrient, and PPMB can supply additional plant available phosphorus to soils, particularly secondary and combined biosolids (which often contain total phosphorus concentrations of 2000 mg/kg or greater). Primary biosolids generally contain much lower concentrations of total P (200 mg/kg or less).

High concentrations of extractable phosphorus in the surface soils can lead to nutrient loadings in surface water due to runoff and/or leaching to shallow groundwater. Soil concentrations of extractable phosphorus higher than 60 mg/L do not provide additional benefits to plant growth, and may result in impacts to surface water quality. Therefore, the above guideline provides an acceptable balance between beneficial use and potential environmental impact.

With the possible exception of forest nurseries, forest soils with concentrations of extractable phosphorus concentrations greater than 60 mg/L are very unlikely. Where high phosphorus soils do occur, applications of PPMB should be assessed on a site-specific basis regarding the amount of fertilizer equivalent phosphate that will be supplied by the biosolid. Additions of PPMB should be restricted to a phosphate application of 20 kg fertilizer equivalent P_2O_5 per hectare per year. With any application, the fertilizer equivalent PPMB phosphate should be subtracted from the amount of fertilizer phosphate that would be recommended for the plants if PPMB were not applied.

3.3.2 Biosolids Criteria and Application Rates

The main benefit of PPMB application to forest soils and land reclamation is usually the organic matter it supplies, although plant nutrients are also important in secondary and combined biosolids. Most soils, particularly marginal forest soils and areas of aggregate extraction, can benefit from large increases in organic matter content. As a result, there is commonly a desire, and need, to apply high rates of amendments to increase soil organic content as much and as quickly as practicable, without adverse effects to the environment.

In research trials, quite high rates of PPMB have been applied to soils without detrimental effects to plant growth, provided an appropriate balance of carbon and nitrogen was maintained. One of the more extreme examples of this is in nursery pot trials where shrubs grew as well or better where the potting mixture consisted of one-third PPMB than where it contained lesser amounts (Chong and Cline, 1993). It is clear that quite high rates of PPMB may be applied without negative effects on plant growth.

Pulp and paper mill biosolids produced in Ontario vary markedly in nutrient content, with most primary biosolids being very low in nitrogen and most other nutrients, and most secondary and combined biosolids being quite high.

The following criteria apply to the pulp and paper mill biosolids to be used for forestry and land reclamation undertakings.

Heavy Metals

- The concentrations of heavy metals in pulp and paper mill biosolids used in forestry and land reclamation programs should not exceed the concentration limits specified in Column 3 of Table 3-2.

Table 3-2: Criteria for Metal Content in Biosolids

1	2	3
	Biosolids and Other Wastes, Maximum Permissible Metal Concentrations	
Metal	**Present Requirement (mg/kg of solids)**	**Long-term Targets (mg/kg of solids)**
Arsenic	170	35
Cadmium	34	4
Cobalt	340	77
Chromium	2800	530
Copper	1700	380
Mercury	11	1.4
Molybdenum	94	1.2
Nickel	420	80
Lead	1100	220
Selenium	34	6
Zinc	4200	840
Boron	Boron does not provide long term pollution concerns like the metals listed above but it is toxic to plants at lower concentrations than any of the metals listed. The maximum boron application in biosolids is one kilogram per hectare per year.	

Note: From part of Table 1 in the Ontario Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land, March 1996.

Most PPMB have metal concentrations that are lower than the concentrations listed in Column 3 of Table 3-2. These are the long-term targets for heavy metals identified in the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA; March, 1996). When PPMB with metal concentrations less than those in Column 3, Table 3-2 are applied to forest soils and land reclamation sites, metal concentrations are not a concern and should not be a consideration in deciding the rates of application. Similarly, for those PPMB with metal concentrations less than those in Column 3 of Table 3-2, the metal concentrations should not be a restriction in assessing the metals concentration or the pH of the soils to which they may be applied.

Applications of PPMB with metal concentrations between the long-term targets (Column 3 of Table 3-2) and the present BUC aerobic biosolids requirements (Column 2 of Table 3-2) should be assessed for the potential metal loadings to determine whether the materials can be applied at reduced rates of application. The maximum permissible metal applications per five year period are listed in Column 5 of Table 3-1.

Pulp and paper mill biosolids with one or more metals present at concentrations greater than those specified in Column 2 of Table 3-2 should not be used in a land application program.

Boron

- Pulp and paper mill biosolids should not be applied at rates that supply more than one kilogram of plant available boron per hectare per year.

Boron can be toxic to plants at lower concentrations than any one of the metals listed in Table 3-2. To avoid phytotoxicity, the maximum recommended hot water soluble boron concentration in soil is 1.0 mg/L. Unlike the other metals listed in Table 3-2, boron tends to leach from the soil and is therefore more of a short-term problem to plant health, rather than a long-term soil accumulation problem.

Boron is also a relatively mobile element in groundwater, and is a potential contaminant to drinking water supplies, with a health-related Ontario Drinking Water Objective of 5.0 mg/L.

There are limited data available regarding boron concentrations in PPMB in Ontario; however, the available information indicates that boron concentrations, obtained from acid digest procedures, are generally below 10 mg/kg. In organic materials such as PPMB, particularly at pH values of 7.5 or higher, a fraction of the boron is insoluble and is not plant available. In soils, plant available boron is traditionally measured using hot water extraction procedures.

