Prince Edward Island Manure Management Guidelines

Prince Edward Island
CANADA

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Preface

All measurements stated in these guidelines are in SI (metric) units. Where Imperial units are given in parentheses they are soft conversions and for comparison only. In practice, SI units will prevail.

The following principles led the development of these guidelines:

- Prince Edward Island is a rural agricultural province and livestock operations have an important role in developing a sustainable future. Producers can establish, operate, and expand their operations in accordance with reasonable management practices.
- Livestock production is a critical part of the province's agricultural landscape. Livestock operations and the manure produced by those operations is a valuable resource with many benefits for soil health.
- Residents and business owners must be aware that there will be certain sights, sounds, and smells associated with normal livestock production practices.
- Producers will adopt a 'Good Neighbour' approach in their operations to avoid creating unnecessary adverse conditions for the general public.
- Climate change is a factor that affects most aspects of agricultural operations. Producers and the public will both benefit from adopting mitigation and adaptation practices.
- Environmental protection standards allow livestock operations to establish, operate, and expand when they are deemed to be compliant within these guidelines and other relevant land use and environmental protection legislation.

1.0 INTRODUCTION

This publication is intended to give direction for sustainable manure management practices on Prince Edward Island, as well as for beneficial management practices current at the time of publication. It will also serve as a guideline for anyone concerned with the establishment and operation of new livestock operations, expansion of existing livestock operations, or changes in land use in a rural area. This document is the successor to “Guidelines for Manure Management for Prince Edward Island”, published in 1999.

These guidelines are intended to complement statutory requirements under the *Environmental Protection Act, Farm Practices Act, Fisheries Act, Public Health Act, Water Act,* and other legislation that relates to agricultural land use. They are intended to be used to:

- Assist livestock producers in their efforts to protect the environment and minimize odour concerns;
- Provide information to the general public and officials to evaluate livestock operations for their potential effects on the environment and surrounding land use;
- Establish standards that can be used to determine acceptable farm practices;
- Guide the development and delivery of government programs.

1.1 Context

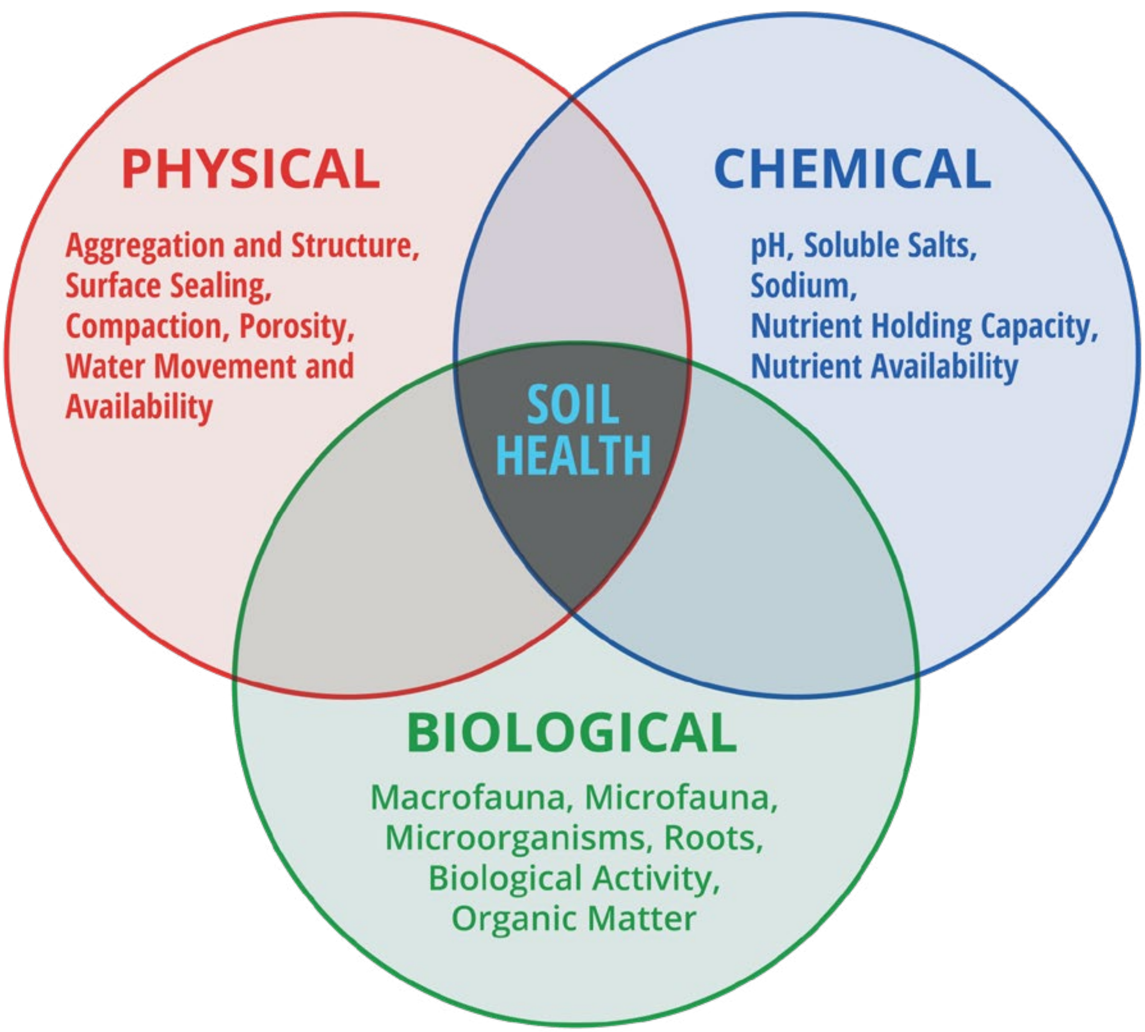
Manure, when properly stored and managed, is not a waste product; it is a valuable resource that can reduce the requirement for chemical fertilizers and improve soil health. Improper management of manure can lead to adverse environmental impacts due to potential water contamination, nutrient overloading, excessive greenhouse gas emissions, and unnecessary odour complaints. These guidelines emphasize the value of manure through the adoption of beneficial management practices and provide practical information to assist producers in reducing greenhouse gas emissions, protecting surface and groundwater, and addressing other environmental challenges related to manure management.

Guidance in this document considers the current need for increasing manure use to improve soil health. This need was noted in the Prince Edward Island Livestock Strategy 2021 – 2025:

> Soil health is a precondition for the success of PEI's agriculture industry, including livestock sectors. Soil organic matter (SOM) has declined significantly in recent decades. Factors such as the reduction in manure usage, increased intensity of crop production, and decreased forage production have had negative impacts on soil structure, organic matter, and overall soil health. As a result, there are opportunities to **sustainably increase manure availability** for land application, which can **contribute to improved soil health.**[1]

1.2 Manure and Soil Health

To understand the value of manure as a resource, it is important to consider its positive effects on soil health. Soil health is the continued capacity of soil to function in a way that sustains biological productivity, maintains air and water quality, and promotes plant, animal, and human health.



1 Prince Edward Island Livestock Strategy 2021 - 2025 p.10 Focus Area 3.3. (Emphasis added).

Impact of Applied Manure on Soil Health

Soil Characteristic Description	Manure Impact
Soil Organic Matter	
Total organic material content of the soil. Affects all of soil's physical, chemical, and biological properties. Directly correlates with soil fertility, plant nutrition, water holding capacity, bulk density, and aggregate stability.	**Increases soil organic matter**
Nutrient Content	
Primarily nitrogen, phosphorus, potassium, and other macro and micronutrients.	**Increases nutrients available to crops**
Cation Exchange Capacity (CEC)	
Ability of the soil to hold and release nutrients and make nutrients available for plant uptake.	**Increases CEC**
pH	
Measure of the level of acidity or alkalinity in the soil. Essential for plant nutrition, growth, and soil's biological and chemical activity.	**Contributes to sustaining higher pH levels**
Bulk Density	
Solid particle mass per unit volume of soil. Compacted soils (higher bulk density) have lower porosity, lower air content, lower water infiltration, and poor plant growth.	**Reduces bulk density and increases soil porosity when applied properly**
Aggregate Stability	
Ability of soil to resist the impact of an external force like rainfall, wind, and water erosion based on its physical structure and properties. An enhanced soil aggregate stability benefits crop growth and prevents erosion.	**Increases aggregate stability**
Water Infiltration	
Movement of water through the soil. Increasing infiltration reduces water and nutrient runoff and enhances water availability for plants.	**Increases water infiltration**
Water Holding Capacity	
Capability of the soil to retain water in water-filled pore spaces that can then be available for crops.	**Increases water holding capacity**
Earthworm Population	
Total number of earthworms within the soil. Presence of earthworm communities accelerates biomass decomposition, nutrient cycling, and building a better pore system, allowing for greater water infiltration and retention.	**Increases soil biological activity and earthworm population**
Microbial Biomass and Activity	
Directly relates to general biological activity, which influences the nutrient availability for crops and the generation of substances that act as "glue" to help build more stable soil aggregates.	**Increases soil biological activity and microbial biomass**

1.3 Beneficial Management Practices

A beneficial management practice (BMP) is a proven, practical recommendation that conserves water, soil, and other natural resources. These practices are beneficial to producers and the environment and may increase productivity and reduce operational costs. Throughout the guidelines, BMP boxes, such as the one shown to the right, highlight recommended practices for manure management.

Beneficial Management Practice

Prepare an emergency action plan and monitor for spills.

2.0 KNOW YOUR MANURE

Manure has properties that should be understood to make decisions about its handling and use. This section discusses the physical characteristics of manure, its odour, its composition, factors that affect its composition, and greenhouse gases as they relate to manure management.

2.1 Physical Characteristics of Manure

2.1.1 Manure Moisture and Dry Matter Content

Livestock manure can be characterized as either a liquid or solid. These two types of manure are typically managed with different systems for collection, storage, and land application. Both liquid and solid manure are composed of animal feces and urine, as well as additional materials such as spilled feed, wastewater, and a range of other minor quantities of materials.

Liquid manure typically contains a dry matter content of 18% or less and can be characterized as being transported by means of gravity flow or pump.

Solid manure typically contains a dry matter content greater than 18% and can be characterized as not flowing or releasing manure liquids when piled. Manure that runs, even if it contains a solids percentage over 18%, should be contained and managed like liquid manure.

2.1.2 Odour

The odour associated with livestock and manure is the result of organic compounds such as hydrogen sulphide (H_2S), ammonia (NH_3), and other gases that are a product of microbial metabolism and animal digestion.

Manure is widely considered to have an unpleasant odour and most complaints surrounding manure management relate to odour. The only method for mitigating odour is to limit the odour's intensity by limiting the formation of odour compounds or the release of these compounds into the atmosphere. Practices to manage odour are found throughout each section of these guidelines.

2.2 Nutrients

Manure contains both macronutrients and micronutrients which contribute to plant growth.

Nutrient		Benefit to Plants
Nitrogen	N	Responsible for plant growth and protein production
Phosphorus	P	Necessary for seed, flower, and fruit production
Potassium	K	Component of plant cells, essential for cell division and development of the growing tip of the plant
Sulphur	S	Common component of protein and vitamins
Calcium	Ca	Essential component of plant cell walls and membranes
Magnesium	Mg	Component in chlorophyll, necessary for photosynthesis

Some forms of nutrients in manure are not immediately available and must first be transformed by microorganisms for crop use. The conversion process may be lengthy, so crops benefit from manure application over more than one growing season.

The following sections detail the important macronutrients N, P, K, and S in manure. Information on nutrient management planning and land application can be found in Section 5.

2.2.1 Nitrogen in Manure

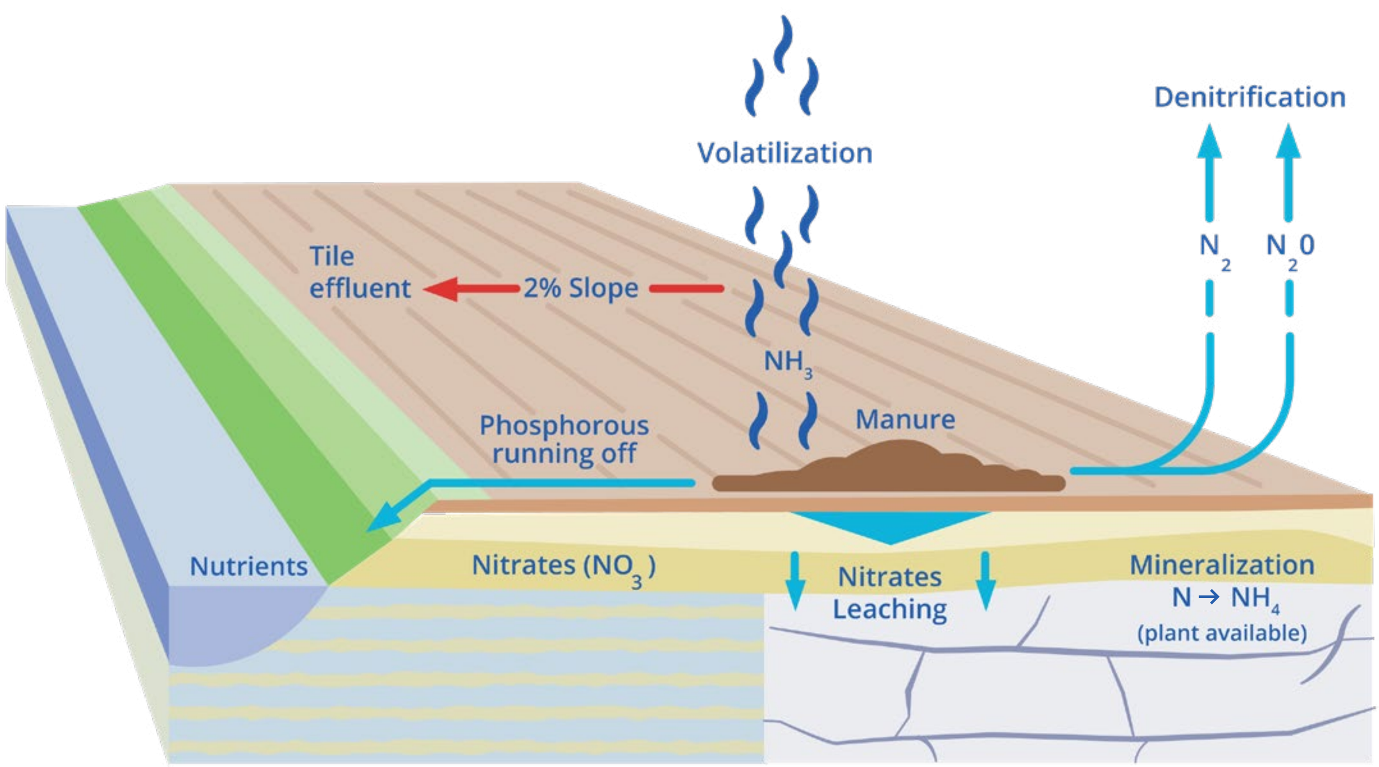
Manure is an excellent source of nitrogen. Nitrogen in manure is stored in two forms – organic and inorganic. Inorganic nitrogen is immediately available to plants but organic nitrogen is tied-up as organic matter and microbial organisms. Organic nitrogen becomes available to plants when it is decomposed or "mineralized" into an inorganic form by microbes. This process can be lengthy and is dependent on soil temperature and moisture levels.

Total nitrogen is a measure of all the forms of nitrogen contained in manure. This includes ammonium N, organic N, and any nitrate N that may exist. The amount of nitrogen in manure will be variable both between and within livestock types and even within the same type of livestock operations.

Nitrogen Type	Form	Immediately Available to Crops?	
Ammonium N	Inorganic	Yes	Under alkaline conditions (pH > 7) some nitrogen can be lost from the manure
Organic N	Organic	No	Not measured directly in manure test analysis but can be estimated as Organic N = Total N – Ammonium N
Nitrate N	Inorganic	Yes	Manures seldom contain nitrate N

Nitrogen Soil Processes

The availability of manure nitrogen as a nutrient source is affected by the form of nitrogen present in the manure, how it is applied, and the soil and weather conditions at the time of application. For example, a manure with high ammonium N content applied on a sunny, warm day will lose valuable nitrogen to the atmosphere. Because of this, it is important to understand nitrogen soil processes to get the best value from manure. The following figure and table detail these processes.



Manure nutrients, especially forms of manure nitrogen, are prone to manure loss as a gas by volatilization of ammonia or through denitrification. Organic and inorganic forms of manure nitrogen can be lost through surface runoff.

Nitrogen Soil Processes

Process	Definition	Factors/Effects
Volatilization	The loss of nitrogen to the atmosphere from the conversion of ammonium to ammonia gas.	Nitrogen lost through volatilization is related to the amount of ammonium in manure, pH of manure, exposure of manure to the atmosphere, and weather conditions.
Nitrification	Ammonium in manure is converted to nitrate by microorganisms in the soil.	Manures contain low or no amounts of nitrate; however significant amounts of nitrate are formed from the ammonium in manure once it is applied to the soil.
Nitrate Leaching	Nitrate nitrogen is highly water soluble and easily moves through the soil profile with water.	The movement of nitrate through the soil profile is more likely to occur in coarse textured soils (i.e. sands, sandy loams) when crops are not present (pre-plant and post-harvest) or if N availability exceeds crop uptake.
Denitrification	The conversion of nitrate to nitrous oxide and nitrogen gases.	Excess nitrate that is not used by plant uptake can convert to gases (N_2 and N_2O) and are released to the atmosphere. Nitrous oxide (N_2O) is a potent greenhouse gas.
Mineralization	Conversion of organic nitrogen to ammonium nitrogen. Mineralization causes nitrogen to become plant available.	Organic nitrogen is released throughout the growing season. Generally, 30-50% of the nitrogen will be mineralized during the first cropping season with the balance mineralized during the next three years.

Practices for conserving manure nitrogen for crops can be found in Section 2.5.3.

2.2.2 Phosphorus in Manure

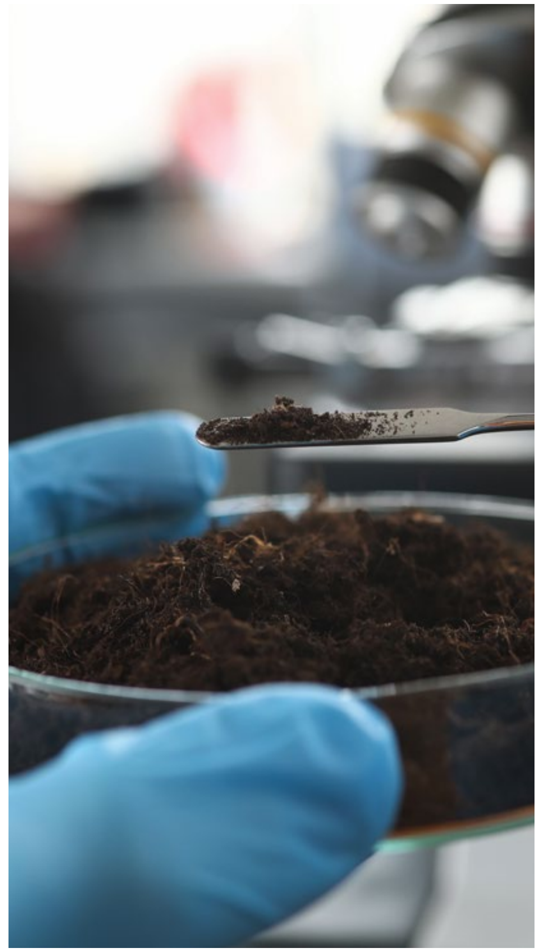
Manure is an excellent source of phosphorus. Generally, 45-70% of manure phosphorus is readily available for crop uptake. Factors that affect phosphorus plant uptake include organic matter content, manure placement, and pH. In moderately acidic soils, such as those found on PEI, iron and aluminum can chemically tie-up “free” phosphorus that would otherwise be plant available at higher pH values.

Information on phosphorus and land application can be found in Section 5.2.1.

2.2.3 Potassium in Manure

Potassium found in manure is readily available to plants and considered equally as effective as commercial fertilizer potassium (known as potash). Between 80-90% of potassium in feed rations are excreted in manure.

Yearly applications of manure in the same fields may result in elevated soil potassium levels. High soil potassium levels are not considered an environmental concern but can cause elevated levels in forages which may be of concern to dairy producers as they can cause health issues such as milk fever and udder edema.



2.2.4 Sulphur in Manure

Livestock manure generally contains 0.25-0.30% sulphur. Approximately 95% of the sulphur is not readily available and must be mineralized to be used by plants.

2.2.5 Micronutrients and Trace Elements in Manure

Micronutrients in Manure	
Copper	Selenium
Manganese	Chromium
Zinc	Iodine
Boron	Cobalt
Molybdenum	Iron

Crops require relatively small amounts of micronutrients for plant growth, but they are important for livestock health. If manure land application is based on nitrogen or phosphorus crop requirements, most micronutrient requirements will be met. Micronutrients that may not be fully supplied by manure are boron, selenium, and zinc. PEI soils are naturally low in boron.

The amount and/or type of manure and how it is applied can have direct effects on micronutrient levels. For instance, zinc levels can be 10 to 100 times higher in swine versus dairy manure. Producers should be aware that the addition of micronutrients to livestock feeds in excess of animal nutrition requirements may negatively impact soil quality.

2.3 Microorganisms

Manure contains large amounts of microorganisms and, subsequently, the land application of manure will increase microbial biomass, microbial activity, and soil respiration, benefiting soil health. Microorganisms accelerate the breakdown of organic substances and make more nitrogen and phosphorus in manure available to plants.

Manure application has the potential to decrease harmful organisms, such as disease-causing pathogens and plant pests, by increasing the number of beneficial organisms in the soil. The effectiveness of manure on different pathogens will depend on complex interactions between the biological, chemical, and physical properties of the soil.

2.4 Organic Matter

Organic matter is comprised of a mixture of living microbial populations and actively decomposing plant residues and animals, as well as stable, previously decomposed plant residues. Manure is an excellent source of organic matter and can contribute to increased organic carbon levels within the soil.

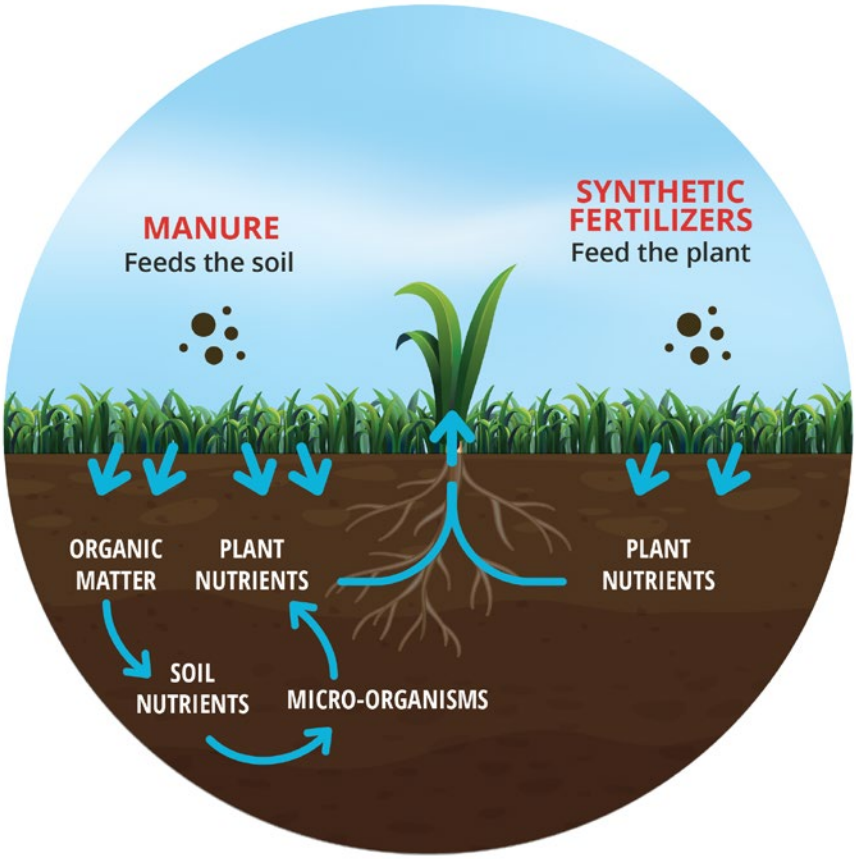
The C:N ratio is the proportion of the organic carbon to total nitrogen in manure. This ratio determines the length of time soil microorganisms take to break down manure and make it an available nutrient source for plants. Manure with a C:N ratio of 20:1 is considered ideal for crop production. A C:N ratio that is too high will tie up soil nitrogen. A C:N ratio that is too low will result in the release of ammonia that would have otherwise been available to the crop and may also result in foul odours during storage.

Carbon : Nitrogen Ratio of Various Organic Materials

Material	C:N Ratio Range[2]
Soil Microbes	4:1 to 9:1
Soil Organic Matter	10:1 to 12:1
Solid Cattle Manure	20:1 (light bedding) to 40:1 (heavy bedding)
Horse Manure	27:1 (straw bedding) 60:1 (sawdust bedding)
Solid Poultry Manure	5:1 layers 10:1 broilers and turkeys
Liquid Hog Manure	< 8:1
Liquid Dairy	15:1
Legume Residues	20:1 to 30:1
Corn Stalks	80:1
Wheat Straw	80:1
Sawdust	500:1

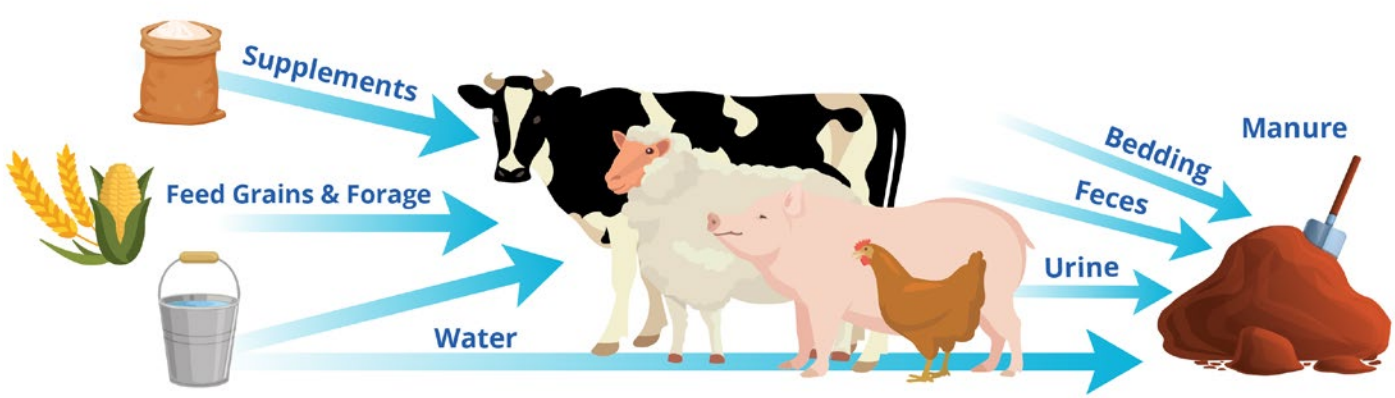
2 Ontario Ministry of Agriculture, Food and Rural Affairs: August, 2022

Soil organic matter (SOM) contributes to beneficial soil functions, including improved resistance to extreme weather events caused by climate change. With sandy soils like those commonly found on PEI, it can be difficult to build and maintain high levels of SOM. The land application of manure helps add nutrients to the soil, but it also replenishes SOM that is lost when fields are cropped. Commercial fertilizers do not provide this same benefit to SOM.



2.5 Factors and Practices Affecting Manure Composition

The composition and nutrient content of manure is highly variable and dependent on the livestock type, age, feed rations, bedding, water content, manure storage type, and storage time. The sections below explain how livestock type and management can affect manure composition.



2.5.1 Type and Age of Livestock

Although livestock are efficient in converting feed to body tissue, a portion of the nutrients in feed are not used by animals and are excreted in manure. As livestock grow, their ability to convert the nutrients in feed to body tissue changes. Livestock that are actively growing will use some nutrients more efficiently than mature animals.

If a feed ration is unbalanced, nutrients in excess of requirements will be excreted. Altering the livestock's diet to closely match their needs in each growth phase can reduce nutrient waste. Enzymes and specific amino acids can be used to modify rations for increased feed efficiency and reduce unused nitrogen and phosphorus in the manure.

2.5.2 Barn Management

Livestock housing determines the amount and type of bedding found in manure. Differences in bedding material – sand, straw, wood chips – all create differences in manure. For example, the C:N ratio of wood chips (200+:1) will be much higher than straw (50–80:1). Sand bedding, which is commonly used on dairy farms, may change the physical properties of the soil, especially if it is applied to the same fields over time.

Liquids are commonly added to manure through normal agricultural practices. Manure liquid, including liquid feed, cleaners from flushing equipment, spillage from waterers, and wastewater, all contribute to manure composition. Although these liquids are relatively dilute, manure will contain chemicals such as surfactants from cleaners, veterinary drugs, heavy metals such as copper from foot baths, and anything else that might be used within a barn on livestock. Chemicals that find their way into a manure storage could enter the food chain or watercourses through field application. Producers should be cautious and careful in their use of chemicals.

2.5.3 Storage and Handling

Uncovered outdoor manure storage systems gather substantial amounts of water from precipitation. Up to 30% of the contents of an uncovered manure storage can be precipitation which dilutes manure nutrients and adds substantial fuel and labour costs to manure handling.

As noted in Section 2.2.1, nitrogen can be lost to the air during storage. Nitrogen loss can be reduced through the following storage management practices:

- Transferring the manure from the barn to the storage system as often as possible, especially during the summer, where the manure will remain cooler;
- Using transfer systems such as bottom loading storage systems that minimize contact between the manure and the air;
- Using covered storage facilities or storage systems with smaller exposed surface areas that reduce contact with the air.

2.6 Greenhouse Gas Emissions from Manure

Greenhouse gas emissions from manure impact the environment both on and off livestock operations. Manure handling and storage practices can impact the magnitude and timing of these emissions. Carbon dioxide, methane, and nitrous oxide are the greenhouse gases of most concern when considering manure management practices. This section introduces manure-related greenhouse gas emissions and their impact on climate change. Relevant sections throughout the guidelines detail management practices that can reduce greenhouse gas emissions from manure.

2.6.1 Greenhouse Gases: Carbon Dioxide, Methane, Nitrous Oxide

Carbon dioxide (CO_2) production occurs throughout the process of storing, handling, and applying manure to crops. Although atmospheric CO_2 is considered a driving factor of climate change, manure is typically not considered a major source of CO_2 in greenhouse gas accounting because it is part of a natural CO_2 cycle.

Methane (CH_4) has a global warming potential 25 times that of CO_2 and a relatively short residence time in the atmosphere of 8-12 years. Methane is produced as a result of the activity of microorganisms in manure and occurs primarily in liquid manure storage systems where oxygen is not present. In 2020, most of the methane production from agriculture in PEI was associated with ruminant animals and methane emissions from manure storage.

Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential 298 times that of CO_2. Nitrous oxide has a relatively long residence time in the atmosphere (120 years) so nitrous oxide emitted today will impact the atmosphere for the next century. Nitrous oxide is produced from bacterial processes involving ammonium and nitrate.

2.6.2 Greenhouse Gas Emissions on Prince Edward Island

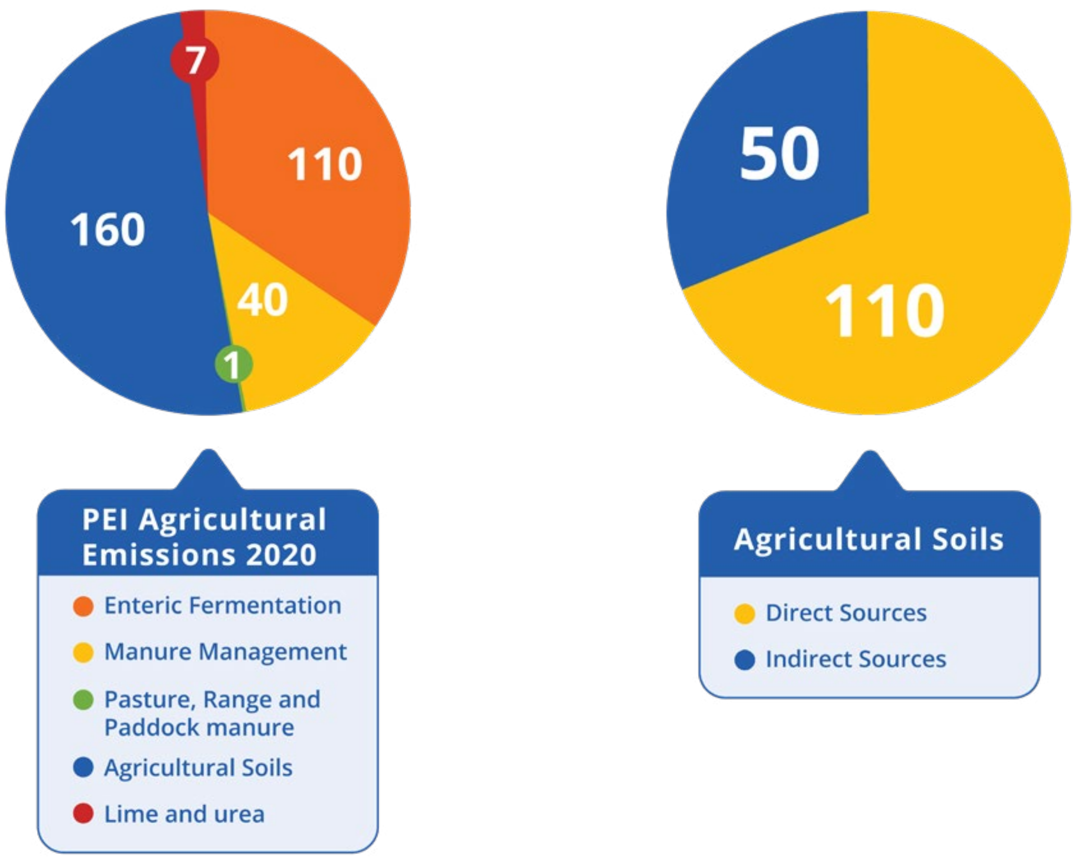


Figure 1: Greenhouse gas emissions from agriculture in Prince Edward Island in 2020. Data as reported in the *Canadian National Inventory Report, 2022.*

In 2020 the province of Prince Edward Island emitted a total of 1,610 kt of carbon dioxide equivalents.[3] Agriculture was responsible for approximately 20% of that number (318 kt CO_2e). Half of agriculture's emissions were direct and indirect emissions from soil, including emissions associated with the land application of manure (Fig. 1). An additional 12.5% of those emissions were associated with methane and nitrous oxide emissions related to manure management.

3 Canada's National Greenhouse Gas Inventory

Emissions associated with manure management remained relatively stable, declining slightly, over the past three decades while direct and indirect emissions from soils have increased in recent years, primarily due to the increased use of synthetic nitrogen fertilizers (Fig. 2). Improved manure management is an important part of Prince Edward Island's strategy to reduce greenhouse gas emissions.

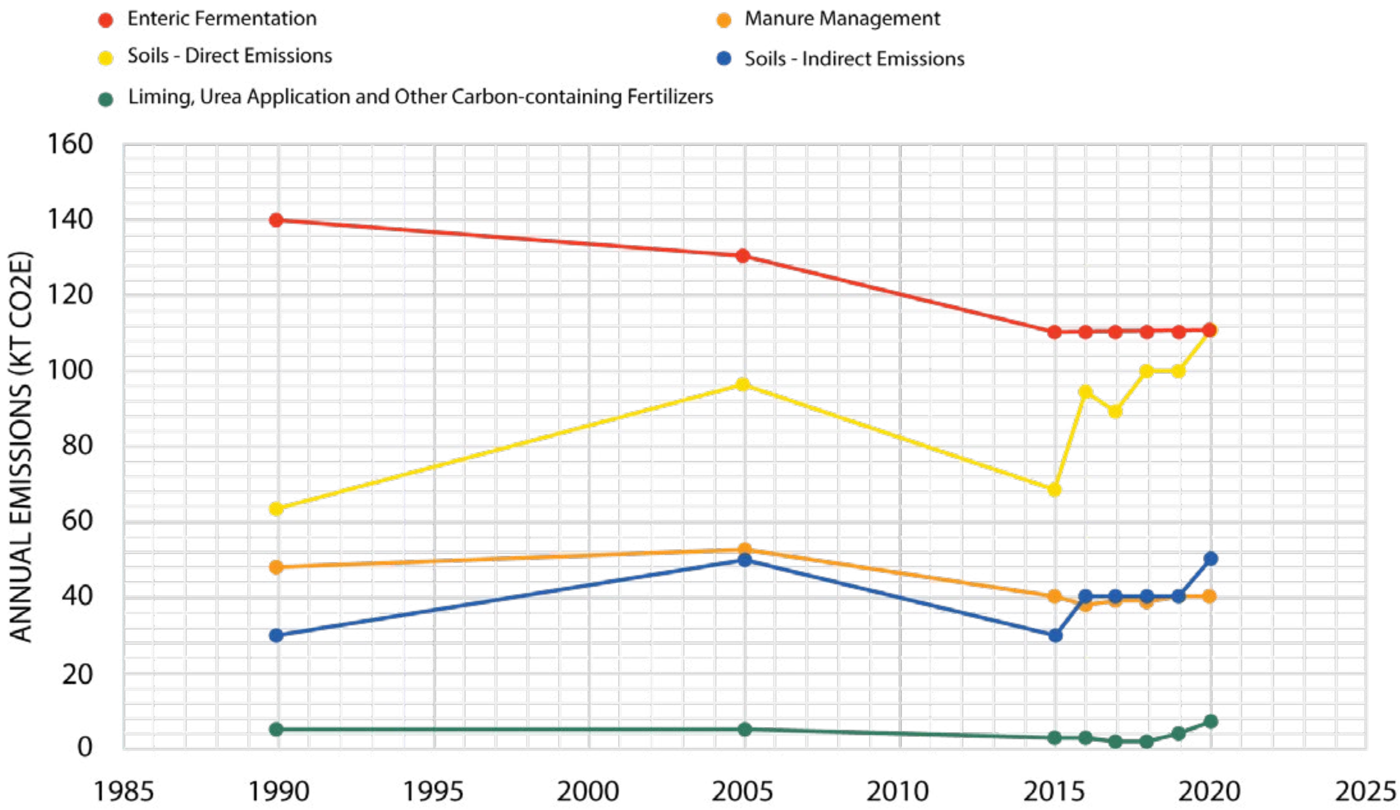


Figure 2: Trends in agricultural greenhouse gas emissions from Prince Edward Island from 1990 to 2020. Data as reported in the *Canadian National Inventory Report, 2022.*

3.0 STORING YOUR MANURE

This section will discuss planning considerations and standards for the construction of various manure storage systems on Prince Edward Island.

3.1 Planning

Relatively long winters and cold, damp spring conditions on Prince Edward Island, combined with seasonal cropping systems, require the storage of manure for long periods of time. Storage systems should be sized to allow producers to spread manure when it can best be used as a fertilizer and have the capacity to avoid overflow and spillage due to extreme weather events. Additionally, manure storage systems should minimize odour, nutrient loss, and greenhouse gas production.

Expanding or Building a New Manure Storage System

When building a new manure storage or expanding an existing one, the following conditions apply:

- The manure storage system should be located within the Minimum Separation Distance (MSD) requirements as laid out in Appendix C1.
- A Development Permit must be obtained from the local Authority Having Jurisdiction prior to construction.

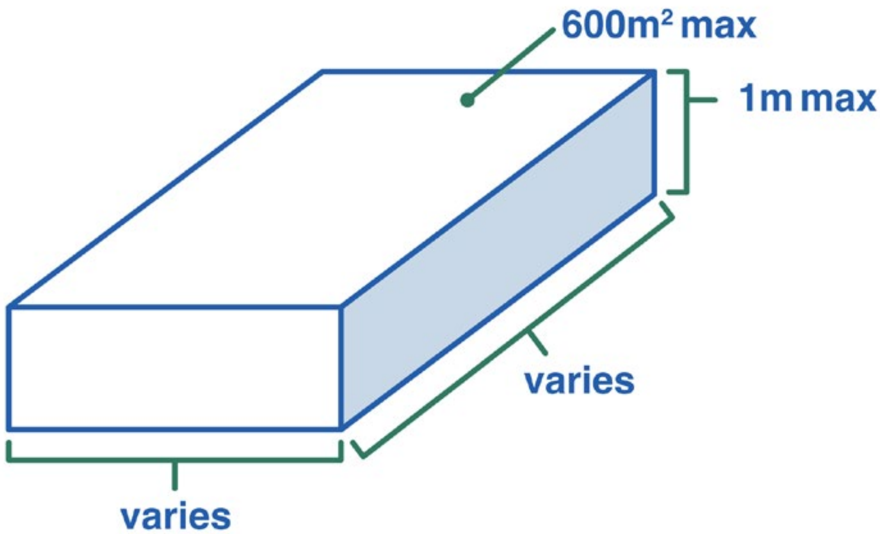
Environmental Assessment

Development Permit applications will be reviewed to determine if an Environmental Assessment is needed and, if so, the level of assessment required. If additional information is needed or an Environmental Assessment is required, the applicant will be contacted directly to discuss the requirements. The complexity of the assessment will vary depending on the size and nature of the proposed project and the surrounding land uses.

Engineering Requirements

Manure storage systems must be designed by a professional engineer, with the exception of small solid manure storage systems. Small manure storage systems are defined as having:

- a volume less than 600 m^3;
- a surface area less than 600 m^2; and
- a containment wall height of 1 m or less.



Small solid manure storage systems should meet siting (MSD) requirements and have appropriate runoff and run-on controls.

For all other manure storage systems, an engineer will be required to prepare the following:

- A clearly dimensioned site plan showing the location of the proposed manure storage system relative to the features described in the development permit application.
- Sealed (stamped) construction drawings that include a summary of the calculations used as the basis for determining the capacity of the storage system.
- An “Engineer’s Commitment Declaration”, prior to construction (see Appendix A1).
- A “Field Review of Construction Declaration”, upon completion of construction (see Appendix A2).

Manure storage systems must be designed and constructed in accordance with *Part 2 – Farm Buildings* of the latest edition of the *National Building Code of Canada.*

Construction of manure storage systems must be reviewed by a qualified professional engineer at intervals appropriate to the stages of construction to ensure compliance with designed drawings.

Beneficial Management Practice

To limit odour production, use transfer systems such as bottom loading storage systems that minimize contact between manure and the air.

3.1.1. Capacity & Sizing

A liquid manure storage system must have the capacity to hold a minimum of 270 days of manure accumulation and the total precipitation that will enter an uncovered storage during that period of time, in addition to any other liquid effluent that is expected to be contained in the storage such as milk house wastewater or silage seepage.

A solid manure storage system without access to adequate field storage must have the capacity to hold a minimum of 270 days of manure accumulation in total. On-site solid manure storage systems, used in combination with field storage, are permitted to have a minimum capacity of 30 days accumulation of manure. Producers should consider field access during harsh weather in determining the capacity of on-site storage.

When expanding a livestock operation, the manure storage systems, as a whole, must meet the 270 day storage capacity requirement. This can be achieved by modifying the existing storage system or by constructing additional storage capacity.

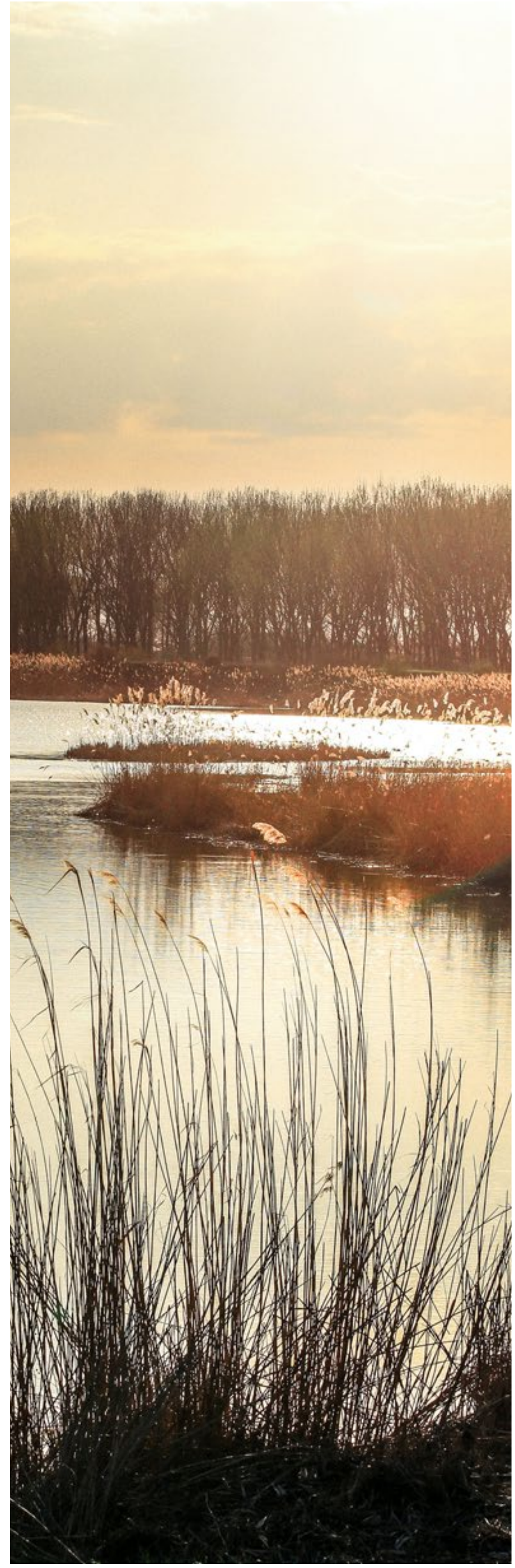
The volume of manure produced must be determined in order to calculate storage requirements. Manure production rates for various livestock species and production systems can be found in Appendix B4. Alternately, manure production rates from a similar existing operation may be used, following an engineering evaluation, as long as they are clearly referenced in the design.