Boron concentrations in PPMB should be measured prior to forestry or land reclamation applications because of its potential toxic effects to plants. It is recommended that hot water extraction procedures be used for boron analyses on PPMB. In pit rehabilitation situations, the concentration of plant available boron in the PPMB should be considered when deciding on the rates of the initial application. If the plant available boron concentration is sufficiently low, it may not restrict the PPMB application rate. However, higher concentrations may be potentially toxic to plants and may affect the initial PPMB application rates.

Calcium, Magnesium and Sodium

- The sodium loadings from PPMB applications should not exceed the limits specified in Table 3-3.

Calcium and magnesium are plant nutrients that can be deficient in acidic soils (and magnesium occasionally in higher pH soils) in Ontario. Sodium, however, is not required for plant growth, and excessive sodium levels can cause long-term impairment to the soil structure. High sodium levels can impede water, air and root penetration.

Much of the soluble sodium will have been removed from PPMB during the dewatering process. Also, PPMB generally contain sufficient exchangeable calcium and magnesium to prevent problems associated with sodium. To prevent damage to soil structure, annual sodium loadings from PPMB in both forestry and land applications should not exceed the levels specified in Table 3-3.

Table 3-3: Sodium Criteria

Soil Texture	Annual Maximum Sodium Addition (kg/ha)
Sands, sandy loams	200
Loams, clay loams, and clays	500

Note: From *Ontario Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land (March, 1996).*

Trace Organic Compounds

- The PCDD/PCDF (polychlorinated dibenzo-p-dioxin / polychlorinated dibenzofuran) level of pulp and paper mill biosolids should not exceed 100 parts per trillion (ppt) I-TEQ (International Toxicity Equivalent factor).
- The PCDD/PCDF level of the receiving soil should not exceed 10 ppt I-TEQ.

Trace organic compounds in PPMB are not detectable or found at very low concentrations, in the order of parts per million. At such levels, trace organic compounds are not expected to pose any environmental impact from the utilization of PPMB. In fact, most organic contaminants of concern to health and the environment are not detected in pulp and paper mill biosolids (WTI, 1996).

The levels of dioxins and furans in pulp and paper mill biosolids are much less than those found in everyday materials such as plastic packaging and household dust (WTI, 1996). The MOE has reported a background value of 7 ppt I-TEQ in Ontario soils (MOE, 1997). The criteria specified above are used by the MOE for allowable dioxin and furan concentrations of solid residuals applied to land.

Nitrogen

Provided the heavy metal, boron and sodium concentrations are not exceeded in the PPMB applications, it can be expected that nitrogen will be the most critical factor controlling the application rate. Applications of PPMB exceeding the forest's or land reclamation site's ability to store and/or utilize the available nitrogen may result in the leaching of nitrate, with potential for adverse effects on groundwater. However, it must be recognized that the dynamics of nitrogen behaviour in forest ecosystems are not yet well understood, and remain the subject of considerable research effort (eg., Henry, 1997; Rowell, 1997; Van Ham, 1996).

Studies that have reported adverse groundwater effects from nitrate leaching in forest ecosystems (either natural or plantations) are generally restricted to higher total nitrogen loadings, ranging from approximately 1,000 to 18,000 kg-N/ha (eg., Bockheim et al, 1988; Brockway and Urie, 1983; Harrison et al, 1994; and Riekirt and Zasoski, 1979). Other studies on forest ecosystems in British Columbia, using municipal sewage biosolids and paper fibre at one-time application rates between 500 and 4,000 kg-N/ha have reportedly shown positive tree growth response with no apparent adverse effects to groundwater or surface water (personal communication, Michael Van Ham, 1998). Pulp and paper mill biosolids with low nitrogen contents and high C:N ratios have also been successfully applied in Ontario to forestry plantations at relatively high rates (212 to 424 dry tonnes/ha) for use as a herbicide substitute in weed control (Lo et al, 1998).

The recommended application rates for PPMB on forestry and land reclamation sites vary depending on the available nitrogen content, the C:N ratio of the biosolids, and the purpose of the application (mulch, fertilization, organic matter addition, etc.). The guidelines presented below are divided into several categories, representing the various functions that PPMB will be used for in forestry and land reclamation situations, and the different materials that are available (ie., a design-by-function approach).

a) Low Nitrogen, High C:N Ratio PPMB Incorporated into the Soil

Purpose of Application:

- organic matter addition
- excess nitrogen sponge effects
- subgrade preparation for land reclamation

In forestry and land reclamation projects, there are situations where it is desirable to apply and incorporate low nitrogen PPMB, with a C:N ratio in excess of 30:1 into the soil as a source of organic matter. Alternatively, the material may function as a "sponge" to immobilize excess available nitrogen in the upper soil horizon. In the context of these guidelines, this category of PPMB function is likely to include only primary biosolids (primary clarifier fibre).

Where there is established or new plant growth requiring available N, nitrogen must then be added to the PPMB application to bring the C:N ratio down to 30:1 in order to prevent nitrogen immobilization and nutrient deficiency in the plants. The exact amount of nitrogen required cannot be calculated exactly due to differences in PPMB and climatic effects; therefore, the following guideline is recommended:

- The application rate of any one high C:N ratio PPMB should be limited to that which would require 150 kg of nitrogen per hectare or less to bring the C:N ratio of the material down to 30:1.