Uncovered liquid manure storage systems must also hold the accumulated precipitation for the period of September 1st through May 31st of each year. Total precipitation amounts over this time period can be calculated from Environment Canada's "Climate Normals" data available online.

Appendix B contains a worksheet and examples to calculate manure accumulation and size manure storage systems.

3.1.2 Environmental Risk Mitigation

Although manure has many beneficial uses, large, concentrated amounts can pose risks to the environment. These risks are mitigated by following guidelines for proper siting and engineering requirements, including consideration of local surface and groundwater conditions. To mitigate the impact of a potential spill, producers should have an Emergency Spill Action Plan (see Appendix F).



Groundwater

Manure liquids that seep into groundwater can contaminate groundwater and drinking water wells. Groundwater contamination can happen quickly when manure finds its way into the water table via highly permeable soils, a poorly sealed well, or fractured bedrock. It can also happen slowly as liquid from leaking storage systems infiltrates the soil over many years. This type of contamination is particularly problematic as it may not be detected for a long time and could take decades to fix.

Surface Water

Manure that leaks from storage systems due to containment breaches or overflows can be disastrous. Microorganisms and nutrients in the manure create conditions in watercourses, estuaries, and wetlands that can kill fish and subsequently poison other plants and animals.

Where groundwater or surface water are contaminated with manure, a producer may be held liable for civil damages or face charges under provincial and federal environmental regulations. **In the event of a spill of any kind, it should be reported to provincial environmental authorities immediately.** Refer to Section 3.5 for more information on spills from manure storage systems.

3.1.3 Siting

Proper siting of a manure storage system is important to protect sensitive natural resources, mitigate odour nuisances with neighbours, and provide a safe and functional system for farm operations. A site assessment of soil, bedrock, and groundwater conditions should be completed by a qualified professional engineer to ensure that the site is suitable for the type of storage planned.

Manure storage systems must be set back a minimum of 90 m (300 feet) from any water wells, watercourses, and wetlands[4]. Where geographical features, property boundaries, or existing operations preclude meeting this setback, authorization from the provincial government is required.

Manure storage systems should be located close enough to barns or confinement areas to allow for convenient filling and still permit future expansion of the facilities. They should be safely accessible for pumping and filling field spreading equipment. Solid manure storage systems should be located in an area that does not collect water and any run-on water should be diverted away from that area.

Minimum Separation Distances (MSDs) determine the required distances between livestock operations and other non-agricultural land uses. Separation between livestock operations and neighbours is intended to compensate for normal odour production, reducing potential conflicts. MSDs apply only to livestock operations. It is not used to calculate separation distances from uses such as kennels, apiaries, greenhouses, mushroom farms, or slaughterhouses.

MSD requirements for livestock operations apply to new and expanding manure storage systems and change of use operations, but not to existing operations. Existing livestock operations that do not meet MSD requirements, and would like to expand, will be considered and reviewed on a case-by-case basis. The views of residents and businesses that are within the MSD of an expanding livestock operation will be given due consideration during the review process.

Beneficial Management Practice

Take precautions to prevent backflow in manure transfer pipes by maintaining an air gap between the outlet of the transfer pipe and the main storage. Backflow can cause serious damage to buildings, livestock, and the environment.

In some jurisdictions, a two-way approach to Minimum Separation Distance is used. New non-agricultural developments must maintain a setback from existing livestock operations or enter into an agreement that acknowledges and accepts the nuisances associated with being situated near a livestock operation.

Tables and calculations for MSD requirements including example worksheets can be found in Appendix C.

[4] Set out in the Prince Edward Island *Water Act*

3.2 Liquid Manure Storage Systems

The moisture content of manure affects its consistency and is the most important single factor when considering the selection of handling equipment and storage facilities. The following section details the requirements for new liquid manure storage systems.

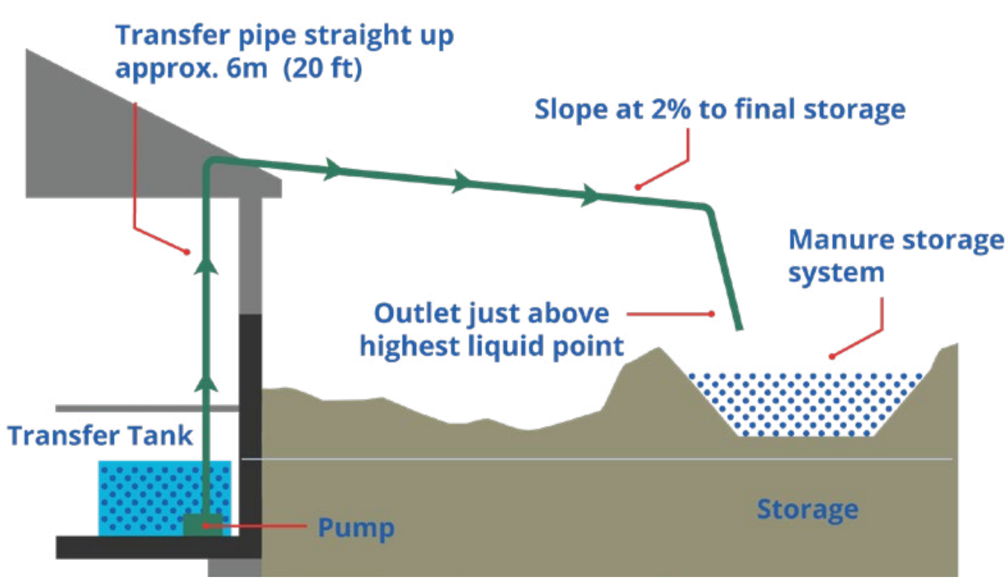
Liquid manure is moved into storage either by mechanical means or by gravity. Gravity systems have no operational cost and are typically more reliable than other systems. However, topography and manure quantity and consistency does not always allow for it.

Liquid manure is typically handled by pumps, if gravity is not an option. These mechanical systems require regular maintenance and electric power to operate. Pumps may be used to move manure from a barn to a storage system that is almost any distance away. In some instances, a very high moisture manure, such as hog manure, can be pumped kilometres away through a pipeline. Where manure is pumped across properties or public roads, additional permits may be required.

When transferring manure to a storage system at a higher elevation, steps must be taken to avoid backflow in the system that could result in serious damage to buildings, livestock, and the environment. Mechanical one-way valves are discouraged as debris in the manure may keep the valve open and create backflow. The safest method is to have an air gap between the outlet of the transfer pipe and the main storage. A common method to transfer manure to a higher elevation is to pump straight up approximately 6 m (20 ft) and then have the pipe slope at a 2% grade to the manure storage system (Fig. 3). When the pump completes a cycle, some of the liquid drains back into the transfer tank but the remaining liquid drains to the main storage. This also prevents manure from freezing in the pipe.

Filling manure storage systems from above the surface exposes manure to the air and will result in increased odour production. Although the increased odour is undesirable, safe operation is the most important factor in the design of a transfer system.

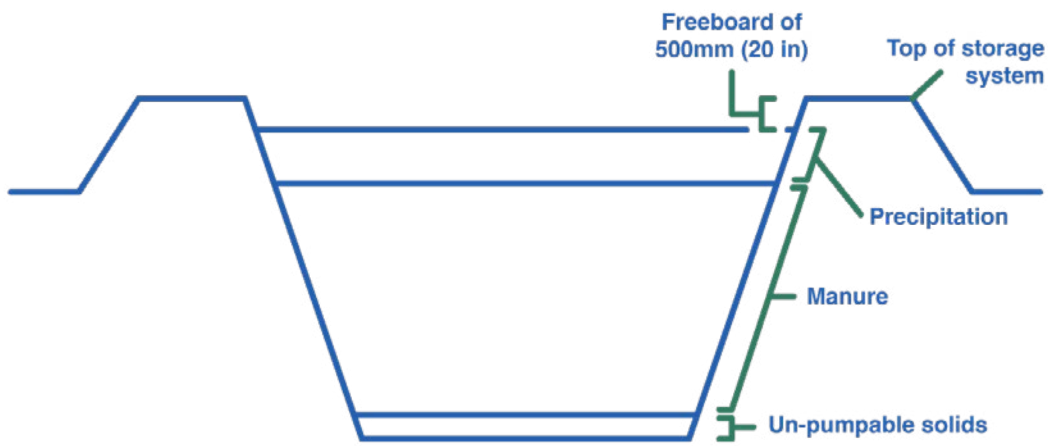
Figure 3: A transfer system that pumps manure straight up and then into the manure storage at a 2% slope prevents backflow.



Freeboard

In addition to the volume of manure calculated in Section 3.1.1, a liquid manure storage must have some reserve capacity, called freeboard, to allow for greater than normal precipitation events during the storage period.

Liquid manure storage systems should have a clearly visible mark showing freeboard to indicate to the producer when the storage is 'full' so that a freeboard of 500 mm (20 in) is maintained at all times. This freeboard must be part of the storage design and exclusive of the calculated required storage. It is not a 'reserve' for extra manure. Liquid manure storage systems with a permanently installed, non-permeable cover are permitted to have a reduced freeboard of 150 mm (6 in).



Liquid Manure Storage Safety

Liquid manure storage systems pose significant safety risks. To mitigate these risks, the following is required[5]:

- A sign warning of dangerous gases shall be installed at every access point to a liquid manure storage tank or under-floor manure transfer chamber.
- For uncovered liquid manure storage systems located outdoors, a permanent safety fence or wall shall be provided that extends to not less than 1500 mm (5 ft) above adjacent grade, is adequately secured at ground level and has gates with latches.
- Where an access point for filling, agitation, emptying or a similar operation exists, a curb or barrier shall be installed between the access point and the storage that is not less than 450 mm (18 in) or of sufficient height to prevent unintended vehicle entry.
- Ladders shall not be installed in closed manure tanks.
- Covers weighing less than 20 kg (45 lbs) providing access to liquid manure storage tanks shall be secured with locking devices.
- Effective gas traps shall be provided in all liquid manure lines between the livestock building and outside liquid manure storage system.
- If animals are housed directly above the manure storage, they should be removed while agitating and pumping or exhaust fans should be run at full capacity.
- Where sumps and holding tanks are located inside a building, a continuously running ventilation system that removes manure gas shall be in place.

5 ASABE EP470.1 – Manure Storage Safety.

Beneficial Management Practice

Monitor the level of manure in a liquid storage system and pump out a portion of the contents when it reaches the freeboard height of 500 mm (20 in) from the top of the storage system.

For manure storage systems that include deep pits and covered tanks, producers should follow the safety guidelines for confined spaces set out in the *Occupational Health and Safety Act.*

See Section 3.2.5 for additional in-barn liquid manure storage system safety precautions.

3.2.1 Concrete Liquid Manure Storage Systems

Concrete manure storage tanks are more costly than earthen storage systems, however, they typically have a more compact footprint and will collect less rainwater. They may also be constructed below or above grade to accommodate different topography or groundwater conditions.

Concrete tanks require design by a qualified professional engineer to withstand all live, earth, hydrostatic, and ice pressure loads. Engineers shall design concrete manure storage tanks to the latest standards referenced in *Part 2 – Farm Buildings* of the latest edition of the *National Building Code of Canada.*

All new or modified concrete manure storage systems must have a base that is no less than

- 500 mm (20 in) above bedrock unless an alternative liner method can be used to protect the groundwater;
- 500 mm (20 in) above the seasonal high level of the water table.

Beneficial Management Practice

Maintain the berms around earthen manure storage systems. Preventing the growth of shrubs and trees will protect liner integrity.

3.2.2 Earthen Liquid Manure Storage Systems

Earthen liquid manure storage systems are a cost-effective way of storing manure and, if engineered and constructed correctly, provide the same level of environmental protection as other options.

As earthen storage systems are constructed with natural materials, it is important to ensure that they will be capable of minimizing potential surface or groundwater pollution. The following minimum design and construction standards shall be used. For more detailed design guidelines, engineers are directed to consult the Atlantic Canada Water and Wastewater Association's most recent version of the *Atlantic Canada Wastewater Systems Guidelines* document.

Clay Liners

Clay liners should be a minimum of 500 mm (20 in) thick for storage floors and 700 mm (28 in) thick for walls to allow for weathering, variations in actual thickness, and pockets of poor-quality material. Alternately, a clay-core dyke may be constructed that is well-keyed into the bottom liner, at a minimum thickness of 3000 mm (10 ft).

To ensure effective sealing, natural clay material used as a liner must satisfy the maximum hydraulic conductivity requirements specified in Appendix D1. Liner material should be placed in maximum 150 mm (6 in) layers and compacted to at least 98% of the material's Standard Proctor Maximum Dry Density.

Field and laboratory testing must be carried out under the supervision of a qualified professional engineer during construction of the storage and liner. A completed Field Review of Construction Declaration must be provided upon completion (see Appendix A4).

For further engineering design guidance on clay liners, see Section 8.6.7 Design & Construction Procedures for Clay Liners in the ACWWA – *Atlantic Canada Wastewater Systems Guidelines.*

Synthetic Liners

If the storage is sited on soils which do not meet the requirements of Appendix D1 or, where suitable clay liner material is unavailable locally, the storage may be lined with a poly liner, synthetic membrane, concrete, or a combination of the above. A suitable leak detection system is recommended in combination with a synthetic liner.

Synthetic liner systems must be designed, and their installation carried out, under the supervision of a qualified professional engineer. Declaration of such shall be provided by the engineer upon completion (see Appendix A2).

Side Slopes Stability

To allow for long-term slope stability and to facilitate placement of liners and cover material, inside slopes should not be steeper than 2:1. Outside slopes should not be steeper than 3:1 and should be seeded with grass and maintained to prevent damage of the liner by tree root systems. To ensure structural stability and prevent leakage, built up berms must be placed in maximum 300 mm (12 in) layers and compacted to at least 98% of the material's Standard Proctor Maximum Dry Density.

Berm Width

Berms should have a top width not less than 2400 mm (8 ft) in order to provide sufficient stability to the berm as well as access for agitation, pumping, and mowing equipment.

Erosion Protection

Concrete pads should be installed below inlets and at agitation/pump out points to reduce the loss of clay liner material or damage to synthetic liners.

All new or modified earthen manure storage structures must have a base (measured from the bottom elevation of the liner) that is no less than:

- 1000 mm (40 in) above bedrock;
- 1000 mm (40 in) above the maximum seasonal high water table.

The lateral distance from an earthen manure storage to a working subsurface (tile) drain should be a minimum of 15 m (50 ft). It is recommended that tile drainage locations be confirmed by excavation prior to constructing a new storage or modifying an existing storage. Decommissioned tile lines should be fully removed and soil should be properly compacted when tile lines are removed.

Beneficial Management Practice

Cover manure storage systems to reduce odour and greenhouse gas emissions and to prevent precipitation from entering the storage system.

3.2.3 Manufactured Liquid Manure Storage Systems

There are several pre-engineered manure storage options. Although typically more costly, these systems offer the advantage of being quick and efficient to construct. The most common of these are above-ground tanks made from glass-coated steel or stainless steel. The height of these tanks is typically greater than concrete tanks and therefore have a very compact footprint for saving space and catching less rainwater. These tanks may have built-in agitation and pumping systems. Pre-engineered manure storage systems must be supplied with drawings sealed (stamped) by a professional engineer and site work requires design by a professional engineer.

3.2.4 Covers for Liquid Manure Storage Systems

Covering liquid manure storage systems is recommended. Common types of covers include negative pressure floating contact covers, inflatable domes, and traditional roof structures. A roof that covers a tank or slatted floor system eliminates precipitation from a storage system, reducing fuel and labour costs when spreading manure and capital costs when constructing a storage system. Impermeable covers also dramatically reduce odour nuisance and greenhouse gas emissions[6] and prevent dilution of nutrients in manure, making the end product more valuable as a fertilizer.

Retrofitting covers on existing storage systems can add manure storage capacity by removing rainwater from the capacity calculation and allowing freeboard requirements to be reduced to 150 mm (6 in). Retrofitting impermeable covers on existing storage systems is not always possible as accumulated gases may react with the tank material. It is recommended to consult a professional engineer when adding a cover to an existing manure storage system.

6 Ammonia and Greenhouse Gas Emissions from Slurry Storage - A Review. Agriculture, Ecosystems and Environment. 2020

3.2.5 In-Barn Liquid Manure Storage Systems

In-barn liquid manure storage is most commonly used in hog facilities but is also found in some dairy and indoor confinement beef operations. This storage system has the advantages of being covered and not requiring any complex mechanical systems to gather the manure. However, there are challenges with these systems – firstly, air quality for barn workers and animals can be a problem; secondly, any operations that need to be done under the floor will be complicated by the confined space of the manure storage.

In-barn liquid manure storage systems should be designed to eliminate human activity in the under-floor space. Entering under-floor manure store systems is extremely dangerous due to the presence of hydrogen sulphide (H_2S). H_2S is heavier than air, flammable in high concentrations, and can be fatal within minutes.

Refer to Section 3.2 for additional safety information in liquid manure storage systems.

3.3 Solid Manure Storage Systems

Solid manure systems are most common in sheep, beef, and poultry operations. The requirements for handling and storage components are described in this section.

Solid Manure Handling Systems

Transfer of manure from a confinement area to long-term storage usually includes the use of either a conventional continuous chain barn cleaner, a shuttle cleaner, a tractor with loader, a ram pump, or a compressed air pump system. In poultry operations, caged layer manure is collected on a belt system directly below the birds and transported to a pile, often in a structure directly attached to the barn.

Beneficial Management Practice

Design in-barn liquid manure storage systems to eliminate human activity in the under-floor space. The greatest danger from enclosed liquid manure storage systems are high concentrations of H_2S, which are not detectable and can be fatal.

3.3.1 In-Barn Solid Manure Storage Systems

It is common for some types of livestock to spend the entire winter season on a bedded manure pack where bedding is added at intervals and builds up over time. This is considered a solid manure storage system. These types of barns will be designed with sufficient depth to store the entire season's worth of manure. The bedded manure pack will typically be cleaned out with a loader tractor and the manure stockpiled nearby for land application. Some designs only allow for a few months' worth of manure pack buildup.

In the case of broiler chickens and similar types of poultry, bedding is placed at the beginning of a cycle and removed after the flock has been transferred out of the barn. A sub-compact tractor may be used to clean out the barn and the manure stockpiled for land application.

3.3.2 Pads and Push Walls

Where stockpiled, solid manure should be stored on a curbed, concrete pad, either with or without a roof. A concrete pad is beneficial as earthen pads tend to rut and become uneven and slippery in wet conditions.

Solid manure storage systems that do not have a concrete slab base should have a minimum of 500 mm (20 in) of compacted earth (95% Standard Proctor Maximum Dry Density) to provide an expected hydraulic conductivity of $1x10^{-7}$ cm/sec to prevent leachate from entering the groundwater. Refer to Appendix D1 for recommended particle size analysis.

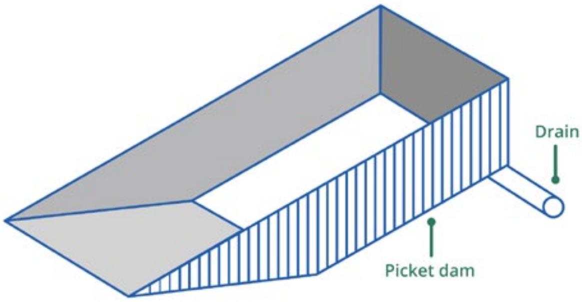
In order to contain the manure and prevent runoff, an earthen berm in combination with a 1200 mm (4 ft) reinforced concrete push wall is recommended. By sloping the floor to one corner opposite the entrance ramp, excess liquids can be removed for land application. Emptying the storage is usually done with a loader tractor. Up slope surface water should be diverted away from the storage.

Beneficial Management Practice

Transfer manure from the barn to the storage system as often as possible, especially during the summer, where the manure will remain cooler.

Solid Manure Storage with Push Wall

Solid Manure Storage with Curb



3.3.3 Picket Dams

Picket dams are similar in design to the simple concrete pad and push walls described in Section 3.3.2 but provide storage while allowing water to drain away. They are constructed on a concrete pad surrounded by a heavy treated timber fence. The gaps between the fence pickets allow moisture and rainwater to leach away leaving the manure drier and easier to handle. Ditches on either side of the storage carry the water away to an engineered vegetated filter strip or an engineered wetland before it returns to the environment. The overall structure allows more solid manure to be stacked in a smaller footprint.

3.3.4 Run-on and Runoff Control

Run-on control

Overland water flow should be directed away from temporary and long-term solid manure storage systems, composting sites, and outdoor exercise yards. This can be achieved through natural or constructed surface water control systems or a combination of both types of systems.

Runoff control

Runoff should be treated as liquid manure. Runoff control methods such as catch basins, vegetated filter strips, and constructed wetlands should be employed to collect and manage liquids. The 1:30 year storm event should form the basis for calculating the size of these systems. They should be lined with a material having an expected hydraulic conductivity of $1x10^{-7}$ cm/sec. A freeboard of 500 mm (20 in) is recommended for catch basins. Runoff catch basins should be pumped to empty and applied as soon as is reasonable after a storm event and the effluent handled as liquid manure.

Systems such as vegetated filter strips or constructed wetlands may also be considered for treatment of runoff from solid manure storage systems. Runoff from livestock feedlots should be handled like runoff from a solid manure pile.

See Section 4 for more information on treating manure runoff.

3.3.5 Short Term and Field Storage

Solid manure may be stored in fields prior to land application. When using field storage for solid manure without effluent containment on a soil base, the following practices are recommended:

- The manure pile should be located on a suitable site which will reduce the potential for surface water and groundwater contamination.
- The manure pile must maintain a minimum separation distance of 90 m (300 ft)[7] from all watercourses, lakes, ponds, natural wetlands, residence(s), public buildings, residential wells or as specified in a municipal well field protection plan.
- The manure pile should be placed to avoid runoff into public road ditches and maintain a minimum separation distance to a public road of 30 m (100 ft).
- The manure pile should not be located in areas where there is accumulated run-on or areas that are subject to water ponding or flooding.
- Up slope surface water should be diverted away from the pile.

3.4 Manure Storage System Maintenance

All manure storage systems should be periodically inspected, whether they are used or not, to determine if they are structurally sound, if enough capacity exists to prevent overflowing, and if all safety components, such as hatches, railings, and fences, are present and in good repair.

Visual Inspection

Frequent visual inspections should be conducted to assess the general condition of a storage system. Inlet points, connections, and areas where walls intersect with each other or the base should be checked. Cracks, erosion, or areas of concern should be documented with photographs that can be used for comparison over time or shared with a professional if necessary. To allow for inspection, areas around a storage system should be regularly mowed and kept free from brush and trees. Any animal burrows, particularly near earthen storage berms, must be addressed.

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[7] Set out in the Prince Edward Island *Water Act*

Run-On

Surface water conditions around a manure storage system should be checked to see that water is running away from or around the system. Areas such as exercise yards and compost piles should be checked for water run-on from other areas. This is particularly important during the spring melt season when surface water is abundant.

Mechanical Check

There are often mechanical parts of a manure storage system that are only used during spreading, pumping, or agitation. This infrequently used equipment should be checked and tested well in advance of its required use. If preventative maintenance is required, it should be completed at this time to reduce the chance of mechanical failure during operation and give sufficient time for repairs.

3.5 Spills from Manure Storage Systems

A modern, properly engineered, manure storage system will have a low potential for spills resulting from system failure. Older, inadequately sized, or poorly sited manure storage systems, however, may be prone to leaks that result in groundwater contamination or breaching, where manure or manure liquids enter the environment. Any of these situations can be classified as a spill.

All producers should have an Emergency Spill Action Plan. Details of how to prepare these plans can be found in Appendix F1.

3.6 Decommissioning Manure Storage Systems

3.6.1 Suspending Use Indefinitely or Temporarily

There is no limit to how long a manure storage system can be temporarily taken out of use, providing it is maintained in a state of good repair.

Beneficial Management Practice

A well thought out Emergency Spill Action Plan will mitigate risks and help ensure that spills are contained and managed quickly and efficiently.

Solid Manure Storage Systems

To temporarily decommission a solid manure storage system, empty the storage of all manure materials using normal handling equipment and field apply as per guidelines (see Section 5.5). Conduct regular inspections of the system to verify its integrity and ensure that potential runoff is properly managed.

Liquid Manure Storage Systems

To temporarily decommission a liquid manure storage system, empty the storage of manure materials using normal handling equipment and field apply as per guidelines (see Section 5.5). To minimize risks to the environment, producers should consider the following recommendations, where applicable:

- Maintain a minimum depth of liquids above the floor and surrounding groundwater in the system over the winter period to avoid frost damage.
- Maintain a minimum freeboard of 500 mm (20 in) at all times. Producers can expect an uncovered storage to slowly fill with precipitation over time, requiring partial emptying on a periodic basis.
- Conduct a visual inspection at least once a year to check for potential structural concerns and to ensure that all safety hazards are addressed.
- Ensure the gravity transfer systems associated with the storage system are properly decommissioned to minimize the risk of injury to anyone or damage to the equipment. Check with the manufacturer for recommendations. Do not create a trapped zone of liquid in a sealed pipe; these zones can develop high gas pressure over time, causing valves to stick or pipes to fail, even causing dangerous explosions if inadvertently moved.

3.6.2 Recommissioning an Existing Manure Storage System

Before returning an existing manure storage system to use, the storage system needs to be inspected inside and out, including any liners and transfer systems. Producers should beware of potential hazardous gas trapped in storage systems that have not been used for a period of time and take necessary safety precautions before entering a storage system.

To complete a thorough inspection, the storage system must be emptied. It is important that the system is not emptied when the water table is higher than the floor of the storage to prevent structural damage.

During the inspection, any signs of damage should be noted, such as:

- cracks
- deteriorating concrete, steel, or liner
- liquid seeping through cracks
- uneven surfaces

Where pipe sections penetrate a wall or floor, producers should ensure that joints between the pipe and tank wall or floor are watertight. If a tank includes a liner, the liner's integrity should be evaluated.

A storage system that has not been used for a period of time may have damage that cannot be seen and may leak to an existing drainage system outside the storage system. It is best to find any outside drainage systems and install an observation/shut-off catch basin into the outlet of the drainage lines. If this is not possible while filling the storage system, it is important to monitor the levels of the storage system and monitor the outlet of any drainage system that could affect the storage. Steps should be taken to remedy any problems immediately.

If there are any concerns about the integrity of the system, liner, or transfer system, consult a professional engineer.

3.6.3 Permanent Decommissioning

Before permanently decommissioning a manure storage system, alternate uses should be considered. For example, a solid manure storage system could serve as a foundation for a covered hay storage structure or a machinery storage. If no alternate uses are available, it is recommended that the storage be properly decommissioned with the following steps:

- Apply all remaining organic materials that remain inside the storage to the land as per guidelines (see Section 5).
- Remove and/or cut off and block all associated transfer piping and equipment to prevent leaks.
- Dispose of all other materials according to provincial regulation.

Steel or Concrete Storage Systems

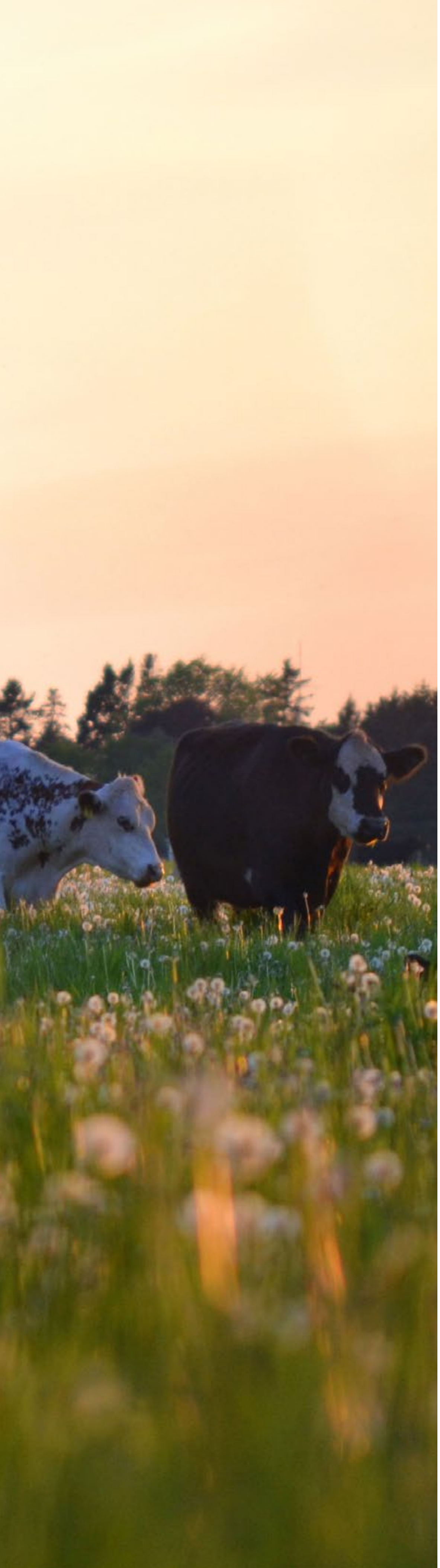
Concrete storage systems should be dismantled and buried on-site. A qualified demolition company can perform the work and ensure that burial of the material does not adversely impact ground or surface water. Steel manure storage systems may be dismantled and recycled. The following steps are recommended:

- Collapse the tank walls onto the floor if the tank is below grade. Destroy the integrity of the floor and walls so that they do not interfere with natural water flow and/or site drainage. Where applicable, recycle steel components.
- Cover the storage site with clean soil or fill material that has a similar permeability to surrounding soil. If the tank is above grade, truck the concrete material elsewhere on the site for use as an inert fill.
- Mound fill above original grade to compensate for settling and top dress with 150 mm (6 in) of topsoil.
- Establish vegetation.
- Do not allow water to pond above the site.

Earthen Storage Systems

For on-site decommissioning of earthen storage facilities, the following steps are recommended:

- Fill storage with clean fill in layers 150–300 mm (6–12 in) thick and compact each layer.
- Mound fill above original grade to compensate for settling and top dress with 150 mm (6 in) of topsoil.
- Establish vegetation, possibly a deep-rooted crop such as alfalfa.
- Do not allow water to pond above the site.



4.0 TREATING YOUR MANURE

The purpose of a treatment system is to convert manure to a more desirable product. The treatment process may be designed to mitigate odour problems, recover nutrients, produce energy, increase the fertilizer value, reduce the volume, or decrease the environmental risk of the manure.

This section will outline the following treatment systems and the feasibility and advantages and disadvantages of each system: composting, anaerobic digestion, manure separation and dehydration, aeration, acidification, constructed wetlands, and vegetated filter strips.

Beneficial Management Practice

Treat your manure to reduce odour and create a higher value product with less potential for environmental contamination.

4.1 Composting

Composting is a process in which microorganisms convert organic material into a soil-like product called compost. This is the same process that decays leaves and other organic debris in nature. Composting merely controls conditions so that materials decompose faster and at a more predictable rate. **Allowing a manure pile to rot without controlling conditions is not composting.**

The physical properties and nutrient content of finished compost are typically quite different from the initial mixture. Moisture evaporates, carbon breaks down, and some volume is lost as carbon dioxide. Through this process, the compost pile volume and weight decreases and concentrates valuable nutrients. Although some nitrogen is lost to the atmosphere, much of it will be converted to more stable, slow releasing organic forms. Composted manure typically releases about 15% of the stored nitrogen in the first year, compared to over 50% for raw manure.

The rate at which manure will compost depends on:

- Moisture content;
- Relative quantities of carbon and nitrogen (C:N ratio) available to the aerobic microorganisms;
- Oxygen level available;
- Size of manure and feedstock particles;
- Temperature in the compost.

Although the composting process releases carbon dioxide, it also reduces potential emissions of the greenhouse gases methane and nitrous oxide compared to stored solid manure.

Windrow/Pile Composting	Windrow composting involves the placement of manure on an all-weather surface in long rows. The piles are turned periodically to mix and introduce air and rebuild bed porosity. This helps to ensure that all the material is uniformly composted. Although mixing can be accomplished with regular farm equipment, the use of specialized equipment is usually more efficient (i.e. compost turners). Windrow composting is relatively simple and inexpensive and usually takes one to four months, depending on the frequency of turning. Some composting operations use active aeration (forced air pipes) or passive aeration (perforated pipes inserted in the piles). An even simpler option is static pile composting. This option requires very little management but has the disadvantages of producing a very inconsistent product, requiring a long period of time, and being suitable only for large piles.
In-Vessel Composting	This system yields the most uniform product and is highly managed through a system of built-in active aeration and purpose-built turning equipment. There is typically a high initial cost to this type of system, including an enclosed building, compost containment bunkers, and pre-cast aeration duct work. Finished compost can be created in a matter of days. Some in-vessel compost systems create enough heat to be used for space heating. After leaving the vessel, the compost material goes through a curing phase for up to three months, followed by a maturing phase where the compost becomes soil organic matter or 'black earth'.
Vermicomposting	Vermicomposting is composting using worms – typically 'red wigglers'. Worms are added to feedstock material and will digest the organic material and leave worm castings in its place. Although this type of composting does not yield high temperatures, there is good evidence that a high proportion of pathogens and seeds are killed. Producers may sell the mature worms for fishing bait as another income stream.

Advantages

- Reduces potential emissions of methane and nitrous oxide
- Reduces moisture and volume by up to 50%, resulting in reduced transportation costs
- Substantially reduces odours within a few days
- Reduces environmental risks as manure is converted to more stable and environmentally-friendly components
- Can reduce soil-borne plant diseases
- Reduces weed seed viability
- May be used as a bedding substitute

Disadvantages

- Releases carbon dioxide
- May have a high initial cost, depending on system used
- Changes availability of manure for land application
- Requires time and management

4.2 Anaerobic Digestion

Anaerobic digesters are used to produce and recover methane gas from the decomposition of manure. This is typically called a biogas system. The methane gas is burned in a generator to produce electricity and heat or burned through a boiler or furnace system as a heat source for on-farm buildings. Larger systems can also use scrubbers to produce a natural gas equivalent, commonly called Renewable Natural Gas (RNG). After digestion is complete, the liquids and solids are available for land application. Typically, the resulting nutrients are high in available nitrogen.

Advantages

- Can be a valuable resource for electricity and heat generation
- Reduces pathogens, viable weed seeds, and odour
- Potential for capture and sale of RNG
- Potential for additional income by introducing off-farm waste streams
- Separated solid digestate (the material left after digestion) can be used for green bedding

Disadvantages

- High capital cost
- Requires considerable management and expertise

4.3 Manure Separation

Manure can be separated into its solid and liquid components, allowing for different treatment processes. Common types of mechanical separators are screen separators, centrifuges, hydrocyclones, and presses (screw or belt types). The liquid remaining after separation is less concentrated and will produce less odour when it decomposes. Depending upon the degree of separation, the solids may be dry enough to be composted and the remaining liquid will be easier to handle when spreading on the land or aerating.

The solid fraction of a separation system can be used as 'green bedding' in barns. This can be a supplement to fresh straw or shavings-based bedding. It is important to use manure solids relatively quickly as green bedding may develop harmful pathogen levels as it is an 'untreated' product. It also may heat and begin composting.

Advantages

- Reduces bedding costs, as sand and straw bedding can be reused after separation
- Land application of liquid portion is easier with solids removed
- Longer hauling distances are possible at lower costs

Disadvantages

- High costs that cannot be fully recovered from the sale of the final product
- Requires two separate manure handling systems

4.4 Aeration

Aeration is the process of mixing air into liquid manure to promote aerobic bacteria growth. Effective aeration systems result in a homogeneous liquid, rich in stable organic nitrogen compounds. Aeration eliminates the need for liquid manure storage agitation and the potential release of methane and other greenhouse gases, as well as hydrogen sulphide, a known contributor of offensive odours from livestock operations.

Advantages

- Very effective odour control
- Reduction in greenhouse gas emissions

Disadvantages

- Significant operational energy cost

4.5 Acidification

Emerging research on manipulating the pH of liquid manure storage systems has produced data demonstrating significant reduction in greenhouse gas emissions and nutrients lost to volatilization. As acidification techniques and other research emerges, it is recommended that producers consult engineers and industry specialists to investigate these new management techniques and their implications for facility design and manure management.

4.6 Constructed Wetlands

A constructed, or engineered, wetland for manure liquid treatment is a shallow, man-made marsh designed, built, and operated to mimic the processes found in natural wetland ecosystems. These systems use wetland plants, fauna, microorganisms, and soil filtration to remove contaminants from manure liquids and create or restore valuable wetland habitat for wildlife.

Constructed wetlands have been proven effective as secondary and tertiary treatment systems for many types of wastewater such as milk house wastewater, manure liquid, food processing effluent, and general surface runoff.

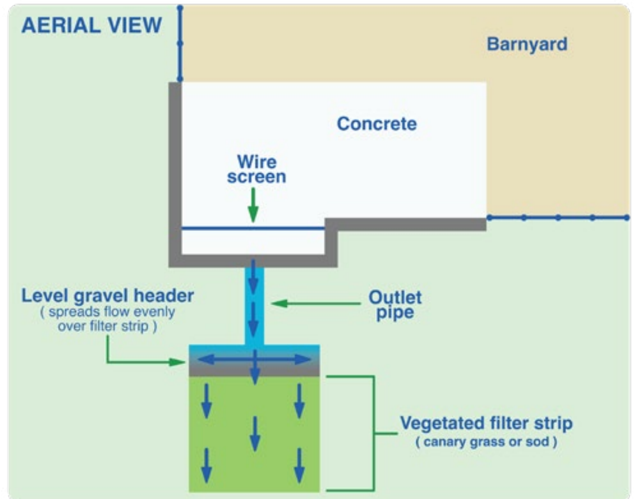
Advantages

- Helps protect the environment and surface and groundwater resources from contamination
- Provides wildlife habitat and has an appealing appearance
- Naturally low-maintenance

Disadvantages

- High capital cost

4.7 Dispersion Trenches and Vegetated Filters Strips



Dispersion trenches are used to treat runoff from manure storage systems. By using the natural contours of the site or shaping the land, a series of low sloped trenches or paths are formed. Dispersion trenches are typically a series of stepped trenches in a 'hairpin' configuration. A long trench system is created in a relatively small parcel of land.

Vegetated filter strips (VFS) are permanent, maintained strips of vegetation designed to reduce and minimize the impact of nutrients and other contaminants found in liquid runoff. VFS systems collect, temporarily store, and regulate flow rates and transport manure liquids from outdoor solid manure storage areas (i.e. solid manure storage systems, compost sites, and livestock enclosures) to and through a treatment and infiltration system.

VFS systems work well for small and medium-sized operations. Typically, a larger operation would be better served by a constructed wetland or a large containment pond.

Advantages

- Contains all the runoff received during a rainfall event and empties slowly through infiltration
- Does not need to be emptied after each major rainfall event

Disadvantages

- Requires regular maintenance, including mowing and landscaping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01/23

5.0 LAND APPLICATION OF YOUR MANURE

As discussed in the introduction to these guidelines, manure is a valuable resource producers can use to improve soil health. Proper land application of the manure is critical to ensure the maximum benefit to the crop is achieved, nuisance odours are minimized, and excess nutrients and greenhouse gases are not released in a way that will harm the environment. This section details planning considerations and practices that will help producers achieve these aims when spreading manure. Topics include nutrient management, application timing, transportation, equipment, methods of spreading liquid and solid manure, separation distances, and record keeping.

5.1 Planning

To effectively apply manure to cropland, producers must have the information and tools required: how much manure is available to spread, the nutrient content of that manure, and when, where, and how to spread it.

5.1.1 Manure Volume

In order for producers to know how much manure they have available to spread in a given year, the total annual volume must be calculated. There are two approaches to this – calculating the volume of manure in storage or estimating annual production using spreading records. Stored manure volumes can be estimated using methods described in Appendix E1; however, it may be difficult to use storage numbers to calculate annual production as the current stored volume will represent only a snapshot of production. Most producers spread at different times during the year and have manure production that varies throughout the season.

Where past data is available, the number of spreader loads per annum can be used to calculate Annual Manure Volume using the spreader's average volume capacity, as shown below:

Annual Manure Volume (m^3) = # of Loads × Average Spreader Capacity (m^3)

Annual Manure Volume, in m^3, needs to be converted to mass, in tonnes, for nutrient management purposes, since manure analyses are expressed on a mass basis.

Annual Manure Mass (tonnes) = Volume (m^3) × Manure Density (tonnes/m^3)

Manure Density varies substantially both by livestock species and farm practices. It is best to calculate density using actual samples (see Appendix E1). The following table, however, shows typical ranges.

Manure Type	Manure Density (tonnes/m^3)
Liquid	1.00
Solid	0.560 – 0.800

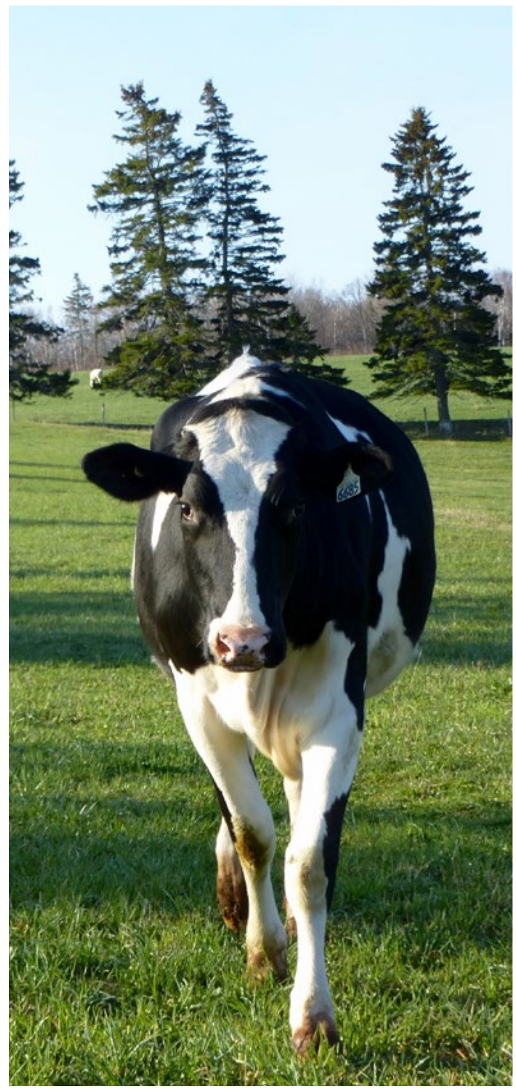
Once the Annual Manure Mass is estimated, the Annual Nutrient Production for any nutrient found in manure can be calculated as follows:

Annual Nutrient Production (kg) = Annual Manure Mass (tonnes) × Nutrient Concentration (kg/tonne)

Although typical manure nutrient concentrations are available from baseline data, the amount of a given nutrient in manure is best determined by lab testing. The following section details how to obtain this information.

Beneficial Management Practice

Sample and test manure for nutrient content to determine correct application rates.



5.1.2 Manure Testing & Baseline Data

Regular manure testing is the most reliable method to determine the nutrient value of manure. Although average published nutrient values of manure are available from the PEI Department of Agriculture, these values should only be used to determine application rates when on-site manure testing has not yet been completed. Nutrient content values can vary significantly by farm and within the same commodity type. Even small differences between actual and estimated nutrient levels can result in under or over-application of manure during spreading.

Example PEI Average Nutrient Content Values for Solid and Liquid Manures from the PEI Manure Nutrient Analysis Survey Project, 2023

	Dry Matter %	C:N Ratio	Nitrogen		P %	K %
			Ammonium-N %	Organic-N %		
Solid Manure						
Beef	22.7	15.7	0.04	0.5	0.1	0.4
Dairy	23.5	14.3	0.05	0.5	0.1	0.5
Poultry (litter pack)	53.5	6.6	0.5	2	0.9	1.4
Liquid Manure						
Dairy	6.0	9.0	0.1	0.08	0.04	0.2
Swine	2.6	2.6	0.2	0.01	0.04	0.2

*The nutrient analysis presented above is expressed on an "as received" or "as is" basis.

To gather good quality samples on-site, producers should follow the procedures below:

Liquid Manure

Multiple samples should be taken from the manure spreader at various times during the application process and aggregated to best represent the manure that will be spread. It is recommended to wait a minimum of 8-10 hours after agitating liquid manure before spreading or testing. Taking aggregate samples from a liquid manure storage system is hazardous and is not recommended.

Solid Manure

Manure piles can usually be sampled at any time of year when manure is not frozen. Multiple samples from different areas of the pile should be taken and aggregated to get the best representation of the manure that will be spread.

Contact the PEI Analytical Laboratories (PEIAL) for recommended sampling and submission procedures.

Interpretation of Manure Analysis Testing

PEI Analytical Laboratories (PEIAL) and other analytical labs offer various manure testing packages. A package that includes ammonium analysis is recommended for all manure types. Ammonium levels are necessary to estimate plant available nitrogen for crops when determining nitrogen availability to the crop from manure after land application. Manure analysis tests can be requested by filling out a Special Product Analysis request form at PEIAL.

Beneficial Management Practice

Collect liquid manure samples during spreading.

Interpretation of Manure Analysis Testing

Special Products Test Report

PEI MANURE NUTRIENT CONTENT SURVEY
PO BOX XXXX
ADDRESS
CHARLOTTETOWN PE
C1A 7N8

PEI Analytical Laboratories
PEI Department of Agriculture and Land
23 Innovation Way
PO Box 2000. Charlottetown, PEI, C1A 7N8

Fax: (902) 368-6299
Telephone: (902) 620-3300

Prince Edward Island CANADA

Client: 123456
Accession: 1234
Samples Reported: DD/MM/YYYY
Samples Received: DD/MM/YYYY

2

Analysis Performed	Lab# 5486-1 Sample: Liquid Dairy Type: Sample Id:	Sample Type: Sample Id:	Sample Type: Sample Id:	Sample Type: Sample Id:
Dry matter %	7.47			
Carbon %	2.77			
CN Ratio%	9.22			
Nitrogen %	.30			
Phosphorus%	.05			
Potassium %	.28			
Calcium %	.10			
Magnesium %	.05			
Copper ppm	2.48			
Zinc ppm	12.95			
Ammonium %	.16			

3

1

Comments:
Samples are reported on an "as received" basis using the dry ash method for analysis.