The above guideline applies to high C:N ratio PPMB that are to be mixed with the soil and where available nitrogen is required for plant growth. The nitrogen required to reduce the C:N ratio can be mixed with the biosolids before spreading or added to the soil at the time of spreading.

Clearly, care must be taken when using high C:N ratio biosolids in these applications to prevent nitrogen immobilization. Due to their limited benefit as a fertilizer supplement, it is likely that forestry applications of primary biosolids will be restricted to other uses, such as mulches for weed and erosion control, and for moisture retention. Alternatively, the materials may be blended with higher nitrogen materials to increase their benefit.

Use of high C:N ratio PPMB to absorb excess available nitrogen in the soil should be assessed on a case-by-case basis, reflecting the site-specific conditions.

b) Low Nitrogen, High C:N Ratio PPMB Left on the Soil Surface

Purpose of Application:

- organic matter addition
- mulch applications (weed and erosion control, moisture retention)

Where high C:N ratio PPMB are applied to the soil and left on the surface as a mulch for weed and erosion control or moisture retention, the breakdown of the material will occur over several years. The nitrogen requirement for breakdown will be spread over that period, with a gradual decrease in the C:N ratio as the material degrades.

Experience with high C:N ratio biosolids in mulching applications has shown that the materials are highly effective for weed control with no negative growth response as long as the plant cuttings and roots have adequate contact with the natural soil. Some studies have used blended PPMB applications in mulch layers to ensure that there is adequate nitrogen for decomposition.

The following guidelines are recommended only for the use of PPMB with nitrogen contents less than 0.5% and C:N ratios greater than 100:1 in mulching and erosion control applications, where the material is to be left on the surface of the soil:

- The application rate of PPMB should be limited to only that required to effectively suppress weed growth, and at no time should the application exceed 400 dry tonnes/hectare.
- Supplemental fertilizer nitrogen may be required to prevent nitrogen deficiency in established or new plantations. The nitrogen requirements should be assessed by a professional forester.
- A minimum mulch thickness of 10 cm is recommended for effective weed and erosion control. The thickness of the mulch should be limited to only that required for the particular application.
- Plant cuttings and transplanted seedling roots should extend a sufficient distance (eg., 15 cm) below the mulch layer to ensure adequate contact with the native soil. The native soil should have sufficient organic matter and nutrients to sustain plant growth.

c) Low C:N Ratio PPMB Left on the Soil Surface or Incorporated into the Soil

Purpose of Application:

- organic matter addition with resulting soil structure improvement
- fertilization
- vegetative growth and development
- mulch applications
- erosion control.

The upper soil horizon in natural forests and silviculture plantations often has a high organic content and high C:N ratio. Initially, this will allow for significant amounts of the nitrogen mineralized from biosolids amendments to become immobilized again (Cole, 1997). However, when the immobilization capacity of the soil organic matter has been met, the application rates must be decreased or there may be losses of nitrate by leaching to the groundwater.

In situations of land reclamation, the mineral soil left exposed at exhausted aggregate extraction operations and open pit mines has very low levels of organic matter (less than 0.5%) and cannot sustain plant growth. By applying PPMB, a soil layer with sufficient organic matter can be produced to support vegetation within a short time. In the short term, high rate applications of PPMB are necessary to build an organic soil layer within a practical time frame. These are generally one-time applications, which can be followed by much lower rates of PPMB

fertilization to meet the plant nutrient requirements. The initial higher rates of application must be designed to control the amount and rate of nitrogen release to prevent adverse groundwater impacts on the application site. The use of blended PPMB's to provide the organic matter without excess nitrogen may be particularly appropriate to these situations.

3.3.3 Vegetation Characteristics

The third category is used to distinguish between forested sites and land reclamation sites.

a) Forest Fertilization Guidelines

- For pulp and paper mill biosolids with C:N ratios of 30:1 or less, the long-term sustainable application rate should be limited to that which supplies no more than the annual plant requirement of fertilizer equivalent nitrogen.

PPMB's in this category would include most, if not all, of the secondary and combined biosolids. The amount of PPMB to be applied in a particular situation (ie., in dry tonnes/ha) will depend on the nitrogen content of the biosolids and the annual plant nitrogen requirement. These requirements should apply whether the biosolids are incorporated into the soil or applied as a surface treatment.

Fertilizer equivalent nitrogen in the biosolids can be calculated as follows:

$$N_f = [NH_4^+] + [NO_3^-] + 0.1\,[N_{org}]$$
where $N_{org} = [N_t] - ([NH_4^+] + [NO_3^-])$

N_f - fertilizer equivalent nitrogen
NH_4^+ - ammonium
NO_3^- - nitrate
N_{org} - organic nitrogen
N_t - total nitrogen

This equation is based on considerable experience with agricultural wastes and sewage biosolids in Ontario. Similar data regarding pulp and paper mill residues are very limited. Research is currently being conducted in British Columbia on the dynamics of nitrogen mineralization in forest ecosystems; however, it is not yet at a stage where predictive models have been verified in field conditions (Doug Rowell, 1998, pers. comm.; Michael VanHam, 1999, pers. comm.) It is expected that the above equation would yield an upper limit estimate of fertilizer equivalent nitrogen derived annually from PPMB.