Date of analysis: DD/MM/YYYY

1 Samples "as received"

Test results are reported on an "as received" basis, which includes the water contained in the manure as submitted. The analysis also measures the dry matter percentage.

2 Client and Sample Identification

Client	Identifier assigned to the producer by the lab
Accession	Unique number assigned to a specific sample
Samples reported	Date the analysis was performed
Samples received	Date the sample was received

3 Manure Test Results

Dry Matter %	Dry matter refers to the dry weight of the manure after the water has been removed. Dry matter is reported as a percentage of solids.
Carbon %	Carbon percentage relates to the amount of total carbon present in the manure.
C:N Ratio	Carbon to nitrogen ratio. This number is helpful to determine if nitrogen will be available to crops immediately after land application. See Section 2.4 for more information on the C:N ratio.

Macronutrients	Nitrogen, phosphorus, potassium, calcium, and magnesium are reported as total percentages and include forms that are available and unavailable to crops. See Section 2.2 for more information on nutrients in manure.
Phosphorus %	Total phosphorus is reported as P. To convert P to the fertilizer equivalent form of P_2O_5 for nutrient recommendations, multiply the P value by 2.29.
Potassium %	Total potassium is reported as K. To convert K to the fertilizer equivalent form of K_2O for nutrient recommendations, multiply the K value by 1.2.
Micronutrients	The micronutrients included in the analysis example are copper and zinc. Contact PEIAL to find out about testing for other micronutrients. See Section 2.2.5 for more information on micronutrients in manure.
Ammonium	Ammonium is a form of nitrogen that is immediately available to crops after land application.

5.1.3 Spreading Agreements

Although many livestock operations are connected to an adequate land base to apply all the manure produced, some producers may require additional land for spreading or be situated near crop producers who would like to share the benefits that manure brings to soil health. To this end, livestock operations can enter into written agreements with other landowners for the land application of manure.

It is recommended for spreading agreements to have a minimum duration of two years and reference the management practices detailed in these guidelines.

Landowners will be more likely to renew an agreement if their land receives benefit from the manure. Unevenly applied manure, damage to property, and complaints from neighbours may cause the landowner to discontinue an agreement. Proper soil and manure testing, development of a nutrient management plan, and uniform, non-compacting application will maintain good relationships.

5.2 Nutrient Management

Nutrient management involves applying nutrients from manure to the soil as efficiently as possible to improve crop yields and protect the environment. Balancing nutrients applied to the soil with crop requirements is the key to effective nutrient management. When applied at the right times and in the right amounts, these added nutrients help achieve optimum crop yields.

A nutrient management plan (NMP) is a document used by a livestock operation that identifies specific fields and crops to receive additional nutrients to meet crop needs through commercial fertilizers, manures, other amendments, and/or a combination of these. **Nutrient management guidance provided in this document should not replace a professionally prepared NMP.**

Effective nutrient management with regards to livestock operations and manure management includes the following steps:

1) Calculate the manure nutrients available on the livestock operation annually, using localized data from testing (see Sections 5.1.1 and 5.1.2).

2) Identify crops to be grown in fields receiving manure and determine the crop nutrient requirements. Crop nutrient requirements are based on predicted yields, soil test results, and crops to be grown.

3) Calculate the manure application rate based on the crop requirements, as well as other considerations, including the soil test results, manure analysis, and planned commercial fertilizer application amounts. On fields receiving manure, use commercial fertilizers only as needed, by calculating the difference between total crop requirements and the amount of nutrients supplied by the manure. Rotate fields receiving manure to avoid nutrient buildup.

Beneficial Management Practice

Develop a nutrient management plan to help achieve optimum crop yields and reduce environmental risks.

Beneficial Management Practice

Keep good records. Record the actual manure application rate on each field.

Beneficial Management Practice

Apply manure to an actively growing crop or within 30 days of planting.

Barley			
	N	P_2O_5	K_2O
L-	50	100	100
L	50	75	100
M	50	50	75
M+	50	50	50
H	50	25	25
H+	50	25	0

Broccoli			
	N	P_2O_5	K_2O
L-	150	400	220
L	150	300	150
M	150	200	150
M+	150	200	150
H	150	150	100
H+	150	100	50

The tables above are an example of Nutrient Recommendation Tables that are available on-line from the PEI Department of Agriculture. All table values are based on soil testing rating tables used by PEI Analytical Laboratories. Fertility recommendations are in kg/ha.

Fields with the lowest soil tests for P and K and where crops with the highest N demand are grown are usually the areas that will benefit the most from the land application of manure.

5.2.1 Nitrogen and Phosphorus Levels

The proportion of nitrogen and phosphorus in manure seldom matches crop nutrient requirements. If manure is applied to meet only the crop nitrogen requirements, there will normally be an excess of phosphorus applied. Similarly, if manure is applied to meet only the crop phosphorus requirements, there will be a shortfall in the nitrogen available to the crop and supplemental inorganic nitrogen will need to be added to make up the shortfall.

Producers should be aware of the dangers of over-application of both nutrients. Phosphorus that is not used by the crop will build up over time in the soil and increase the risk of runoff to surface water. Nitrates that are not used by the crop can easily be transported to groundwater via leaching through the soil profile and can eventually make their way to surface waters.

Both phosphorus and nitrates in surface waters can result in reduced oxygen levels and increased risk of algal blooms that subsequently have negative effects on aquatic life and fish populations. On PEI all drinking water comes from groundwater wells so this type of contamination is very harmful. To avoid these environmental impacts, manures and fertilizers should be carefully applied to meet crop requirements.

The Phosphorus Index (P-Index) is a risk assessment tool to help evaluate the potential risk to the surrounding environment when applying manure to the land. The following table is a management guideline for manure application based on PEI soil P-Index levels. It is recommended to consult this table when considering manure application rates to assess a field's potential risk for phosphorus loss. For P-Index values within the High Risk Class or greater, seek professional agronomic advice in terms of manure application rates and crop requirements to prevent further risks associated with increased soil phosphorus levels. Contact a representative at the PEI Department of Agriculture for more information on phosphorus levels and the P-Index. [8]

[8] The document "Determining Phosphorus Fertilization Requirements for Potatoes based on Phosphorus Saturation Index for PEI" is available from the PEI Department of Agriculture for more information.

Phosphorus Management Guideline

Risk Class	P-Saturation Index (% P/Al)		Threshold Interpretation
	For soils with pH < 5.5	For soils with pH > 5.5	
Very Low Risk	0-7	0-4	No restriction on phosphorus application.
Low Risk	7-11	4-7	
Moderate Risk	11-19	7-14	Possible risk to surface water. Monitor soil phosphorus accumulation.
High Risk	19-21	14-16	Adverse impact to surface water. Prevent further increases in soil phosphorus accumulation.
Very High Risk	21-30	16-23	Adverse impact to surface water. Phosphorus application determined by crop removal.
Extremely High Risk	>30	>23	

Beneficial Management Practice

Adopt 'Good Neighbour' practices. Be considerate when using fields a short distance upwind of neighbours and try to spread when weather conditions will minimize odours (cool and windy mornings).

5.3 Timing

The timing of manure land application is critical to achieve the best results. Land application in cool conditions results in less odour and nutrient loss compared to warm humid conditions.

Manure should not be applied on wet, saturated soils to avoid compaction and runoff.

Spring application of manure is most desirable as nutrient availability in manure is closely related to the time of crop uptake. Generally, manure should be applied to an actively growing crop or within thirty days of planting. Land application at other times during the year has a higher risk of nutrient loss.

Seasonal Considerations for Land Application

Season	Recommended Practices	Risks to Consider
Spring	• Apply to crops with the highest nitrogen requirement; high-yielding crops use N more efficiently (monitor soil P levels). • Apply to row crops as side dressing after plants emerge (dribbling). • Apply to land designated for annual crops before seeding. • Apply to well-drained soils.	• Loss of N to atmosphere on moist, poorly drained soils and cold, wet soils. • Odour. • Wet soils are prone to compaction. • Planting too soon after heavy manure application can create ammonia toxicity and reduce germination and seed growth.
Summer	• Apply liquid manure to grassy pastures and hay fields – land is dry and less prone to compaction. • Apply liquid manure to forage and pastures to be reseeded/rotated. • Side dress liquid manure on row crops. • Apply liquid manure on cereal stubble. • Apply liquid manure to forage crops as soon as possible after harvest and before re-growth. • Apply to grasslands. • Apply to pasture early to avoid trampling regrowth.	• Rill erosion and runoff along injection strips. • "Smothering" of forages (mainly an issue with solid manures not spread uniformly and/or spread at high rates). • Loss of N if there is no rainfall within 72 hours of manure application. Rain helps nitrogen soak in.
Fall	• Apply solid or liquid manure prior to seeding winter cereals or cover crops. • Apply manure after harvest and incorporate manure within 24 hours of application, if early in fall and erosion risk is low. • Apply to annual crop land that will be planted with winter cover crops.	• Risk of ammonia loss if not incorporated, no rain and temperature is >10°C. • Risk of leaching if not absorbed by actively growing crop cover – avoid application on sandy soils. • Risk of denitrification and compaction on cold, wet and poorly drained soils. • Manure that soaks in too slowly on wet fields is at risk of runoff. • Risk of soil erosion after manure incorporation if tilled late in the fall.
Winter	• Do not apply manure to frozen or snow-covered ground.	• Manure applied to frozen or snow-covered ground will cause runoff. • Wet soils are prone to compaction.

Source: Adapted from Best Management Practices: Manure Management. OMAFRA

Manure should not be applied to frozen or snow-covered ground. In case of emergency winter application, the following steps are recommended:

- Apply on level fields and non-sensitive areas.
- Reduce application rates.
- Increase setback distances from surface water.
- Avoid spreading on land with a history of runoff.
- Apply to fields with heavy crop residue or seeded to perennial forages or winter cover crops where there is less possibility of runoff or flooding.

Beneficial Management Practice

Avoid applying manure to wet soils to prevent nutrient loss, runoff, and soil compaction.

5.4 Transportation

Transporting manure to fields involves the use of heavy equipment or pipes. The main risks associated with manure transportation are related to human safety and the environment. These risks can be mitigated by correctly operated, well-maintained equipment.

Equipment should be mechanically sound with properly operating brakes and equipped with appropriate safety features such as tire chains, signals, marker lighting, and driver restraints. Equipment should be appropriately sized for manure loads and topography.

Beneficial Management Practice

Avoid surface application on steeply sloping lands adjacent to watercourses, lakes, ponds and wetlands.

Producers should avoid hauling manure over fields as much as possible to prevent soil compaction. The compaction caused by tankers can be minimized by using large flotation tires and applying manure when fields are dry.

If manure is transported to fields by pipe or hose, pumps and piping needs to be regularly monitored for proper operation and leaks. While in operation, the system must be carefully monitored. If a sudden drop in pressure or flow rate at the application point occurs, the system should be stopped and checked for leaks.

Permanent manure transfer pipeline systems should be designed by a professional engineer. Piping systems should be designed to meet all applicable regulations and consider environmental risks. Pressure sensors, safety shutoffs, and other risk-reducing equipment should be installed. Larger systems may require more than one operator to monitor the system effectively and communicate hazards and problems. Manure transfer pipeline systems require an Emergency Spill Action Plan (see Appendix F1).

5.5 Manure Spreading

Choosing the method of manure application depends on the physical characteristics of manure (solid or liquid), the type of livestock operation, manure handling and storage, type of spreader, and cost. Manure application technology should meet the criteria for practicality, durability, desirable distribution pattern, and minimal environmental impact.

Beneficial Management Practice

Calculate proper application rates and calibrate equipment.

5.5.1 Calibration

The key to any application method is proper calibration. Calibration ensures that equipment will uniformly deliver manure nutrients at the desired rate. If a spreader is not calibrated, application rates will not be accurate.

Contact the PEI Department of Agriculture for more information on manure spreader calibration. Two common calibration techniques are described in the table below:

Beneficial Management Practice

Maintain good surface crop residues on fields prior to application.

Technique	Method
Load Area Method	Estimate the weight or volume of manure in a loaded spreader and then determine the area to spread the entire load.
Weight Area Method	Weigh the manure spread over a known area to calculate the rate at which the manure was applied.

5.5.2 Liquid Manure Application

Liquid manure is commonly transported to fields by tankers or drag hose systems for land application.

A liquid manure tanker is a pull-type or self-propelled machine that carries and distributes manure over fields. In general, manure tankers require less time to set up than a drag hose system and are more suited to fragmented farms divided by physical barriers or properties not under a farmer's control. However, this transportation method is time and fuel intensive and increases the likelihood of soil compaction.

Beneficial Management Practice

Maintain a grassy separation along watercourses.

Drag hose systems typically consist of a series of pumps and drag hoses that run across the land to transport manure to fields where it can be applied. When maintained and used properly, drag hoses do not pose a high risk to the environment; however, producers should be aware that an improperly functioning system could quickly create severe environmental hazards in the event of a failure.

Once transported to a field, liquid manure can be surface applied or injected directly into the soil. Broadcast, injection, or dribble bar/trailing shoe systems are common technologies used to spread liquid manure. Irrigation spreading is not recommended on PEI due to excessive odour production and high nutrient loss due to volatilization.

Type	Description	Considerations
Injection	Uses discs, cultivators, or knives to open soil for application below the surface of the soil.	• Low runoff potential • Low odour • Low nutrient loss • Requires more horsepower and fuel than other application methods • High maintenance costs • High initial equipment cost
Dribble Bar/Trailing Shoe	Uses bar or boom with drop hoses that 'dribble' manure onto the soil. Can be applied to standing crops.	• Low to medium runoff potential • Low to medium odour • Low to medium nutrient loss to volatilization • Requires less horsepower and fuel than injection • Lower maintenance cost than injection • High initial equipment cost
Broadcast	Applies manure on soil surface, and/or crop, or crop residue. Can be applied to standing crops.	• High runoff potential compared to other applications methods • High odour • High nutrient loss • Requires the least amount of horsepower, fuel, and time of all application methods • Lowest maintenance cost • Lowest initial equipment cost • Requires a second pass to incorporate manure

Manure should be incorporated as soon as possible after spreading. The longer manure remains on the surface without incorporation the higher the risk of nutrient loss and excessive odour.

Nitrogen Loss by Percentage Based on Weather Conditions and Incorporation

Method of Application	Weather Conditions				
	Average	Cool Wet	Cool Dry	Warm Wet	Warm Dry
Injected	0	0	0	0	0
Incorporated 1 day	25	10	15	25	50
Incorporated 2 day	30	13	19	31	57
Incorporated 3 day	35	15	22	38	65
Incorporated 4 day	40	17	26	44	72
Incorporated 5 day	45	20	30	50	80
Not Incorporated	66	40	50	75	100
Irrigated	Above +10%	Above +10%	Above +10%	Above +10%	Above +10%
Standing/Cover Crop/Stubble	35	25	25	40	50

MARC 2008. Manure Application Rate Calculator software for Manitoba, Manitoba Agriculture, Food and Rural Initiatives.

5.5.3 Solid Manure Application

Solid manure is spread using broadcasting equipment followed by tillage to incorporate the manure into the soil. **Manure should be incorporated as soon as possible after spreading.** The longer manure remains on the surface without incorporation the higher the risk of nutrient loss and excessive odour.

Spreading solid manure evenly can be a challenge. The majority of older or lower-cost manure spreaders do not adequately chop manure to prevent large lumps from being deposited. These lumps create uneven fertility, take longer to breakdown, and may cause issues with other equipment being used in the field. Solid manure spreaders with better chopping action reduce this problem.

Beneficial Management Practice

Incorporate soon after spreading (within 24 hours if possible) to increase nutrient retention and reduce odour.

5.5.4 Separation Distances

A land application separation distance is the minimum distance maintained between application areas and areas that may be vulnerable to water contamination to reduce the potential for contaminants reaching ground or surface water.

Beneficial Management Practice

Follow setbacks and recommended separation distances.

The slope of the land must also be considered when spreading manure. As the slope increases, the chance that manure may run off increases, so application rates should be reduced and distances from watercourses and wetlands increased. Sloping land should be maintained with a reasonable amount of crop cover to provide protection against manure runoff.

To reduce the risk of contaminating surface water or wells, the separation distance acts to absorb runoff and prevent it from travelling down slope. The effectiveness of this separation area depends on factors such as soil conditions and application rates. Good judgment must be used in all cases to ensure that runoff does not enter surface water or wells.

Separation Distances for Land Application

Distance From	
Residences and businesses	Spread to Property Line
Watercourse or wetland boundary [9]	15 m (50 ft)
Flowing watercourse where slope of land adjacent to the watercourse is less than 5%	30 m (100 ft)
Flowing watercourse where slope of land adjacent to the watercourse is 5% or greater	60 m (200 ft)

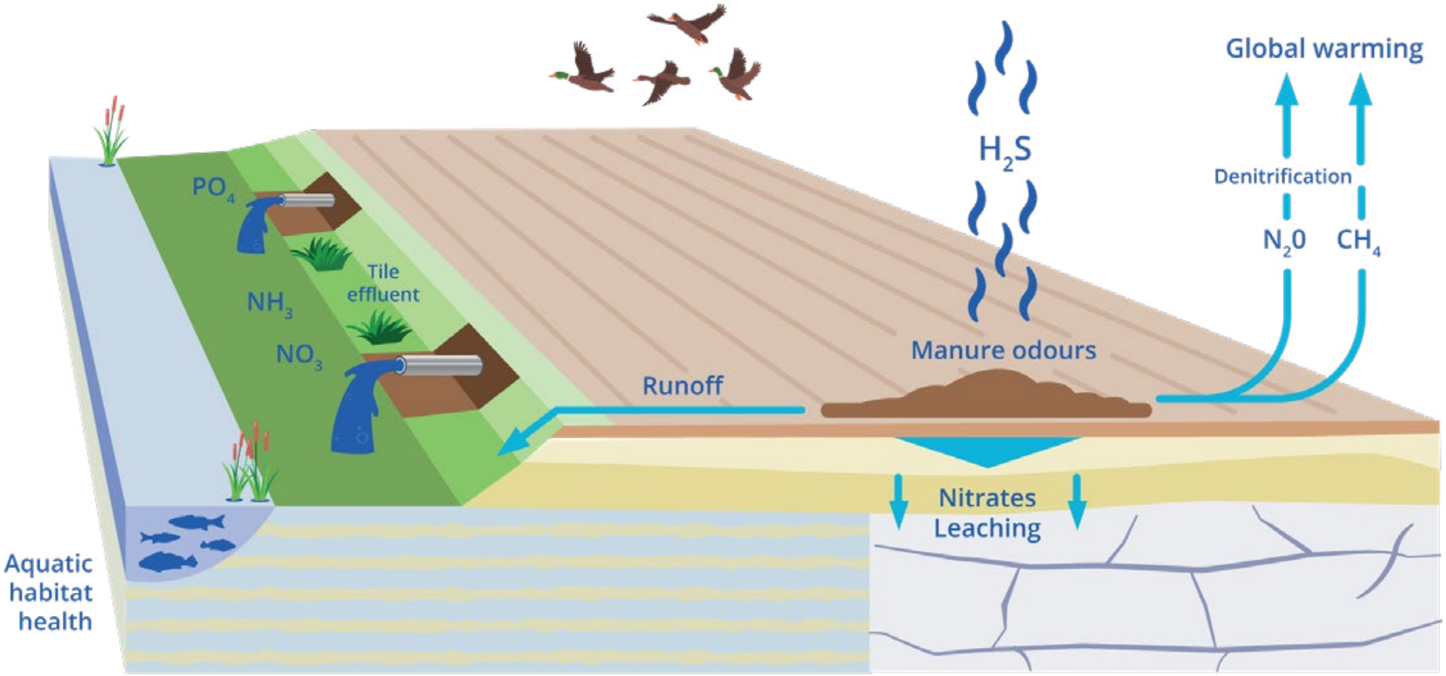
5.6 Record Keeping

Producers should keep detailed records during land application. Thorough record keeping is critical for forward planning as described in Section 5.1.1 and ensures proper manure application and field distribution. It also provides the producer with written records that clearly indicate guidelines were followed, in the event of environmental contamination or other conflicts. Records should include dates, locations, products, crops, weather conditions, and rates of application.

5.7 Environmental Risk Mitigation in Land Application

Ensuring that manure application does not degrade environmental conditions should be a primary goal in field application. In addition to risks to aquatic life described previously, bacteria and viruses may be introduced to the environment, increasing the potential for disease spread. In some cases, diseases can be introduced to livestock through their feed and potentially passed on through their manure to humans, other livestock, or to plants through the soil. Producers should be aware of the potential diseases that their feed or bedding sources can carry, give consideration to the risks, and ensure good biosecurity practices when handling and spreading manure. Excessive nitrates from manure leaching into drinking water can create a health hazard for humans and reduce livestock performance.

[9] Set out in the Prince Edward Island *Environmental Protection Act*



Manure Affects the Environment: Manure can improve soil health and provide crop nutrients but becomes an environmental risk if not managed properly.

Groundwater pollution is usually due to the downward movement of nutrients through the soil. If the amount of nutrients added to the soil consistently exceeds the crop demand, accumulation will occur.

Producers should be especially aware of risks to surface water where fields have tile drains installed. Outflow from these systems are a direct connection from soil to surface water. If high nutrient levels are identified at drainage outflows, producers should take immediate action. If problems have occurred in the past, there may be an issue with macropores moving liquids to tiles. Pre-tilling soils or reducing application rates are ways to address this problem.

Beneficial Management Practice

Avoid applying liquid manure when drainage tiles are running. Running tiles indicate that soil moisture content is too high to safely spread manure.

Sensitive Areas

In some areas, soil and groundwater conditions may be especially sensitive to land application. The degree of sensitivity depends on the type and depth of the soils present above an aquifer, the depth of the water table, and the type of vegetation at the soil surface. The surrounding land uses are also an important factor in determining sensitivity to manure application. For example, municipal drinking water supply well fields are considered sensitive areas.

Where very permeable soils such as coarse sands or gravels immediately overlay an aquifer or where the overburden above an aquifer is very shallow, nutrients applied to the soil surface may leach rapidly downward beyond crop rooting depths and reach the aquifer. Since these areas tend to be well drained, crop vegetation is often relatively sparse and plant uptake of nutrients is low.

Where any of these conditions exist, land application should be avoided or greatly reduced from recommended rates. Consult a professional agronomist for site specific recommendations in these sensitive areas before applying manure.

Manure Over-Application

Over-application of manure occurs when manure is deposited in the environment in a quantity that exceeds the rate of nutrient uptake by plants or when runoff carries nutrients away from the intended area during land application. Most often this is a result of an unintentional release of manure.