The above nitrogen limitations require some estimate of the nitrogen requirements of the trees to be grown. This may not be readily available in many forest situations; however, it is essential in order to make proper use of the organic matter and nutrients while protecting surface and groundwater from nitrogen impacts

High initial rates of PPMB applications can be assimilated by a forest or plantation ecosystem with a high C:N ratio organic soil horizon through nitrogen immobilization, storage and uptake. However, not all of the nitrogen dynamics of forest systems are understood at present, and it is apparent that in the long-term, a sustainable balance based on tree and understory nitrogen requirements must be achieved. A safe upper limit for the initial, one-time application of PPMB with a C:N ratio of less than 30:1 appears to be in the order of 1000 kg-N (total N) per hectare, for sites with good capacity for assimilation. However, the safe initial rate of PPMB application is highly dependent on biosolids characteristics, soil properties, site hydrogeology, vegetation type and age. Such applications must be assessed on a case-by-case basis with input from a professional forester. As a minimum, the following information is necessary for the assessment:

- PPMB characterization and test results (physical testing, organic carbon, nutrients (including total pH plus nitrate and ammonia) metals, trace organics))
- Soil testing results (soil type, texture, geochemical profile)
- Site characterization (land area, topography, drainage, groundwater conditions, adjacent land use, buffer zones, etc.)
- Vegetation (existing or proposed species, harvest cycle, maintenance program, weed control, etc.)

In addition, groundwater and surface water monitoring programs may be warranted on sensitive sites to assess the potential for water quality impacts.

b) Land Reclamation Guidelines

- For land reclamation sites, a one-time application of pulp and paper mill biosolids at a C:N ratio of 30:1, sufficient to increase the soil organic matter content in the upper 15 centimetres of soil to between 2% and 6% (% dry weight basis), could be applied. Prior to any application, a detailed site assessment should be conducted to ensure that the site is not particularly sensitive to potential groundwater impacts.
- Where warranted due to potential groundwater impacts identified in the assessment, primary clarifier fibre or other high C:N ratio material should initially be spread and incorporated into to the exposed mineral soil subgrade to provide organic matter and assist with immobilization of any excess mineralized nitrogen from the low C:N ratio material.
- Subsequent applications of pulp and paper mill biosolids should be applied at fertilization rates that do not exceed the plant nitrogen requirements.

The purpose of a land reclamation program is to return disturbed areas such as former gravel pits, quarries and open pit mines to productive use by rapidly establishing a soil layer with sufficient organic matter and available nutrients to sustain vegetative growth and reproduction. There is considerable experience in various European and North American jurisdictions, including Ontario, which has demonstrated that land application programs using municipal sewage biosolids and PPMB can be managed to reclaim land without adverse effects to the environment (Bending and Moffat, 1997; Hill et al., 1979; Sopper, 1993; WESA, 1998). Detailed monitoring of land reclamation sites amended with biosolids has shown that there is a potential for initial leaching of nitrogen compounds through the upper soil column, depending on biosolids N-loadings and site conditions. However, these concentrations return rapidly to background conditions, with no long-term impact to groundwater quality.

The potential short-term impacts to the shallow subsurface can be mitigated by adequate site selection and assessment, and by controlling the amount of available nitrogen introduced in the biosolids. This entails controlling the initial application of biosolids and ensuring that there is sufficient attenuation available through natural degradation processes, nitrogen immobilization and plant uptake. The use of high C:N ratio PPMB, such as primary clarifier fibre, below or mixed with the application of secondary or combined biosolids will assist in nitrogen immobilization and provide organic matter to the soil.

The PPMB being applied above the primary clarifier fibre should have a C:N ratio of less than 30:1 to ensure that there is adequate nitrogen mineralization for vegetation needs. Vegetation should be established as soon as practical after the biosolids are applied. With spring applications, this could frequently be during the same growing season.

Continued annual or bi-annual (once every two years) applications of low C:N ratio material is appropriate at reduced application rates as supplemental fertilizer for vegetation and to provide additional organic matter. The equation found in Section 3.3.3 (a) should be used to determine the fertilizer equivalent nitrogen. The rates should not supply more nutrients than required for the vegetation growth.

3.4 TIMING OF APPLICATIONS

3.4.1 Low Nutrient PPMB's (C:N ratios greater than 30:1)

Products which are very low in plant nutrients, such as most primary biosolids, are very suitable as mulches with little risk of nutrient runoff, even at high rates of application. Application of mulches is acceptable at any time of the year provided there is less than 15 cm of snow on the ground where it is to be applied, and when the soil is dry enough to prevent serious soil compaction during application.

PPMB's left on the surface can provide excellent soil protection. Fall application is particularly advantageous on erosion-prone soils to reduce early spring loss.

Where high C:N ratio PPMB's are to be incorporated into the soil, they can also be applied at any time the soil is dry enough to prevent serious compaction, and may be incorporated when the soil is dry enough to cultivate with light cultivation equipment. Late summer or fall application and incorporation of these materials may help to immobilize any excess nitrogen, which is frequently present on cultivated lands at this time of year.

Any supplemental nitrogen that is required with high C:N ratio materials to assist in decomposition should be applied the spring following incorporation to minimize the potential for nutrient leaching and runoff.

3.4.2 Moderate to High Nutrient PPMB's (C:N ratios less than 30:1)

These products, including secondary and combined PPMB's, can be applied and either left on the soil surface or incorporated. Generally, the rates of application will be limited by the material's fertilizer equivalent nitrogen concentrations and the nitrogen requirements of the forestry or land reclamation site. Spring and summer applications are preferred to make the best possible use of the nitrogen and to minimize nutrient losses. The sites should be dry enough at the time of application to prevent serious soil compaction and damage to tree roots.

3.5 SITE CRITERIA

In addition to the above criteria, which are intended to ensure appropriate application rates for PPMB applications to forestry and land reclamation sites, the following guidelines are provided for site assessment purposes. This assessment will minimize the risk of environmental impact to surface water, groundwater, wells and neighbouring land.

3.5.1 Separation Distances

Separation distances from the application area to potential receptors are required to reduce nuisance impacts and to prevent contamination of surface water and groundwater supplies. The required separation distances are presented in Tables 3-4 and 3-5. Reductions from these separation distances may be permitted on a case-by-case basis, depending on site-specific circumstances and the type of biosolids to be applied.

Separation from Surface Watercourses

- A minimum horizontal separation distance between the PPMB land application site and a surface watercourse should be maintained as specified in Table 3-4.

For the purposes of these guidelines, a surface watercourse is defined as a natural or established watercourse or an open municipal drain along which water flows on a continuous or intermittent basis. In addition, ponds, lakes, springs, wetlands, and points of direct access (such as catch basins for drainage tiles or municipal drains) should be treated as watercourses for purposes of determining separation distances.

The separation distances presented in Table 3-4 were developed taking into account land slope and soil permeability (MOE / OMAFRA, 1996). Reduced separation distances may be appropriate under the following circumstances:

- receiving sites are dry and incorporation is within 24 hours (applicable only to PPMB with C:N ratios less than 30:1);
- there are site features, such as berms, natural ridges, etc., to prevent the direct movement of PPMB to watercourses;
- the receiving site and/or the surrounding watercourses are vegetated in a way that will prevent or inhibit precipitation from washing PPMB residues into watercourses.

However, under no circumstances should PPMB be applied or stored within 10 metres of any surface watercourse.

Table 3-4: Separation Distances between Application Area and Surface Watercourses

Maximum Sustained Slope	Soil Permeability	Separation Distance for High Nutrient, Low C:N PPMB* (metres)	Separation Distance for Primary PPMB (metres)
0 – 3 %	Rapid to Moderately Rapid	50	10
	Moderate to Slow	100	20
3 – 6 %	Rapid to Moderately Rapid	100	20
	Moderate to Slow	200	40
6 – 9 %	Rapid to Moderately Rapid	150	30
	Moderate to Slow	Not permitted	50
> 9 %	All permeabilities	Not permitted	50

Note: * This category includes secondary, combined and de-inking residues.

Soil permeabilities to be determined in accordance with OMAFRA's Drainage Guide for Ontario. Soil types to be determined from site testing or from County Soil Maps.

In addition to maintaining separation distances from the watercourses described above, the location of the receiving site and the application operations must reflect the following constraints:

- applications to floodplains and other areas that are prone to seasonal or frequent flooding should be avoided;
- applications to low-lying depressions and swales should be avoided when these features are wet;
- PPMB may be applied to areas of depressions and swales when these features are dry enough to support the application/spreading equipment without operational difficulty and so as to prevent soil compaction.

Separation from Groundwater

In accordance with section 15 of Ontario Regulation 347 regarding standards for organic soil conditioning sites, it must be ensured that the maximum level of the groundwater table is at a sufficient distance below the ground surface to prevent impairment of the groundwater in aquifers. The MOE uses a guideline of 0.9 metres from the ground surface to the maximum level of the groundwater table; however, a reduction in this separation distance may be considered, where a site-specific assessment indicates other hydrogeologic conditions will be sufficient in meeting the MOE's Reasonable Use Guidelines for groundwater management (MOE, 1994a).

Separation from Bedrock

- A minimum soil thickness of 1.5 metres should be present above bedrock on forestry and land reclamation sites to be used for PPMB applications.

This separation distance is designed to protect groundwater quality from infiltration of soluble parameters in the biosolids, as there is a reduced attenuation capacity in fractured bedrock aquifers relative to unconsolidated deposits.

A reduced thickness of soil overlying bedrock may be considered in situations where the biosolids application rate is to be reduced, where only primary PPMB's are to be applied, or where the site is sufficiently isolated to prevent long-term groundwater impacts.

Separation from Water Supply Wells

- A horizontal separation distance of at least 15 metres from the PPMB application area to a drilled well of a depth greater than 15 metres should be maintained.
- A horizontal separation distance of at least 90 metres from the PPMB application area to any other well, including dug wells, should be maintained.

These separation distances are intended to protect water supplies from surface water runoff and potential groundwater impacts related to PPMB applications. Any abandoned water supply wells within these separation distances should be permanently closed following MOE protocol (MOE, 1994b) to prevent any seepage of biosolid residues into the water supply aquifer.