To avoid an over-application or an unintended release of manure during land application:

- **Spread manure according to the Nutrient Management Plan;**
- **Calibrate application equipment to follow the application rate specified in the Nutrient Management Plan;**
- **Follow setbacks and separation distances;**
- **Avoid spreading before rain events.**

See Appendix F1 for information on Emergency Spill Action Plans.

6.0 LEGISLATION

The following legislation is applicable to manure management:

Building Codes Act, R.S.P.E.I. 1988, cap. B-5.1

Environmental Protection Act, R.S.P.E.I. 1988, cap. E-9

Fisheries Act, R.S.P.E.I. 1988, cap. F-13.01

Farm Practices Act, R.S.P.E.I. 1988, cap. F-4.1

Occupational Health and Safety Act, R.S.P.E.I. 1988, cap. O-1.01

Planning Act, R.S.P.E.I. 1988, cap. P-8

Public Health Act, R.S.P.E.I. 1988, cap. P-30.1

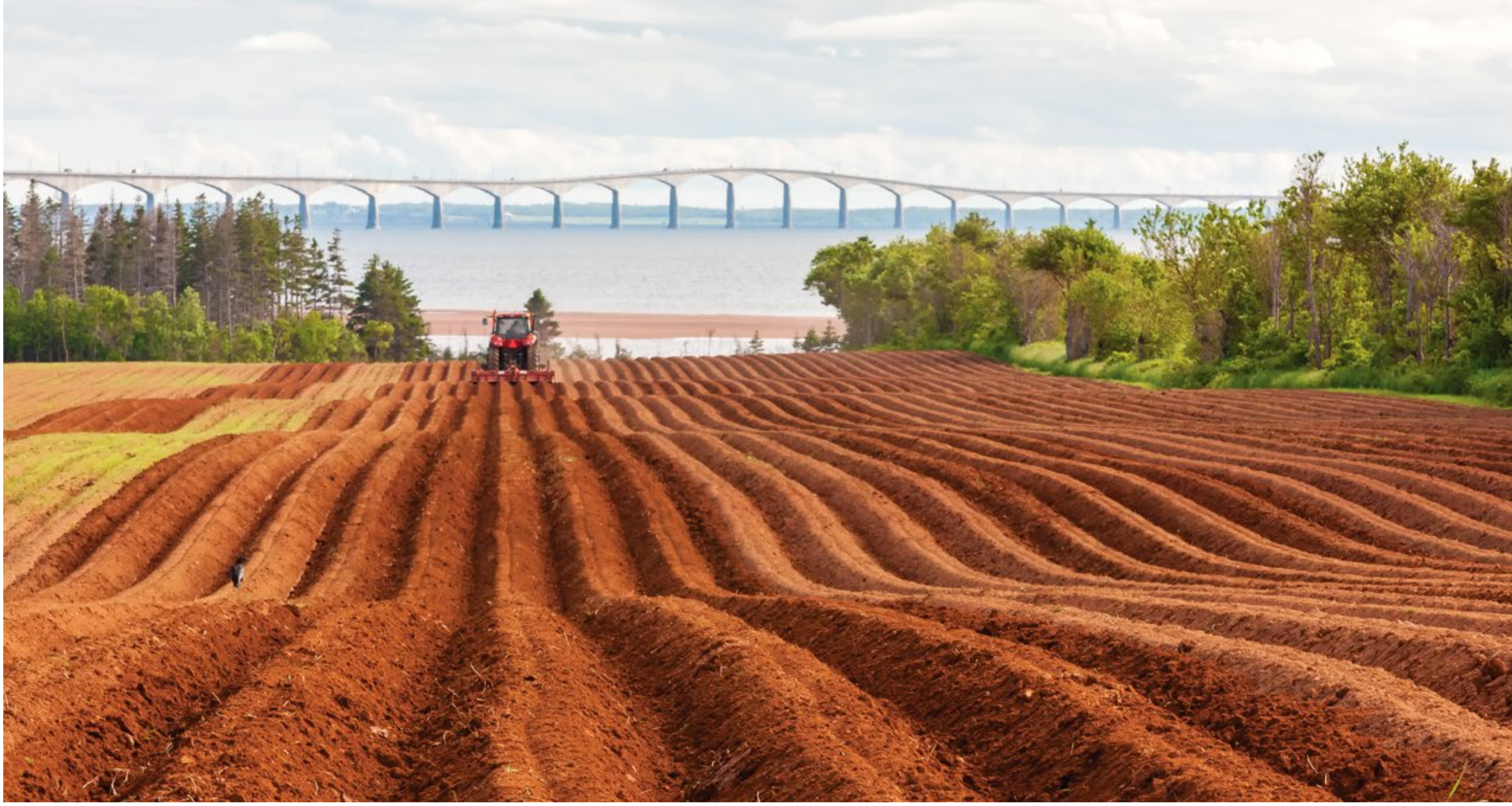
Water Act, R.S.P.E.I. 1988, cap. W-1.1

7.0 DEFINITIONS

BERM	An artificial mound constructed from compacted soil that may be used for such purposes as buffering, retaining agricultural liquid waste, agricultural waste and diverting or stopping surface water.
COMPOSTING	The biological degradation or breakdown of organic matter by a managed process.
CONTAINMENT WALL	A wall, or portion of a wall, designed to carry the loads imposed upon it by the storage of solid manure and to be robust enough to withstand associated mechanical loads such as those generated by machinery impact and abrasion. In the case of a covered manure storage, the containment wall is only that portion of the wall designed to contain solid manure and does not include the portion of the wall that does not act to contain the solid manure.
DEVELOPMENT	Defined in the Planning Act as the locating, placing, erecting, constructing, altering, repairing, removing, relocating, replacing, adding to or demolishing structures or buildings in, under, on or over the land. This applies to manure storage systems.
DEVELOPMENT PERMIT	A permit issued for a DEVELOPMENT under the *Planning Act* regulations or pursuant to a bylaw but does not include a building permit issued under the *Building Codes Act.*
EARTHEN MANURE STORAGE	A structure constructed primarily of earthen materials serving as a manure storage for livestock facilities.
FIELD STORAGE	Remote SOLID MANURE storage location, typically located away from livestock enclosures that allows for short term storage of material prior to field application.
FREEBOARD	Reserve capacity in a MANURE STORAGE SYSTEM to allow for greater than normal precipitation events.
GREENHOUSE GAS	A gas that absorbs and emits radiant energy, causing the greenhouse effect.
GROUNDWATER	Any flowing or standing water below the surface of the earth.
LIQUID MANURE	MANURE that is in a liquid state, predominately found with a dry matter content of 18% or less, and can be characterized as being transported by means of gravity flow or pump.
LIVESTOCK	Includes, but is not limited to, animals commonly referred to as cows, cattle, swine, horses, sheep, goats, and poultry for the purposes of this document.

LIVESTOCK OPERATION	Any enclosure (i.e. yard and/or building) where animals are kept for the purpose of rearing, confinement, or feeding. A MANURE STORAGE SYSTEM for these animals is deemed to be part of the operation. This does not include pastures or grazing areas.
MANURE	Livestock feces and urine, associated feed losses, bedding, litter, soil and wastewater.
MANURE LIQUID	A liquid produced on the farm that requires management and cannot be directly discharged into a watercourse or wetland and includes wastewater, contaminated runoff, and silage leachates.
MANURE STORAGE SYSTEM	A permanent structure, reservoir, catch basin, lagoon, cistern, gutter, tank, or bermed area which can contain manure prior to its use or FIELD STORAGE. This includes in-barn and under-barn solid and liquid manure storage systems.
MINIMUM SEPARATION DISTANCE	A SETBACK established between a livestock facility and adjacent land uses to minimize odour nuisance.
NATIONAL BUILDING CODE OF CANADA	The model building code of Canada. This document refers to the 2020 code or newer.
NUTRIENT UNIT	The amount of nutrients that give the fertilizer replacement value of the lower of 43 kg of nitrogen or 55 kg of phosphate.
PROFESSIONAL ENGINEER	An engineer who is a member in good standing of the Association of Professional Engineers of Prince Edward Island and holds a license to practise issued by the Association.
SETBACKS	The horizontal distance between a lot line or a zoning boundary and buildings, structures, boundaries, and/or areas.
SMALL SOLID MANURE STORAGE SYSTEM	A small solid MANURE STORAGE SYSTEM has a volume less than 600 m^3; a surface area less than 600 m^2; and a containment wall height of 1 m or less.
SOIL HEALTH	The capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health.
SOLID MANURE	MANURE that is in a solid state, predominately found with a dry matter content of greater than 18% and can be characterized as not flowing or releasing MANURE LIQUIDs when piled.
VEGETATED FILTER STRIP	A densely vegetated strip of land engineered and constructed to intercept and treat runoff by settling, filtration, dilution, adsorption of pollutants and infiltration into the soil.
WATERCOURSE	An area which has a sediment bed and may or may not contain water, and without limiting the generality of the foregoing, includes the full length and width of the sediment bed, bank and shore of any stream, spring, creek, brook, river, lake, pond, bay, estuary or coastal body, any water therein, and any part thereof, up to and including the watercourse boundary.

WATERCOURSE BOUNDARY	(i) In a non-tidal WATERCOURSE, the edge of the sediment bed, and (ii) In a tidal watercourse, the top of the bank of the watercourse, and where there is no discernible bank, the mean high water mark of the watercourse.
WELL	An artificial opening in the ground (i) from which water is obtained, (ii) made for the purpose of exploring for or obtaining water, or (iii) made for geothermal purposes.
WETLAND	(i) An area which contains hydric soil, aquatic or water-tolerant vegetation, and may or may not contain water, and includes any water therein and everything up to and including the wetland boundary, and (ii) without limiting the generality of the foregoing, includes any area identified in the Prince Edward Island Wetland Inventory as open water, deep marsh, shallow marsh, salt marsh, seasonally flooded flats, brackish marsh, a shrub swamp, a wooded swamp, a bog or a meadow.
WETLAND BOUNDARY	An area where the vegetation in a WETLAND changes from aquatic or water-tolerant vegetation to terrestrial vegetation or water-intolerant vegetation.



8.0 BIBLIOGRAPHY

Section 2: Know Your Manure

Carbon:Nitrogen Ratios of Organic Amendments, Ontario Ministry of Agriculture, Food and Rural Affairs [https://www.ontario.ca/page/carbonnitrogen-ratios-organic-amendments], 2022

Farm Practice – Odour. British Columbia Ministry of Agriculture [Order No. 870.218-64], 2014

Manure Characteristics. Midwest Plan Service, 2004

Manure Characteristics and Land Base Code. Alberta Agriculture and Rural Development, 2013

Manure Characteristics, Testing and Sampling. Purdue University [ABE-166-W], 2021

Manure Production and Characteristics. American Society of Agricultural and Biological Engineers [ASAE D384.2], 2005

National Inventory Report 1990 - 2020: Greenhouse Gas Sources and Sinks in Canada. Government of Canada: Environment and Climate Change Canada [Report En81-4E-PDF], 2022

Nutrient Management Protocol for Ontario. Ontario Ministry of Agriculture, Food and Rural Affairs [Regulation 267/03], 2007

Odour From a Compost Facility. National Collaborating Centre for Environmental Health, 2018

Properties of Manure. Manitoba Agriculture, Food and Rural Development, 2015

Section 3: Storing Your Manure

Ammonia and Greenhouse Gas Emissions from Slurry Storage - A Review. Agriculture, Ecosystems and Environment. T. Kupper, C Hani, A. Neftel, C Kincaid, M. Buhler, B. Amon, A. VanderZaag, 2020

Atlantic Canada Wastewater Systems Guidelines. Atlantic Canada Water & Wastewater Association, 2022

Closure of Manure Storage Facilities and Manure Collection Areas. Natural Resources Conservation Board [Agdex 096-90], 2018

Environmental Risk Screening Tool. Natural Resources Conservation Board [Version 1.2], 2011

Farm Environmental Management in Canada : Manure Storage in Canada. Statistics Canada, 2003

Farm Structures Factsheet: Manure Storage Structures. British Columbia Ministry of Agriculture [Order No. 383.000-1], 2015

Handling Runoff from Solid Agricultural Source Material Storages and Outside Livestock Areas. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 10-005], 2018

Identifying Manure Storage Facilities and Manure Collection Areas at Confined Feeding Operations. Natural Resources Conservation Board [Technical Guideline Agdex 096-94], 2018

Short Term Solid Manure Storage Requirements. Natural Resources Conservation Board

Siting Requirements for Permanent Nutrient Storage Facilities. Ontario Ministry of Agriculture, Food and Rural Affairs [Agdex 720/538], 2013

Storage of Liquid Manure, Ontario Ministry of Agriculture, Food and Rural Affairs [Order 21-075, Agdex 721], 2021

Storage Structures. Manitoba Conservation, 2007

Technical Reference Document for Liquid Manure Storage Structures: Earthen Manure

Section 4: Treating Your Manure

Composting

Agricultural Composting Basics. Ontario Ministry of Agriculture, Food and Rural Affairs [05–23, Agdex 720/400], 2005

Compost – Basics of On-Farm Composting. New Brunswick Agriculture, Aquaculture and Fisheries, 2015

On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service, Cooperative Extension [NRAES-54], 1992

On-Farm Composting in British Columbia. British Columbia Ministry of Agriculture, 2019

On-Farm Manure Management Through Composting. Nova Scotia Environmental Farm Plan, 2018

Anaerobic Digestion

Anaerobic Digestion Basics, Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 15-031, Agdex 720/400], 2015

Manure Separation

Beneficial Management Practices: Environmental Manual for Livestock Producers in Alberta. Government of Alberta, 2010

Solid-Liquid Separation of Manure and Effects on Greenhouse Gas and Ammonia Emissions. University of Wisconsin-Extension [Factsheet], 2017

Understanding Mechanical Solid-Liquid Manure Separation. Agriculture and Agri-food Canada, 2005

Using Separated Manure Solids for Compost Bedding. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 15-019, Agdex 410/721], 2015

Aeration

Aeration of Liquid Manure. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 04-033, Agdex 743], 2019

Farm Practices Guidelines for Pig Producers in Manitoba. Government of Manitoba, 2007

Manure Storage & Handling – Aeration Overview. Iowa State University [Factsheet AMPAT 14], 2014

Constructed Wetlands

Constructed Wetland Design Manual for Beef and Dairy Farm Wastewater Applications in Ontario. Ontario Rural Wastewater Centre, 2018

Constructed Wetlands for the Treatment of Agricultural Wastewater in Atlantic Canada. Atlantic Committee on Land and Engineering, 2005

Vegetated Filter Strips

Low Impact Development Stormwater Management Planning and Design Guide. Credit Valley Conservation, 2019

Vegetated Filter Strip System Design Manual. Ontario Ministry of Agriculture, Food and Rural Affairs [Publication 826], 2006.

Vegetated Filter Strips Near Surface Water in the Pacific Northwest. Oregon State University [EM 8876-E], 2008

Vegetated Filter Strips Systems for Animal Feeding Operations, Kansas State University Agricultural Experiment Station and Cooperative Extension Work [MF-2454], 2000

Section 5: Land Application of Your Manure

Applying Manure on Frozen or Snow Covered Ground. Natural Resources Conservation Board, 2018

Beneficial Management Practices: Environmental Manual for Livestock Producers in Alberta. Alberta Agriculture, Food and Rural Development [Agdex 13088], 2015

Best Management Practices: Manure Management. Ontario Ministry of Agriculture, Food and Rural Affairs, 2005

Determining Phosphorous Fertilization Requirements for Potatoes Based on Phosphorus Saturation Index for PEI. PEI Agriculture and Fisheries, 2018

Digging into Canadian Soils: An Introduction to Soil Science. Canadian Society of Soil Science, 2021

Land Application Considerations for Animal Manure, MU Extension, University Of Missouri-Columbia, 2018

Land Application of Manure for Beneficial Reuse, US Department of Agriculture [Publication #220388], 2006

Manure Management for Farms Producing More Manure Than Their Crops Need. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 05-025, AGDEX 743/530], 2019

Manure Spill Prevention and Response. Alberta Agriculture, Food and Rural Development [https://www.alberta.ca/manure-spill-prevention-and-response]

Nitrogen Loss by Percentage Based on Weather Conditions and Incorporation. Manure Application Rate Calculator Software for Manitoba. Manitoba Agriculture, Food and Rural Initiatives, MARC 2008

Removing Liquid Manure from Storage. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 14-027, Agdex 743], 2014

Sustainable Animal Manure Management Strategies and Practices IntechOpen, 2018

Tri-Provincial Manure Application and Use Guidelines. Government of Manitoba, 2005

Winter Application of Manure and Other Agricultural Source Materials. Ontario Ministry of Agriculture, Food and Rural Affairs [Factsheet 10-073, Agdex 720/538], 2010

9.0 APPENDICES

APPENDIX A1: Engineer's Commitment Declaration

Preamble

Manure storage systems requiring a development permit must be designed by a qualified Professional Engineer licensed to practice in the Province of Prince Edward Island.

Professional engineers are required by their regulations and bylaws to ensure the general public of competent standards and ethical conduct in engineering. As such, manure storage systems designed in conformance with the minimum standards of the *Guidelines* must have sufficient drawings and documents to show how these standards have been met.

Section 3 of the *Guidelines* require the manure storage system to be reviewed at intervals appropriate to the stage of construction to determine general compliance with the design drawings (and all revisions).

Completed commitment declarations for these field reviews of construction may be submitted to any party requiring confirmation that the system has been completed in conformance with the *Prince Edward Island Manure Management Guidelines.*

To Whom it May Concern:

Re: ____

(date)

____

(address of project)

____

(name of project)

____

(description of project)

This is to advise that I am the professional engineer appointed by the owner to perform the field review of construction for this project.

I hereby declare that:

1. The manure storage system has been designed in conformance to the *Prince Edward Island Manure Management Guidelines* and the codes referenced therein;
2. I will coordinate the review of any changes to the design drawings to determine that the changes conform to the *Guidelines*; and
3. I will complete the *Field Review of Construction Declaration.*
4. Please be advised that I may delegate some or all of my duties associated with the field review of construction to another person employed by me or my firm where it is consistent with prudent professional practice to do so. All delegated functions will be performed under my supervision in accordance with the *Engineering Profession Act.*

(print name) (signature) (initials) (print name of firm or company) (company COA number) (print address line 1) (print address line 2) (postal code) (telephone) (email)	Affix below the seal of the licensed professional engineer in accordance with provincial legislation.

APPENDIX A2: Field Review of Construction Declaration

To Whom it May Concern:

Re: ____

(date)

____

(address of project)

____

(name of project)

____

(description of project)

I hereby declare that I have fulfilled my obligations for the field review of construction as defined in the commitment declaration for this project, and advise that I have reviewed the work at intervals appropriate to determine substantial compliance with the design drawings (and all revisions).

____________________ (print name) ____________________ (signature) (initials) ____________________ (print name of firm or company) ____________________ (company COA number) ____________________ (print address line 1) ____________________ (print address line 2) (postal code) ____________________ (telephone) ____________________ (email)	Affix below the seal of the licensed professional engineer in accordance with provincial legislation.

APPENDIX B1: Manure Storage Volume Worksheet

Step 1 – Storage System Type

- Determine storage system type (solid or liquid) and the required number of days of storage.

Manure Storage System Type (solid or liquid, covered or uncovered)	
Manure Storage Period (days of storage required)	

Step 2 – Volume of Manure

- Determine volume of manure, bedding, and wastewater. Be sure to include all sources that will be added to the manure storage system.
- Using data from Appendix B4 for manure production rates, calculate the accumulated volume for storage.

(A)	(B)	(C)	(D1)	(D2)	(D)	(E)	(F)	(G)
Livestock Type	Livestock Weight (kg)	Livestock Number	Liquid Manure Production Rate (m^3/1,000 kg/day)	Solid Manure Production Rate (m^3/1,000 kg/day)	Total Manure Production Rate (m^3/1,000 kg/day) (D1+D2)	Storage Period (days)	Utilization Factor (see Appendix B4)	Volume* (m^3)
							Total Volume (all livestock types) Add values in Column (G)	

**Volume (G) = [Livestock Weight (B) × Livestock Number (C) × Manure Production Rate (D) × Storage Period (E) × Utilization Factor (F)] ÷ 1000*

Step 3 – Uncovered Storage

- Add accumulated precipitation for storage period as noted below.
- Precipitation data can be found on Environment Canada's website under "Climate Normals".

Location	
Area of Storage	
Storage Duration	

Month	Monthly Precipitation (mm)	Copy Storage Months Here*
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Total		

**Copy only months where storage occurs (typically September 1st - May 31st for 270 day liquid storage systems).*

Precipitation Volume (m^3) = Total Precipitation (mm) ÷ 1000 (mm/m) x Total Surface Area (m^2)

Step 4 - Total Storage Volume

Manure/Wastewater/Bedding Volume (Step 2)	
Precipitation Volume (Step 3)	
Total Storage Volume	

Total volume will be calculated differently for solid and liquid manure storage systems. Uncovered liquid manure storage systems must contain all precipitation for the storage months used in the calculation above, whereas solid manure storage systems may be designed to allow for drainage of precipitation to a runoff catch basin or engineered treatment system and that system must be designed to consider total annual precipitation volumes.

Total Storage Volume = Manure Volume (Step 2) + Precipitation Volume (Step 3)

Include freeboard height in the final design after the storage dimensions are determined (see Guidelines Section 3.2).
500 mm (20 in) for open topped storage systems
150 mm (6 in) for closed top storage systems

For solid manure storage systems, calculate manure volume as per Step 2 and only add precipitation to the total volume required if all precipitation will be detained in the storage system itself.

APPENDIX B2: Liquid Manure Storage Volume Example

Step 1 – Storage System Type

- Determine storage system type (solid or liquid) and the required number of days of storage.

Manure Storage System Type (solid or liquid, covered or uncovered)	Dairy barn, Holstein, liquid manure, uncovered concrete tank. Free stall with sand bedding.
Manure Storage Period (days of storage required)	270

Step 2 – Volume of Manure

- Determine volume of manure, bedding, and wastewater. Be sure to include all sources that will be added to the manure storage system.
- Using data from Appendix B4 for manure production rates, calculate the accumulated volume for storage.