Separation from Residences

- A minimum horizontal separation distance of 90 metres from the PPMB application area to the property boundaries of any individual residence should be maintained.
- A minimum horizontal separation distance of 450 metres from the PPMB application area to the property boundaries of any residential area should be maintained.

The above criteria are specified in section 15 of Ontario Regulation 347 regarding standards for organic soil conditioning sites. For purposes of this guideline, a residential area is defined as three or more residential lots with common boundaries, and dwellings within 300 metres of each other.

Separation distances from residences are required to mitigate off-site odour and airborne particle impacts. Odours are usually encountered during loading/unloading and spreading operations, and for short periods after spreading. Under certain circumstances, such as the following, the separation distances may be reduced on a case-by-case basis:

- For primary biosolids: the total storage time, on and off-site, is less than 30 days;
- For secondary and combined biosolids: the total storage time on and off-site is less than 10 days, and the materials are to be incorporated into the soil within 24 hours of spreading.

However, under no circumstances are the separation distances to be reduced to less than 25 metres and 50 metres for an individual residence and a residence in a residential area, respectively.

The criteria for separation distance from residences does not apply to the individual residence occupied by the owner, lessor or operator of the forestry site or former gravel pit, etc. that is to receive the PPMB application.

Table 3-5: Separation Distances from Site Features

Site Feature	Separation Distance (metres)	Notes
Water table	0.9	Measured vertically
Bedrock	1.5	Measured vertically
Drilled wells more than 15 metres deep	15	Measured horizontally
All other wells, including dug wells	90	Measured horizontally
Individual residences	90	Measured horizontally
Residential areas	450	Measured horizontally

3.5.2 Land Slope

- The land slope criteria specified in Table 3-4 should be maintained for PPMB applications to forestry and land reclamation sites.

Although it is desirable to apply PPMB to relatively flat-lying sites to minimize the risk of runoff into surface watercourses, the solid nature of most PPMB's will serve to reduce this risk even on steeply sloping forestry sites. There is considerable experience in British Columbia and the Northwestern U.S. with the use of municipal sewage biosolids and PPMB in mountainous forested terrain, which indicates that the materials can be applied at fertilization rates on steeply sloping sites with minimal adverse environmental effects.

Pulp and paper mill biosolid applications to sites where a continuous slope exceeds 9% can be considered on a case-by-case basis, provided there is adequate protection to adjacent surface watercourses. Use of high fibre PPMB (eg., primary biosolids) left on surface as an erosion control measure may be appropriate in such cases.

4.0 OPERATIONAL GUIDELINES

The following are recommended practices in order to ensure a properly managed PPMB application program on approved forestry and land reclamation sites, with minimal nuisance impacts to neighbouring properties.

4.1 HAULAGE FROM GENERATOR TO APPLICATION SITE

The hauler contracted to transport the biosolids from the mill to the application site must hold a valid Organic Waste Management Systems Certificate for the specific materials to be transported. The hauler must be in compliance with all conditions of the Certificate, as well as all other relevant federal and provincial transportation regulations.

Documentation of the quantities of PPMB delivered to the site are to be kept by the hauler and provided to the generator. The generator should provide copies of these records to the owner of the application site.

Additional guidelines related to spreading and incorporation are provided in Section 4.4.

4.2 ODOUR CONTROL

Secondary and combined biosolids are biologically active, as a result of the microrganisms from the secondary treatment systems. Strong odours may be associated with these materials if they become anaerobic during decomposition in storage. The odours are typically generated when the piles are disturbed during loading/unloading and spreading operations, and usually dissipate within 1 to 2 days after spreading operations have been completed.

The potential nuisance impact of odours can be managed by maintaining the separation distances from residences presented above in Section 3.5.1. Storage piles and loading/unloading operations should be kept as far away from neighbouring residences as practical. Avoiding activities associated with PPMB when the atmospheric conditions could cause odours to linger and be transported in the direction of sensitive receptors will also assist in minimizing the nuisance impacts.

4.3 BIOSOLIDS STORAGE

Storage of PPMB will be required due to weather conditions, site conditions, scheduling of applications, and other factors that prevent immediate spreading. Research conducted in Quebec and Ontario has shown minimal impact to groundwater from storage of PPMB on agricultural sites, both in winter and summer conditions. However, it is important that the storage of biosolids occurs in such a manner that prevents surface water runoff that may result in impacts to watercourses.

Dry biosolids (30% solids or greater, % by dry weight) will tend to absorb water in storage, and can usually be stored without need for runoff or leachate controls. Wet biosolids (25% solids or less) have the potential to generate seepage from direct drainage and release of moisture as the solids decompose in storage. It may be necessary to construct control measures, such as berms, swales, ditches, vegetative buffers, etc. to prevent any direct discharge of seepage from the storage piles into surface watercourses. This must be determined on a site-specific basis during the initial appraisal of an application site. Regardless of the solids content, all separation distances specified in Section 3.5.1 should be maintained from the storage pile. The land slope of the area used for storage should be 3% or less.

Adequate capacity for the volume of PPMB to be applied on the site in one year, based on the approved application rate(s), should be available. The duration of biosolids storage at the approved site should not exceed eight months in any one calendar year. Piles should be made as compact and visually unobtrusive as possible, and should be located in such a manner so as to prevent nuisance odour impacts (eg., if possible, in an area that the prevailing wind direction is not oriented toward sensitive receptors). Access roads to and from the storage area should be maintained passable at all times, with the exception of snow clearing, which can be done on an as-needed basis.

4.4 FORWARDING, SPREADING & INCORPORATION

The nature of forwarding and spreading operations at the application site will depend on the type of PPMB to be applied and the purposes of the application (eg., mulching vs. fertilization, etc.). Therefore, some flexibility must be allowed in the techniques to be applied. However, the general guidelines and principles outlined below should be followed in the development of PPMB spreading procedures on forestry and land reclamation sites:

- PPMB should be applied to the soil in a manner that ensures a uniform, evenly distributed application. Application techniques may include broadcasting, dozers, spreading using dump boxes, etc.

- Dewatered biosolids (30% solids content or greater) can be applied with conventional agricultural spreading equipment, or small dozers and loaders. Operation of the spreading equipment should be conducted in such a way and at times of the year that prevents soil compaction, rutting and damage to trees.

- Spreading and incorporation equipment must be small enough to easily manoeuvre around the site, in particular, among the rows of tree plantations; but large enough to efficiently accommodate the quantities to be applied. Small tractors, manure spreaders, harrows and discs, or dozers, box trailers and tracked loaders are ideal for these operations.

- PPMB applied as a mulch for weed control, etc. should be thickly and evenly applied to the surface of the soil. A minimum thickness of 10 cm is recommended for an effective mulch layer.

- Where biosolids are to be incorporated into the soil as a fertilizer, light cultivation equipment is generally employed. Incorporation should be completed in as short a time as possible after spreading to minimize volatilization losses of ammonia, and to control odours.

4.5 WINTER SPREADING

Experience with PPMB applications on forestry sites has demonstrated that winter applications can be successfully completed with minimal risk to the environment. The primary concerns associated with PPMB applications during winter conditions include the movement of residues with surface runoff to watercourses, and the movement of biosolids particles with wind across relatively smooth, frozen or ice-covered ground.

The following guidelines are recommended for PPMB applications during winter conditions:

- PPMB with solids contents greater than 30% can be applied to frozen and snow-covered ground, where the depth of snow cover is less than 15 cm.

- The slope of the land surface on the application site in the area of winter spreading should be less than 3%.

- The minimum setback distances from watercourses, etc. specified in Section 3.5.1 should be adhered to.

- Biosolids should not be applied to ice-covered ground, including low-lying depressions, to avoid movement by wind and runoff.

- Biosolids should not be spread during extended periods of thawing, or when runoff (rain, freezing rain, snowmelt, etc.) is expected.

- PPMB with higher moisture contents may be spread on frozen and snow-covered ground (snow cover less than 15 cm), provided the risk of surface runoff is minimal. This may be achieved on relatively flat-lying (ie., less than 3% slope), well-drained sites or sites with established vegetation to reduce runoff.

- The initial application of PPMB to land reclamation sites should only be conducted during winter conditions if the site is well-drained and there are no significant areas of ponded water following snowmelt.

4.6 BLENDING WITH OTHER MATERIALS

It is feasible to blend PPMB with other materials, or blend together PPMB's with differing characteristics, to obtain a material with improved opportunities for beneficial use. Some examples of such usage are provided below. Until sufficient experience is obtained for a functional use of a particular PPMB blend, it is recommended that each situation be addressed on a case-by-case basis. The primary purpose of blending other materials with PPMB must be to provide incremental benefit to the application site, rather than to increase waste disposal quantities.

- Blends of low and high nitrogen PPMB's may be advantageous as a means of increasing the soil organic matter. Higher rates of application will frequently be desirable to more rapidly increase soil organic matter content. Blends of PPMB's may also be effective in reducing the amount of supplemental nitrogen required for low nitrogen, high C:N ratio biosolids.

- A multi-layer technique of applying a low C:N ratio PPMB material underneath a mulch of high C:N, low nitrogen material has been used to control weeds and promote growth in newly-planted cuttings.

- The slow release organic nitrogen in PPMB may be effectively co-utilized with high nitrogen materials such as livestock manures and commercial fertilizers to provide a sustained nutrient release over a full growing season, and to increase the organic matter, which provides much greater long-term benefits to the soil than inorganic fertilization.

A blended mixture consisting of a material that is classified as a waste under Ontario Regulation 347, with other materials that are exempt from the regulation (eg., livestock manure) would result in a mixture that is classified as a waste. Such materials can only be utilized on a site that has been approved under the *Environmental Protection Act* provisions (ie., an organic soil conditioning site), in accordance with any conditions of a Certificate of Approval. Therefore, prior to using a blended material involving PPMB, a comprehensive plan should be developed, including the purpose of the application, characterization of all materials, application rates and techniques, etc.

It is also important that the blended materials are thoroughly mixed together to ensure uniform distribution across the application site. Periodic inspections and actual testing may be warranted to verify adequate blending, and to document the mixture characteristics.

4.7 MONITORING AND ASSESSMENT PROGRAMS

In order for a PPMB application program to be beneficial to a forestry or land reclamation site, knowledge of the biosolids characteristics, which may vary with time, and the needs of the receiving site, must be obtained. The receiving site should be assessed in terms of the soil characteristics, the past usage and intended future usage, tree species and density, etc. The following guidelines pertain to PPMB characterization and monitoring, and to soil sampling.