(A)	(B)	(C)	(D1)	(D2)	(D)	(E)	(F)	(G)
Livestock Type	Livestock Weight (kg)	Livestock Number	Liquid Manure Production Rate (m^3/1,000 kg/day)	Solid Manure Production Rate (m^3/1,000 kg/day)	Total Manure Production Rate (m^3/1,000 kg/day) (D1+D2)	Storage Period (days)	Utilization Factor (see Appendix B4)	Volume* (m^3)
Dairy – Milking Age Cows (Large Frame) – Free Stall	700	150	0.12	n/a	0.12	270	1.0	3,402
Dry Cows: Dairy – Milking Age Cows (Large Frame) – Free Stall	700	25	0.12	n/a	0.12	270	1.0	567
Dairy – Heifers Large Frame – Free Stall	295	10	0.07	n/a	0.07	270	1.0	56
Dairy – Calves Large Frame – All	90	10	n/a	0.1	0.1	270	1.0	24
							Total Volume (all livestock types) Add values in Column (G)	4,049

Volume (G) = [Livestock Weight (B) × Livestock Number (C) × Manure Production Rate (D) × Storage Period (E) × Utilization Factor (F)] ÷ 1000

Volume (Row 1) = 700 X 150 X 0.12 X 270 X 1.0 ÷ 1000 = 3,402
Volume (Row 2) = 700 X 25 X 0.12 X 270 X 1.0 ÷ 1000 = 567
Volume (Row 3) = 295 X 10 X 0.07 X 270 X 1.0 ÷ 1000 = 56
Volume (Row 4) = 90 X 10 X 0.1 X 270 X 1.0 ÷ 1000 = 24

Step 3 – Uncovered Storage

- Add accumulated precipitation for storage period as noted below.
- Precipitation data can be found online on Environment Canada's website, under "Climate Normals".

Location	Watervale, PE [Charlottetown, PE]
Area of Storage	35m diameter concrete tank = 962.1 m^2
Storage Duration	September 1 to May 31

Month	Monthly Precipitation (mm)	Copy Storage Months Here*
January	101.0	101.0
February	83.2	83.2
March	86.3	86.3
April	83.7	83.7
May	91.0	91.0
June	98.8	–
July	79.9	–
August	95.7	–
September	95.9	95.9
October	112.2	112.2
November	112.5	112.5
December	118.1	118.1
Total	1,158.3	883.9

Precipitation Vol. (m3) = Total Precipitation (mm) ÷ 1000 (mm/m) X Surface Area (m^2)
= 883.9 ÷ 1000 X 962.1
= 850 m^3

Step 4 - Total Storage Volume

Total Storage Volume = Manure Volume (Step 2) + Precipitation Volume (Step 3)

Include freeboard height in the final design after the storage dimensions are determined (see Guidelines Section 3.2).
500 mm (20 in) for open topped storage systems
150 mm (6 in) for closed top storage systems

Total Storage Volume = 4,409 m^3 + 850 m^3
= 4,899 m^3

APPENDIX B3: Solid Manure Storage Volume Example

Step 1 – Storage System Type

- Determine storage system type (solid or liquid) and the required number of days of storage.

Manure Storage System Type (solid or liquid, covered or uncovered)	Covered manure storage, chicken broilers 2.5–3.0 kg
Manure Storage Period (days of storage required)	270

Step 2 – Volume of Manure

- Determine volume of manure, bedding, and wastewater. Be sure to include all sources that will be added to the manure storage system.
- Using data from Appendix B4 for manure production rates, calculate the accumulated volume for storage.

(A)	(B)	(C)	(D1)	(D2)	(D)	(E)	(F)	(G)
Livestock Type	Livestock Weight (kg)	Livestock Number	Liquid Manure Production Rate (m^3/1,000 kg/day)	Solid Manure Production Rate (m^3/1,000 kg/day)	Total Manure Production Rate (m^3/1,000 kg/day) (D1+D2)	Storage Period (days)	Utilization Factor (see Appendix B4)	Volume* (m^3)
Broiler Chickens 2.5–3.0kg	0.92	7,000	n/a	0.1104	0.1104	270	0.7	134
							Total Volume (all livestock types) Add values in Column (G)	134 m^3

**Volume (G) = [Livestock Weight (B) x Livestock Number (C) x Manure Production Rate (D) x Storage Period (E) x Utilization Factor (F)] ÷ 1000*

Volume (Row 1) = [0.92 X 7,000 X 0.1104 X 270 X 0.70] ÷ 1000 = 134 m^3

Step 3 – Uncovered Storage

- Add accumulated precipitation for storage period as noted below.
- Precipitation data can be found online on Environment Canada's website, under "Climate Normals".

Location	n/a
Area of Storage	n/a
Storage Duration	n/a

Month	Monthly Precipitation (mm)	Copy Storage Months Here*
January	n/a	-
February	n/a	-
March	n/a	-
April	n/a	-
May	n/a	-
June	n/a	-
July	n/a	-
August	n/a	-
September	n/a	-
October	n/a	-
November	n/a	-
December	n/a	-
Total	n/a	0

Precipitation is not included in this calculation, because the storage system is covered, but precipitation data may be necessary for associated catch basins or engineered wetlands.

Step 4 - Total Storage Volume

Total Storage Volume = Manure Volume (Step 2) + Precipitation Volume (Step 3)

Include freeboard height in the final design after the storage dimensions are determined (see Guidelines Section 3.2).
500 mm (20 in) for open topped storage systems
150 mm (6 in) for closed top storage systems

Total Storage Volume $= 134\ m^3 + 0$

$= 134\ m^3$

APPENDIX B4: Manure Production Data Table

The following table provides manure production rate information for sizing manure storage systems in Appendix B1. It also includes nutrient unit information and Factor 'A' numbers required for minimum separation distance (MSD) calculations in Appendix C1.

Note: A nutrient unit is the amount of nutrients that give the fertilizer replacement value of the lower of 43 kg of nitrogen or 55 kg of phosphate.

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		**m^3/1000 kg /day**	**%**	**m^3/1000 kg /day**	**%**	**animal /NU**	**m^2/ animal**	
Beef – Backgrounders (7 - 12.5 months)									
Confinement	308	0.90	0.0724	9	0.0604	22	3	4.650	0.8
Yard/Barn	308	0.90			0.0604	22	3	3.720	0.8
Beef - Brood Cows (includes calves to weaning)									
Confinement	590	1.00	0.0724	9	0.0604	30	1	9.290	0.7
Deep Bedded	590	1.00			0.0812	45	1	9.290	0.7
Yard/Barn	590	1.00			0.0604	30	1	4.650	0.7
Beef - Feeders (7 - 16 months)									
Confinement Bedded Pack	394	0.75			0.0687	30	3	4.650	0.8
Confinement Pack Scrape	394	0.75	0.0724	9	0.0604	22	3	4.650	0.8
Confinement Total Slats	394	0.75	0.0724	9			3	1.860	0.8
Yard/Barn	394	0.75			0.0604	22	3	4.180	0.8

Livestock Category	Average Weight	Utili-zation Factor	Liquid Produc-tion Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Live-stock Hous-ing Ca-pacity	Factor A (Barn Odour Poten-tial)
	kg		**m³/1000 kg /day**	**%**	**m³/1000 kg /day**	**%**	**animal /NU**	**m²/ animal**	
Beef - Short Keep (12.5 - 17.5 months)									
Confinement	492	0.83	0.0724	9	0.0604	22	2	6.040	0.8
Chickens - Broiler Breed-er Growers (females and males transferred out)									
Floor System	0.71	0.83			0.1124	60	300	0.158	0.7
Chickens - Broiler Breed-er Layer (females and males transferred in)									
Cages	3.04	0.90			0.0749	60	100	0.121	0.7
Litter With Slats	2.63	0.90			0.0562	65	100	0.195	0.7
Chickens – Broilers									
<2 kg shipping weight	0.67	0.70			0.1104	60	351	0.071	0.7
2.01-2.5 kg shipping weight	0.74	0.70			0.1104	60	300	0.083	0.7
2.51-3.0 kg shipping weight	0.92	0.70			0.1104	60	250	0.099	0.7
>3.01 kg shipping weight	1.17	0.70			0.1104	60	199	0.124	0.7
Chickens - Layer Pullets (day olds)									
Cages	0.41	0.83	0.1124	13.9	0.0624	25	500	0.028	0.7
Litter	0.41	0.83			0.1249	58	500	0.186	0.7

Livestock Category	Average Weight	Utili-zation Factor	Liquid Produc-tion Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Live-stock Hous-ing Ca-pacity	Factor A (Barn Odour Poten-tial)
	kg		**m³/1000 kg /day**	**%**	**m³/1000 kg /day**	**%**	**animal /NU**	**m²/ani-mal**	
Chickens - Laying Hens									
Belt And Other Removal System (daily)	1.43	0.96	0.1124	11.1	0.0624	20	150		1.0
Belt With Air Drying (daily)	1.43	0.96			0.0624	30	150		1.0
High Rise - Stored In Barn	1.43	0.96			0.0624	20	150		1.0
Liquid - Stored In Barn	1.43	0.96	0.1124	11.1			150		1.0
Chinchilla - Breeding Fe-males (including males/ rep/market animals)									
All	0.57	1.00			0.1561	66	320	0.743	0.8
Dairy - Calves Large Frame									
All	90.7	1.00	0.0750	11	0.0955	45	6	3.250	0.7
Dairy - Calves Medium Frame (Guernsey Size)									
All	74.4	1.00	0.0750	11	0.0955	45	7	2.970	0.7
Dairy - Calves Small Frame (Jersey Size)									
All	60.8	1.00	0.0750	11	0.0955	45	8.5	2.600	0.7

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		m³/1000 kg /day	%	m³/1000 kg /day	%	animal /NU	m²/animal	
Dairy - Heifers Large Frame									
Deep Bedded	295	1.00			0.0516	40	2	6.500	0.7
Free Stall	295	1.00	0.0714	11	0.0599	19	2	6.970	0.7
Manure Pack Outside Access	295	1.00			0.0516	40	2	3.720	0.7
Pack Scrape 1 Side	295	1.00	0.0714	11	0.0516	40	2	9.290	0.7
Pack Scrape 2 Sides	295	1.00	0.0714	11	0.0516	40	2	8.360	0.7
Dairy - Heifers Medium Frame (Guernsey Size)									
Deep Bedded	249	1.00			0.0516	40	2.4	5.200	0.7
Free Stall	249	1.00	0.0714	11	0.0599	19	2.4	5.570	0.7
Pack Scrape	249	1.00	0.0714	11	0.0516	40	2.4	7.430	0.7
Dairy - Heifers Small Frame (Jersey Size)									
Deep Bedded	204	1.00			0.0516	40	2.9	4.650	0.7
Free Stall	204	1.00	0.0714	11	0.0599	19	2.9	4.920	0.7
Pack Scrape	204	1.00	0.0714	11	0.0516	40	2.9	6.500	0.7
Dairy - Milking Age Cows* Medium Frame (Guernsey Size)									
Bedded Pack	550	1.00			0.1020	45	0.85	15.300	0.7
Free Stall	550	1.00	0.1165	9	0.0952	21	0.85	9.290	0.7
Pack Scrape	550	1.00	0.1165	9.1	0.1020	45	0.85	15.300	0.7
Sand**	550	1.00	0.1264	9.1	0.1051	21	0.85	0.000	0.7
Tie Stall	550	1.00	0.1165	9	0.0952	21	0.85	8.360	0.7

* A dairy farm typically has milking cows, dry cows, heifers and calves. For MSD purposes, multiply the number of milking cows by 1.5 to account for the followers (dry cows, heifers, and calves) when they are all kept on the same farm.

** Use the livestock housing capacity for a similar layout for non-sand bedding systems. If sand is not fully removed after each emptying of the storage system, additional capacity should be added.

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		m^3/1000 kg /day	%	m^3/1000 kg /day	%	animal /NU	m^2/animal	
Dairy - Milking Age Cows (Large Frame)*									
4 Row Free Stall Head To Head	700	1.00	0.1165	9.1	0.0952	21	0.7	11.600	0.7
4 Row Free Stall Tail To Tail	700	1.00	0.1165	9.1	0.0952	21	0.7	10.200	0.7
6 Row Free Stall	700	1.00	0.1165	9.1	0.0952	21	0.7	9.290	0.7
Bedded Pack	700	1.00			0.1020	45	0.7	16.700	0.7
Pack Scrape	700	1.00	0.1165	9.1	0.1020	45	0.7	16.700	0.7
3 Row Free Stall	700	1.00	0.1165	9.1	0.0952	21	0.7	9.760	0.7
Sand**	700	1.00	0.1264	9.1	0.1051	21	0.7	0.000	0.7
Tie Stall	700	1.00	0.1165	9.1	0.0952	21	0.7	10.200	0.7
Dairy - Miking Age Cows* Small Frame (Jersey Size)									
Bedded Pack	454	1.00			0.1020	45	1	13.500	0.7
Free Stall	454	1.00	0.1165	9	0.0952	21	1	8.360	0.7
Tie Stall	454	1.00	0.1165	9.1	0.0952	21	1	7.430	0.7
Pack Scrape	454	1.00	0.1165	9.1	0.1020	45	0.85	13.500	0.7
Sand**	454	1.00	0.1264	9.1	0.1051	21	1	0.000	0.7
Ducks – Peking									
Breeders	2.95	1.00			0.3765	57	105	0.465	0.8
Growers	1.04	0.90	0.3627	7	0.3471	57	105	0.167	0.8

* A dairy farm typically has milking cows, dry cows, heifers and calves. For MSD purposes, multiply the number of milking cows by 1.5 to account for the followers (dry cows, heifers, and calves) when they are all kept on the same farm.

** Use the livestock housing capacity for a similar layout for non-sand bedding systems. If sand is not fully removed after each emptying of the storage system, additional capacity should be added.

Livestock Category	Average Weight	Utili-zation Factor	Liquid Produc-tion Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Live-stock Hous-ing Ca-pacity	Factor A (Barn Odour Poten-tial)
	kg		**m^3/1000 kg /day**	**%**	**m^3/1000 kg /day**	**%**	**animal /NU**	**m^2/ani-mal**	
Goats - Dairy Does (including unweaned offspring)									
Confinement	77.1	1.00			0.0453	30	8	1.860	0.7
		0.00							
Goats - Dairy Kids									
Confinement	16.3	1.00			0.0453	30	32	0.743	0.7
Goats - Feeder Kids (>20 kg)									
Confinement	18.1	1.00			0.0375	30	32	0.743	0.7
Goats - Mature Meat Goat (including un-weaned offspring)									
All	72.6	1.00			0.0375	30	8	1.390	0.7
Horses - Large Frame (including unweaned offspring)									
Box Stalls	680	1.00			0.0887	46	0.7	30.200	0.7
Horses - Medium Frame (including unweaned offspring)									
Box Stalls	454	1.00			0.0887	46	1	23.200	0.7
Horses - Small Frame (including unweaned offspring)									
Box Stalls	227	1.00			0.0887	46	2	16.300	0.7

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		m^3/1000 kg /day	%	m^3/1000 kg /day	%	animal /NU	m^2/animal	
Rabbits - Breeding Does (includes bucks/rep/fryers)									
1 Tier Cages	4.54	1.00			0.1561	45	40	1.800	0.8
2 Tier Cages	4.54	1.00			0.1561	45	40	0.892	0.8
3 Tier Cages	4.54	1.00			0.1561	45	40	0.595	0.8
Sheep - Dairy and Feeders Lambs									
Confinement	33.2	0.75			0.0378	30	20	0.929	0.7
Outside Access	33.2	0.75			0.0378	30	20	0.557	0.7
Sheep - Dairy Ewes and rams (including unweaned offspring and replacements)									
Confinement	93	1.00			0.0556	40	6	2.140	0.7
Outside Access	93	1.00			0.0556	40	6	2.140	0.7
Sheep - Meat Ewes and Rams (including unweaned offspring and replacements)									
Confinement	79.4	1.00			0.0556	40	8	2.140	0.7
Outside Access	79.4	1.00			0.0453	30	8	1.390	0.7
Swine - Gilts (Breeders)									
All	90.3	0.85	0.0893	2.7			5	1.390	1

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		m^3/1000 kg /day	%	m^3/1000 kg /day	%	animal /NU	m^2/animal	
Swine - Sows (dry) and Boars									
Deep Bedded Pack	136	1.00			0.0818	45	3.5	2.790	1
Full or Partial Slats	136	1.00	0.1167	2.5	0.0974	15	3.5	2.790	1
Swine - Sows with Litters									
All	181	1.00	0.1167	2.1	0.0974	15	3.5	6.500	1
Swine - Weaners									
Non-SEW	15.9	0.80	0.1779	2.7	0.1542	13	20	0.399	1.1
Non-SEW (wet/dry)	15.9	0.80	0.1305	3.6	0.1542	13	20	0.399	1.1
SEW	11.3	0.80	0.1779	2.7	0.1542	13	20	0.353	1.1
SEW (wet/dry)	11.3	0.80	0.1305	3.6	0.1542	13	20	0.353	1.1
Turkeys - Breeder Toms									
All	15.9	1.00			0.0437	58		0.557	0.7
Turkeys - Broilers (<6.2 kg)									
All	2	0.85			0.0562	60	133	0.149	0.7
Turkeys – Hens (6.2 - 10.8 kg)									
Brooded in another building	4.08	0.77			0.0541	60	110	0.232	0.7
Brooded in the same barn	2.87	0.85			0.0559	60	110	0.232	0.7

Livestock Category	Average Weight	Utilization Factor	Liquid Production Rate	Liquid Dry Matter	Solid Production Rate	Solid Dry Matter	Nutrient Units	Livestock Housing Capacity	Factor A (Barn Odour Potential)
	kg		**m^3/1000 kg /day**	**%**	**m^3/1000 kg /day**	**%**	**animal /NU**	**m^2/animal**	
Turkeys – Toms (>10.8 kg)									
All	6.03	0.80			0.0410	60	75	0.325	0.7
Turkeys - Turkey Breeder Layers									
All	9.07	1.00			0.0437	58		0.372	0.7
Turkeys - Turkey Starter Barn (0 to 6 weeks)									
All	0.68	0.80			0.1249	58	267	0.093	0.7
Veal - Grain Fed									
All	140	0.90	0.0724	9	0.0604	22	6	5.850	0.8
Veal - Milk Fed									
All	102	0.80	0.0906	0.7	0.1389	40	6	2.790	1.1

Source: Adapted from Nutrient Unit Tables for Ontario. OMAFRA

APPENDIX C1: Minimum Separation Distance Worksheet

Farm Name/Owner____

Address _______________________________________ Postal Code____________

Phone ______________________ Email__________________________________

Check all that apply:

☐ New livestock facilities

☐ Modifications to existing livestock facilities

☐ Manure storage

☐ Rebuilding (i.e. after fire)

☐ Other ______________________

List the type and maximum number of livestock housed at any time on the property.

Type of Livestock Housed/ Fenced	Existing	Proposed	Total

Manure Storage Information

Check all that apply:

Solid Manure Collection	Solid Manure Storage	Liquid Manure Collection	Liquid Manure Storage
☐ Barn Cleaner/Belts	☐ Manure Pack in Barn	☐ Alley Scrapers	☐ Full Storage Under Slat
☐ Tractor	☐ Covered Storage	☐ Flush System	☐ Uncovered Concrete or Steel Storage
☐ Manure Pack in Barn	☐ Uncovered Storage with Runoff Catch Basin	☐ Fully slatted floor	☐ Uncovered Earthen Storage
☐ Other: ____________	☐ Uncovered Storage with Integrated Runoff Contain-ment	☐ Other: ______________	☐ Covered Concrete or Steel Storage
	☐ Other: ____________		☐ Covered Earthen Storage
			☐ Other: ______________

Site Plan

Attach a clearly drawn site plan showing all details required on the PEI building permit application.

Calculation of Nutrient Units

Type of Livestock	Number of Existing Livestock (a)	Number of Existing Nutrient Units (see Appendix B4) (b)	Number of Livestock to be added (c)	Number of Nutrient Units to be added (see Appendix B4) (d)	Total Number of Livestock (a)+(c)	Total Nutrient Units (see Appendix B4) (b)+(d)
		Total 1=		Total 2=		Total 3=

1) Calculation of Existing / Additional Nutrient Units

Existing Livestock (a) divide by Livestock per Nutrient Unit (see Appendix B4) = Existing Nutrient Units (b)

Livestock to be added (c) divide by Livestock per Nutrient Unit (see Appendix B4) = Nutrient Units to be added (d)

Does the number of livestock fall within the normal range of livestock housing numbers for the structures as outlined in the applicable code of practice from the National Farm Animal Care Council?

Yes ____ No ____

If no, please justify____

2) Calculation of Percentage Increase (Refer to above Calculations)

Nutrient Units to be added (Total 2) divide by Existing Nutrient Units (Total 1) and multiply by 100= % increase [_____]

3) Calculation of Factors

Refer to Appendix B4 for Factor A by Livestock Type **Factor A :** ________

Total Nutrient Units Appendix C2 and obtain Factor B from Appendix C2 **Factor B :** ________

Percent Increase from Step 2 and obtain Factor C from Appendix C2 **Factor C :** ________

Type of Manure System (Solid=0.7, Liquid= 0.8) **Factor D :** ________

4) Building Base Distance: (Metres)

Factor A x Factor B x Factor C x Factor D = Base Distance 'F ': [_______]

5) Manure Storage Base Distance: (Metres)

Take Base Distance 'F' and refer to Appendix C2 Base Distance 'S': [_______]

Land Use / Property Lines	Factor	Livestock Building	Manure Storage
Non Zoned Areas and Agriculture or Agriculturally Related Commercial Use, Recreational or Industrial zones	1.0		
*Areas zoned in accordance with official plans and by-laws of a municipality, except areas zoned agricultural	2.0		
**Property Lines: Nearest Side or Rear Lot Line	0.05		
Public Road Boundary	0.10		

* Upon recommendation of the Municipal Council, Factor 2.0 may be decreased, at the discretion of the Minister responsible for the Environmental Protection Act.