4.7.1 PPMB Sampling and Analysis

The purpose of conducting PPMB analyses is to ensure that the material is suitable for application and that a uniform and consistent quality material is being used, and to match the application rates to the needs of the receiving site.

It is important that regular monitoring of the PPMB being used in a land application program be undertaken to confirm application rates based on nutrient loading or other factors, estimate supplemental fertilizer requirements, and adjust timing of the applications, if necessary.

Grab samples of the pulp and paper mill biosolids can be collected from the dewatering discharge points, or from storage areas. Samples from a representative number of individual sampling points should be collected using a shovel or trowel and mixed together to yield a single, uniform composite. The composite is then sub-sampled for analysis.

Where the PPMB samples are collected from a large storage pile, care must be taken to collect samples that are representative of the full depth profile and spatial variability within the pile.

The recommended containers and preservation techniques for various classes of analysis are presented in Table 4-1. Analysis for organic parameters should occur as soon as possible after sample collection.

Table 4-1: Sample Containers and Storage for PPMB Samples

Parameter Group	Container	Storage Comments
Inorganics & organic carbon	plastic, glass	
VOC's	amber glass, preferably VOC vials with teflon-lined lids	kept cool (<4^{o}C); out of sunlight; decant free water, minimize headspace; no contact with plastics.
PAH's and PCDD/PCDF	solvent-rinsed, amber glass foil or teflon-lined lids	kept cool (<4^{o}C); out of sunlight; refrigerate at all times.
All other organics	solvent-rinsed glass, foil or teflon-lined lids	kept cool (<4^{o}C); out of sunlight; refrigerate for storage; no contact with plastics.

Sampling quality assurance and quality control measures should follow established industry practices, including sampling observations, record-keeping, sample chain of custody documentation, and replicate samples, if warranted. Guidance for field and lab QA/QC protocols is provided in the document, *Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario*, developed by the MOE Standards Development Branch (MOE, 1996).

Frequency of PPMB analysis

The parameters and frequency of analysis for PPMB should be undertaken as outlined in Table 4-2. These criteria only apply when consistent historical records of all parameters can be established. More frequent analyses would be necessary under the following general conditions and as specifically noted:

- where the analytical data and records show considerable variations of individual parameter values between individual samples, and especially macro-nutrients, nitrogen and phosphorus,

- where changes in feedstocks, manufacturing processes, chemicals or other additives, and effluent treatment processes could result in changes of PPMB properties.

Table 4-2: Analysis Frequency for Pulp and Paper Mill Biosolids

Parameter	Frequency of Sampling and Analysis
pH	Monthly
Total solids (TS)	Monthly
Organic carbon	Monthly
Total nitrogen	Monthly
Ammonia ($NH_4 + NH_3$ -N)	Monthly
Nitrate (NO_3 -N)	Monthly
Phosphorus	Monthly
Potassium	Monthly
Chloride (total & soluble)	Monthly
Sulphate (total & soluble)	Monthly
Calcium (total & soluble)	Monthly
Magnesium (total & soluble)	Monthly
Sodium (total & soluble)	Monthly
Arsenic	Quarterly (see Note 1.)
Cadmium	Quarterly
Chromium	Quarterly
Cobalt	Quarterly
Copper	Quarterly
Lead	Quarterly
Mercury	Quarterly
Molybdenum	Quarterly
Nickel	Quarterly
Selenium	Quarterly

Zinc	Quarterly
Boron	Quarterly
Other metal/elements of potential concern (aluminum, manganese, etc.)	Quarterly
Dioxins/Furans	Yearly
VOC's	Yearly
PCB's	Yearly
Other trace organics	as warranted

Notes: 1. The frequency of metals analysis can be reduced to once annually if four consecutive quarterly results for all metals are below the concentrations specified in Column 3 of Table 3-2.

4.7.2 Receiving Soil Analyses

Areas proposed for initial and re-applications of PPMB (ie., following a five year Certificate of Approval cycle), should be characterized to determine the suitability of the site to receive PPMB applications. Also, since the application rates, particularly for tree fertilization, should be suited to the plant nutrient requirements, an assessment of the proposed land use and vegetation should be carried out.

Soil sampling procedures should follow those outlined in the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA, 1996). Documentation of the soil sampling should include the following:

- Sampling methods and dates completed, sampling materials, and any special handling procedures;
- Names of companies conducting the sampling and analyses, and the chain of custody records;
- Summary of the laboratory methods, protocols, standards and quality assurance procedures;
- Results and interpretation of soil analyses.

The soil analyses should include the following parameters:

- Soil pH;
- Total organic carbon, total nitrogen, and C:N ratio;
- Organic carbon

- Phosphorus (sodium bicarbonate extractable);
- Exchangeable and total sodium, calcium, magnesium and other soluble salts, if warranted;
- Metals (arsenic, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium and zinc); and
- Any other specific parameters of interest to the forestry or land reclamation site.

Note that the metals analyses are not necessary for soils receiving PPMB with metal concentrations less than those specified in Column 3 of Table 3-2. Guidelines regarding analytical procedures and method detection limits for soils are provided in Appendix I of the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE / OMAFRA, 1996).