** This distance may be decreased with the agreement of the adjacent property owner.

APPENDIX C2: Minimum Separation Distance Data Tables

FACTOR 'A' can be found in Appendix B4 – Manure Production Data Table

Table 1: Factor 'B' (Final Nutrient Units)

Nutrient Units	Factor B	Nutrient Units	Factor B	Nutrient Units	Factor B	Nutrient Units	Factor B
5	107	95	313	500	578	1600	821
6	119	100	318	520	585	1650	829
7	129	110	327	540	592	1700	836
8	138	120	335	560	598	1750	844
9	145	130	343	580	605	1800	851
10	152	140	350	600	611	1850	858
12	164	150	357	620	617	1900	865
14	175	160	366	640	623	1950	872
16	183	170	374	660	629	2000	879
18	191	180	383	680	635	2100	892
20	198	190	392	700	640	2200	905
22	205	200	400	720	646	2300	917
24	210	210	409	740	651	2400	929
26	216	220	418	760	656	2500	941
28	221	230	426	780	661	2600	952
30	225	240	435	800	666	2700	963
32	230	250	444	850	679	2800	974
34	234	260	452	900	690	2900	985
38	241	280	470	1000	713	3200	1015
40	245	290	478	1050	723	3400	1034
45	253	300	487	1100	733	3600	1053
50	261	320	501	1150	743	3800	1071
60	275	360	522	1250	762	4200	1105
65	281	380	531	1300	771	4400	1121
70	287	400	540	1350	780	4600	1136
75	293	420	548	1400	789	4800	1152
80	298	440	556	1450	797	5000	1166
85	304	460	564	1500	805	7500	1326
90	309	480	571	1550	813	10000	1455

Table 2: Factor 'C' (Percentage Increase)

Percentage Increase	Factor C	Percentage Increase	Factor C	Percentage Increase	Factor C
0-50	0.70	120	0.9	280	1.03
55	0.72	130	0.9	300	1.04
60	0.73	140	0.9	325	1.05
65	0.75	150	0.9	350	1.06
70	0.76	160	0.9	375	1.07
75	0.77	170	0.9	400	1.08
80	0.78	180	1.0	425	1.09
85	0.79	190	1.0	450	1.10
90	0.81	200	1.0	500	1.11
95	0.82	220	1.0	550	1.12
100	0.83	240	1.0	650	1.13
110	0.85	260	1.0	700	1.14

Note: For new livestock operations or if the % increase is greater than 700%, use Factor C = 1.14

Table 3: Manure Storage Basic Distance 'S' (Siting Distances for Manure Storage Systems)

	Column 1	Column 2	Column 3	Column 4
Minimum Base Distance 'F' for the Building (m)	Covered Storage[1] Systems (m)	Uncovered and Runoff Storage[2] Systems (m)	Uncovered Liquid and Runoff[3] Storage Systems (m)	Earthen Liquid and Runoff Storage[4] Systems (m)
40	40	55	119	324
45	45	60	123	326
50	50	65	128	328
55	55	70	132	331
60	60	74	136	333
65	65	79	140	335
70	70	84	144	337
75	75	89	149	340
80	80	94	153	342
85	85	99	157	344
90	90	104	161	346
95	95	108	166	348
100	100	113	170	351
105	105	118	174	353
110	110	123	178	355
115	115	128	182	357
120	120	133	187	360
125	125	138	191	362
130	130	142	195	364
135	135	147	199	366
140	140	152	204	368
145	145	157	208	371
150	150	162	212	373
160	160	172	220	377
170	170	181	229	382
180	180	191	237	386
190	190	201	246	391
200	200	210	254	395
210	210	220	263	399
220	220	230	271	404
230	230	239	280	408
240	240	249	288	413
260	260	269	305	422
280	280	288	322	430
300	300	307	339	439
320	320	327	356	448
360	360	366	389	466
380	380	385	406	475
400	400	404	423	484
420	420	424	440	492
440	440	443	457	501
480	480	482	491	519
500	500	502	508	528
550	550	550	550	550

1 Covered storage systems for manure, runoff and milk house wastewater. Includes any covered concrete, steel or earthen storage systems, in-barn solid manure packs and storage under fully slatted floors.

2 Uncovered solid manure storage on a concrete slab. Includes the runoff catch basins (concrete or earthen) used for capturing liquids from solid manure storage or runoff from yards. If yards are scraped into runoff storage, use column 3 when runoff catch basin is a concrete or steel tank and column 4 when runoff catch basin is earthen. Milk house wastewater may be added to runoff catch basin.

3 Uncovered concrete or steel tanks used for storing liquid manure, milk house wastewater, or yard runoff where yard is scraped into storage.

4 Uncovered earthen or earthen-sided storage with a concrete floor to be used for storing liquid manure or yard runoff when yard is scraped into storage.

APPENDIX C3: Minimum Separation Distance Examples
EXAMPLE MSD WORKSHEET 1

For MSD Calculation of a NEW 1000 Hog Feeder Barn with Open Top Concrete Tank

Farm Name/Owner John X. Sample

Address 123 Country Road Postal Code C1A1A1

Phone 902-555-1234 Email Johnx@sample.com

Check all that apply:

- [x] New livestock facilities
- [ ] Rebuilding (i.e. after fire)
- [ ] Modifications to existing livestock facilities
- [ ] Other ______________________
- [x] Manure storage

List the type and maximum number of livestock housed at any time on the property.

Type of Livestock Housed/ Fenced	Existing	Proposed	Total
Swine - Full Slats	0	1000	1000

Manure Storage Information

Check all that apply:

Solid Manure Collection	Solid Manure Storage	Liquid Manure Collection	Liquid Manure Storage
☐ Barn Cleaner/Belts	☐ Manure Pack in Barn	☐ Alley Scrapers	☐ Full Storage Under Slat
☐ Tractor	☐ Covered Storage	☐ Flush System	☒ Uncovered Concrete or Steel Storage
☐ Manure Pack in Barn	☐ Uncovered Storage with Runoff Catch Basin	☒ Fully slatted floor	☐ Uncovered Earthen Storage
☐ Other: ____________	☐ Uncovered Storage with Integrated Runoff Contain-ment	☐ Other: ______________	☐ Covered Concrete or Steel Storage
	☐ Other: ____________		☐ Covered Earthen Storage
			☐ Other: ____________

Site Plan

Attach a clearly drawn site plan showing all details required on the PEI building permit application.

Calculation of Nutrient Units

Type of Livestock	Number of Existing Livestock (a)	Number of Existing Nutrient Units (see Appendix B4) (b)	Number of Livestock to be added (c)	Number of Nutrient Units to be added (see Appendix B4) (d)	Total Number of Livestock (a)+(c)	Total Nutrient Units (see Appendix B4) (b)+(d)
Swine (Full Slab)	0	0	1000	285.7	1000	285.7
		Total 1= 0		Total 2= 285.7		Total 3= 285.7

1) Calculation of Existing / Additional Nutrient Units

Existing Livestock (a) divide by Livestock per Nutrient Unit (see Appendix B4) = Existing Nutrient Units (b)

Livestock to be added (c) divide by Livestock per Nutrient Unit (see Appendix B4) = Nutrient Units to be added (d)

Does the number of livestock fall within the normal range of livestock housing numbers for the structures as outlined in the applicable code of practice from the National Farm Animal Care Council?

Yes X No ____

If no, please justify____

2) Calculation of Percentage Increase (Refer to above Calculations)

Nutrient Units to be added (Total 2) divide by Existing Nutrient Units (Total 1) and multiply by 100= % increase [N/A NEW]

3) Calculation of Factors

Refer to Appendix B4 for Factor A by Livestock Type — **Factor A :** 1

Total Nutrient Units Appendix C2 and obtain Factor B from Appendix C2 — **Factor B :** 478

Percent Increase from Step 2 and obtain Factor C from Appendix C2 — **Factor C :** 1.14

Type of Manure System (Solid=0.7, Liquid= 0.8) — **Factor D :** 0.8

4) Building Base Distance: (Metres)

Factor A x Factor B x Factor C x Factor D = Base Distance 'F ': [436m]

5) Manure Storage Base Distance: (Metres)

Take Base Distance 'F' and refer to Appendix C2 Base Distance 'S': [457m]

Land Use / Property Lines	Factor	Livestock Building	Manure Storage
Non Zoned Areas and Agriculture or Agriculturally Related Commercial Use, Recreational or Industrial zones	1.0	436m	457m
*Areas zoned in accordance with official plans and by-laws of a municipality, except areas zoned agricultural	2.0	872m	914m
**Property Lines: Nearest Side or Rear Lot Line	0.05	21.8m	22.8m
Public Road Boundary	0.10	43.6m	45.7m

* Upon recommendation of the Municipal Council, Factor 2.0 may be decreased, at the discretion of the Minister responsible for the Environmental Protection Act.

** This distance may be decreased with the agreement of the adjacent property owner.

APPENDIX C3: Minimum Separation Distance Examples
EXAMPLE MSD WORKSHEET 2

For MSD Calculation of an Expansion from 50 Jersey Milk Cows (including followers) to 100 Jersey Milk Cows (including followers) with Open Top Concrete Manure Tank, sand bedding.

Note: If followers (heifers, calves, dry cows) are included, multiply number of milking cows by 1.5 to calculate livestock numbers

Farm Name/Owner John X. Sample

Address 456 Farm Lane Postal Code C1B1B2

Phone 902-555-4321 Email Johnx@sample.com

Check all that apply:

- ☐ New livestock facilities
- ☒ Modifications to existing livestock facilities
- ☒ Manure storage
- ☐ Rebuilding (i.e. after fire)
- ☐ Other ______________________

List the type and maximum number of livestock housed at any time on the property.

Type of Livestock Housed/ Fenced	Existing	Proposed	Total
Dairy Milking (Jersey)	75	75	150

Manure Storage Information

Check all that apply:

Solid Manure Collection	Solid Manure Storage	Liquid Manure Collection	Liquid Manure Storage
☐ Barn Cleaner/Belts	☐ Manure Pack in Barn	☒ Alley Scrapers	☐ Full Storage Under Slat
☐ Tractor	☐ Covered Storage	☐ Flush System	☒ Uncovered Concrete or Steel Storage
☐ Manure Pack in Barn	☐ Uncovered Storage with Runoff Catch Basin	☐ Fully slatted floor	☐ Uncovered Earthen Storage
☐ Other: ____________	☐ Uncovered Storage with Integrated Runoff Contain-ment	☐ Other: ______________	☐ Covered Concrete or Steel Storage
	☐ Other: ____________		☐ Covered Earthen Storage
			☐ Other: ______________

Site Plan

Attach a clearly drawn site plan showing all details required on the PEI building permit application.

Calculation of Nutrient Units

Type of Livestock	Number of Existing Livestock (a)	Number of Existing Nutrient Units (see Appendix B4) (b)	Number of Livestock to be added (c)	Number of Nutrient Units to be added (see Appendix B4) (d)	Total Number of Livestock (a)+(c)	Total Nutrient Units (see Appendix B4) (b)+(d)
Dairy Milking (Jersey Sand)	75	75	75	75	150	150
		Total 1= 75		Total 2= 75		Total 3= 150

1) Calculation of Existing / Additional Nutrient Units

Existing Livestock (a) divide by Livestock per Nutrient Unit (see Appendix B4) = Existing Nutrient Units (b)

Livestock to be added (c) divide by Livestock per Nutrient Unit (see Appendix B4) = Nutrient Units to be added (d)

Does the number of livestock fall within the normal range of livestock housing numbers for the structures as outlined in the applicable code of practice from the National Farm Animal Care Council?

Yes X No ____

If no, please justify____

2) Calculation of Percentage Increase (Refer to above Calculations)

Nutrient Units to be added (Total 2) divide by Existing Nutrient Units (Total 1) and multiply by 100= % increase [100]

3) Calculation of Factors

Refer to Appendix B4 for Factor A by Livestock Type — **Factor A :** 0.7

Total Nutrient Units Appendix C2 and obtain Factor B from Appendix C2 — **Factor B :** 357

Percent Increase from Step 2 and obtain Factor C from Appendix C2 — **Factor C :** 0.83

Type of Manure System (Solid=0.7, Liquid= 0.8) — **Factor D :** 0.8

4) Building Base Distance: (Metres)

Factor A x Factor B x Factor C x Factor D = — Base Distance 'F ': [166m]

5) Manure Storage Base Distance: (Metres)

Take Base Distance 'F' and refer to Appendix C2 — Base Distance 'S': [229m]

Land Use / Property Lines	Factor	Livestock Building	Manure Storage
Non Zoned Areas and Agriculture or Agriculturally Related Commercial Use, Recreational or Industrial zones	1.0	166m	229m
*Areas zoned in accordance with official plans and bylaws of a municipality, except areas zoned agricultural	2.0	332m	458m
**Property Lines: Nearest Side or Rear Lot Line	0.05	8m	11.4m
Public Road Boundary	0.10	17m	1.7m

* Upon recommendation of the Municipal Council, Factor 2.0 may be decreased, at the discretion of the Minister responsible for the Environmental Protection Act.

** This distance may be decreased with the agreement of the adjacent property owner.

APPENDIX C3: Minimum Separation Distance Examples
EXAMPLE MSD WORKSHEET 3

For MSD Calculation of a New Broiler Barn with 60,000 Birds (2.01 – 2.5 kg) with Open Top Solid Manure Storage System

Farm Name/Owner Richard N Sample

Address 8910 Henwood Dr Postal Code C1C1C1

Phone 902-555-5678 Email RichardN@sample.com

Check all that apply:

- [x] New livestock facilities
- [ ] Rebuilding (i.e. after fire)
- [ ] Modifications to existing livestock facilities
- [ ] Other ______________________
- [ ] Manure storage

List the type and maximum number of livestock housed at any time on the property.

Type of Livestock Housed/ Fenced	Existing	Proposed	Total
Chickens Broiler 2.01-2.05 kg	0	60,000	60,000

Manure Storage Information

Check all that apply:

Solid Manure Collection	Solid Manure Storage	Liquid Manure Collection	Liquid Manure Storage
☐ Barn Cleaner/Belts	☐ Manure Pack in Barn	☐ Alley Scrapers	☐ Full Storage Under Slat
☒ Tractor	☐ Covered Storage	☐ Flush System	☐ Uncovered Concrete or Steel Storage
☐ Manure Pack in Barn	☐ Uncovered Storage with Runoff Catch Basin	☐ Fully slatted floor	☐ Uncovered Earthen Storage
☐ Other: ____________	☒ Uncovered Storage with Integrated Runoff Containment	☐ Other: ____________	☐ Covered Concrete or Steel Storage
	☐ Other: ____________		☐ Covered Earthen Storage
			☐ Other: ____________

Site Plan

Attach a clearly drawn site plan showing all details required on the PEI building permit application.

Calculation of Nutrient Units

Type of Livestock	Number of Existing Livestock (a)	Number of Existing Nutrient Units (see Appendix B4) (b)	Number of Livestock to be added (c)	Number of Nutrient Units to be added (see Appendix B4) (d)	Total Number of Livestock (a)+(c)	Total Nutrient Units (see Appendix B4) (b)+(d)
Chickens Broiler 2.01-2.05 kg	0	0	60,000	200	60,000	200
		Total 1= 0		Total 2= 200		Total 3= 200

1) Calculation of Existing / Additional Nutrient Units

Existing Livestock (a) divide by Livestock per Nutrient Unit (see Appendix B4) = Existing Nutrient Units (b)

Livestock to be added (c) divide by Livestock per Nutrient Unit (see Appendix B4) = Nutrient Units to be added (d)

Does the number of livestock fall within the normal range of livestock housing numbers for the structures as outlined in the applicable code of practice from the National Farm Animal Care Council?

Yes X No ____

If no, please justify______________________________

2) Calculation of Percentage Increase (Refer to above Calculations)

Nutrient Units to be added (Total 2) divide by Existing Nutrient Units (Total 1) and multiply by 100= % increase [N/A NEW]

3) Calculation of Factors

Refer to Appendix B4 for Factor A by Livestock Type **Factor A :** 0.7

Total Nutrient Units Appendix C2 and obtain Factor B from Appendix C2 **Factor B :** 400

Percent Increase from Step 2 and obtain Factor C from Appendix C2 **Factor C :** 1.14

Type of Manure System (Solid=0.7, Liquid= 0.8) **Factor D :** 0.7

4) Building Base Distance: (Metres)

Factor A x Factor B x Factor C x Factor D = Base Distance 'F ': [223m]

5) Manure Storage Base Distance: (Metres)

Take Base Distance 'F' and refer to Appendix C2 Base Distance 'S': [230m]

Land Use / Property Lines	Factor	Livestock Building	Manure Storage
Non Zoned Areas and Agriculture or Agriculturally Related Commercial Use, Recreational or Industrial zones	1.0	223m	230m
*Areas zoned in accordance with official plans and by-laws of a municipality, except areas zoned agricultural	2.0	446m	460m
**Property Lines: Nearest Side or Rear Lot Line	0.05	11m	12m
Public Road Boundary	0.10	22m	23m

* Upon recommendation of the Municipal Council, Factor 2.0 may be decreased, at the discretion of the Minister responsible for the Environmental Protection Act.

** This distance may be decreased with the agreement of the adjacent property owner.

APPENDIX D1: Soil Liner Design Data

Laboratory proctor density testing and hydraulic conductivity testing should be conducted on three samples which roughly outline the area of the proposed manure storage. Material at each test location should be an aggregate bulk sample from the top to the bottom of the proposed clay liner material source. Particle size, proctor dry density and hydraulic conductivity testing should be completed to determine the suitability of the liner material. Results of these tests must meet or exceed the criteria outlined in Section 3.2.2: Earthen Liquid Manure Storage Systems.

Storage System Type	Minimum Liner Thickness (m)	Hydraulic Conductivity (cm/s)
Liquid Manure Storage System	1.0	Not more than 1×10^{-7}
Catch Basin	1.0	Not more than 5×10^{-7}
Solid Manure Storage System	0.5	Not more than 5×10^{-7}

Compacted Liners

Bench scale hydraulic conductivity testing should be completed according to the methods described in ASTM D5084. A factor of 10 reduction will be applied to laboratory testing hydraulic conductivity values.

Natural Liners

Where site conditions allow, a natural in-situ liner may be considered. In-situ hydraulic conductivity testing should be completed according to the methods described in ASTM D2434-19.

Detailed instructions for testing can be found in *Subsoil Investigations for Manure Storage Facilities and Manure Collection Areas.* Natural Resources Conservation Board, April 2020. Technical Guideline Agdex 096-62.

APPENDIX E1: Calculating Manure Volume and Density

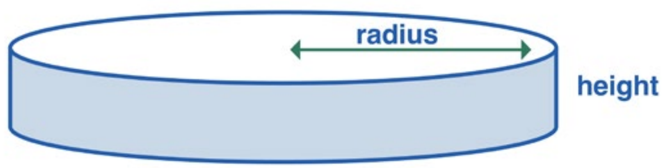
Manure Volume Calculation Methods

One approach to determine manure volume is to estimate the volume based on the geometry of the storage. Liquid storage systems can be measured to determine the average volume per metre depth. Total volume is the average depth of fill per annum. This may need to be tracked over time when storage systems are pumped out frequently. The following are some basic storage shapes and the corresponding formula for the estimation of volume:

Rectangular

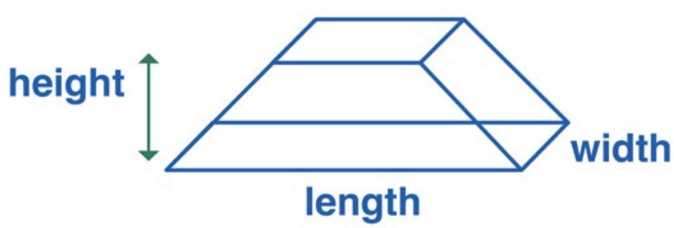
Volume = length × width × height

Circular



Volume = π × radius^2 × height

Stack systems are far more irregular in their shape and are more difficult to approximate. Volume of litter or manure packs can be estimated as surface area x average depth. This requires that depth be recorded at enough points to represent a good average. One approach is simply to use one half of an estimate of the volume of a rectangular storage of similar dimensions.



Volume ~ (length x width x height) /2

Volume of solid manure storage systems or earthen manure storage systems may be estimated if the manure pile or lagoon dimensions are reasonably uniform. Otherwise, it is more practical to make estimates based on livestock numbers. Count manure loads during spreading to verify estimates for future use.

Liquid Manure

The density of manure is generally close to one and therefore the manure volume (m^3) ~ manure mass (tonnes); or, L = kg (approximately).

Solid Manure

Solid manure is less dense than liquid manure (i.e., 1 m^3 weighs less than 1 tonne). Density can be roughly estimated by weighing a known volume of solid manure by the following method:

1. Weigh an empty 20 litre bucket
2. Fill it to the brim with water and weigh again
3. Find the water mass by difference
4. Water mass, kg = volume, L (water has a density of 1.00 kg/L)
5. Fill the bucket to the brim with manure, packed to a similar density as the stack or litter pack, and weigh, to determine the manure mass per volume

Manure Density = Mass in bucket (kg) / bucket volume (L)

Solid Manure Density Example

Step 1	20 Litre Bucket	0.5 kg
Step 2	Filled 20 Litre Bucket	18 kg
Step 3	Water Mass	17.5 kg
Step 4	Volume	17.5 L
Step 5	Manure Mass	14 kg

(14 kg/17.5 L= 0.8 kg/L)

APPENDIX F1: Emergency Spill Action Planning

Emergency response plans are developed by livestock producers as well as organizations involved in manure transportation and land application. Every manure production and storage site should have a spill mitigation and remediation plan. Emergency contact information should be readily available, including contact information for local government agencies such as Environment, Transportation, Agriculture and Fisheries, including the Environmental Emergency Response service that is on call 24 hours a day to respond to environmental emergencies (1-800-565-1633). A list of equipment and labour resources such as hydro vac trucks, earth moving equipment, tow trucks, and road safety personnel should also be included.

General components of a good action plan include:

- Assessment of the emergency situation, including immediate (e.g. manure on the roadway or manure flowing over a containment berm) and longer-term hazards (e.g. water contamination down slope or degradation of storage berms through erosion).
- Proposed actions to mitigate the hazard.
- Types of spills which may be encountered, such as incident spills in fields, manure pump and pipeline malfunctions, spills on roadways, spills in fields, and spills due to breach or overflow of a manure storage.

Actions for mitigation of spill incidents:

- Ensure the area is safe to enter following an incident.
- Tend to human injuries and life safety concerns such as clearly marking a hazardous stretch of roadway.
- If possible, reduce or eliminate ongoing spills. This could be as simple as shutting off a pump.
- Evaluate the site to assess the extent of the spill and hazards to the environment.
- Contain the spill. This could involve creating berms or dikes across a hill to slow and contain the flow. If the spill is in a ditch or stream, create a series of dams to contain the manure and contaminated water.
- Thoroughly document and photograph throughout the entire incident from discovery, containment, remediation and repair stages.
- Contact necessary authorities.

Manure spills are best prevented through proper management and careful manure application.

Other Resources and Tools

Emergency Action Planning to Avoid or Minimize Manure Discharges from Pork Operations. US Pork Center of Excellence, 2006

Emergency Action Planning for Commercial Manure Applicator, NRCB

Manure Spill Emergency Response Plan. Government of Wisconsin

Farm-related Spills of Manure or Other Materials. OMAFRA, 2016

APPENDIX F2: Emergency Spill Action Plan Template

This plan should be reviewed annually and understood by farmers, employees, and commercial land spreading contractors. Copies should be available to employees and contractors and posted in key public locations at the livestock operation.

Emergency Contact List

Business or Farm Name:____

Date Created:____

Environmental Emergency Response 24-hour Line: 1-800-565-1633
Emergency: 911

	Name	Phone
Business/Farm Main Contact		
Business/Farm Alt. Contact		
PEI Transportation		
PEI Agriculture		
PEI Environment		
Municipality		

Develop a Map

Map(s) should include the following:

- Routes of travel including roadways, fields, and approaches
- Location of manure storage system and manure land application sites
- Sensitive occupancies en route (e.g. hospitals, schools, public buildings)
- Wells
- Surface water sources such as lakes, streams, and wetlands
- Storm water and drainage ditches, catch basins, and flow paths
- Other sensitive areas

Anticipated overland flow paths should be noted for all features noted above.

Earth-Moving and Manure Pumping/Spreading Equipment

Earth-moving and manure pumping equipment to assist with spill remediation efforts are listed below. This should include neighbouring livestock producers, excavation equipment operators, pumping, and storage companies. Where possible, develop prearranged plans with neighbours, equipment operators, and authorities having jurisdiction.

Equipment	Location	Name	Phone

Acknowledgements

The updates to the Prince Edward Island Manure Management Guidelines were developed through a collaborative process with specialists from the PEI Department of Agriculture, the PEI Department of Environment, Energy, and Climate Action, and Rural Roots Engineering and Design Ltd., the project consultant. The process included consultation sessions with Prince Edward Island's livestock industry organizations and the public.

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