BEST MANAGEMENT PRACTICES

Nutrient Management Planning

REVISED EDITION, 2006

Canada

Ontario

OFA Ontario Federation of Agriculture

What is a Best Management Practice or "BMP"?

- a proven, practical and affordable approach to conserving soil, water and other natural resources in rural areas

Who decides what qualifies as a BMP?

- a team that represents many facets of agriculture and rural land ownership in Ontario, including farmers, researchers, natural resource managers, regulatory agency staff, extension staff and agribusiness professionals

What is the BMP Series?

- innovative, award-winning books presenting many options that can be tailored to meet your particular environmental concern and circumstances
- current BMP titles are:
  Buffer Strips
  Establishing Tree Cover
  Farm Forestry and Habitat Management
  Field Crop Production
  Fish and Wildlife Habitat Management
  Greenhouse Gas Reduction in Livestock Production Systems
  Horticultural Crops
  Integrated Pest Management
  Irrigation Management
  Livestock and Poultry Waste Management
  Managing Crop Nutrients
  Manure Management
  No-Till: Making It Work
  Nutrient Management
  Nutrient Management Planning
  Pesticide Storage, Handling and Application
  Soil Management
  Streamside Grazing
  Water Management
  Water Wells
  Woodlot Management

How do I obtain a BMP book?

- if you're an Ontario farmer, single copies of each title are available at no cost through the Ontario Ministry of Agriculture, Food and Rural Affairs
- to purchase single copies or bulk orders of all other titles, and to order complete sets of BMP books, please contact: Ontario Federation of Agriculture, Ontario Agricentre, Attn: Manager, BMP, 100 Stone Rd. W., Guelph, ON N1G 5L3. Phone: 1-800-668-3276
- for an on-line order form, go to: http://www.omafra.gov.on.ca/english/products/best.html
- please note that prices vary per title and with quantity ordered

CONTENTS

METRIC-IMPERIAL CONVERSION FACTORS

Convert		To		Metric
%	►	kg/1000 L	multiply by	10
%	►	kg/tonne	multiply by	10
mg/L	►	%	divide by	10,000

Convert		To		Imperial
%	►	lbs per 1000 gallons	multiply by	100
%	►	lbs per ton	multiply by	20
ppm	►	%	divide by	10,000

Note: 1 m^3 = 1000 L

CONVERSIONS – METRIC AND IMPERIAL

Common Conversions

1 gallon	=	4.546 litres	1 acre	=	0.405 hectare
1 gallon	=	1.201 US gallons	1 acre	=	43,560 $feet^2$
1 gallon	=	0.161 ft^3	1 lb/ac	=	1.12 kilogram/hectare
1 US gallon	=	3.785 litres	1 ton/ac	=	2.25 tonnes/hectare
1 US gallon	=	0.833 Imp gallons	1 gal/ac	=	11.2 litre/hectare
1 ton	=	0.907 tonne	1000 gal/ac	=	11200 litre/hectare
1 pound	=	0.454 kilogram	1000 gal/ac	=	11.2 $metre^3$/hectare
1 tonne	=	2205 pounds	1 metre	=	3.28 feet
1 $foot^3$	=	6.229 gallons	1 metre	=	39.4 inches

Application Rate Conversions

Metric to Imperial (Approximate)			Imperial to Metric (Approximate)		
Litres per hectare x 0.09	=	gallons per acre	Gallons per acre x 11.23	=	litres per hectare (L/ha)
Litres per hectare x 0.36	=	quarts per acre	Quarts per acre x 2.8	=	litres per hectare (L/ha)
Litres per hectare x 0.71	=	pints per acre	Pints per acre x 1.4	=	litres per hectare (L/ha)
Millilitres per hectare x 0.015	=	fluid ounces per acre	Fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
Grams per hectare x 0.015	=	ounces per acre	Tons per acre x 2.24	=	tonnes per hectare (t/ha)
Kilograms per hectare x 0.89	=	pounds per acre	Pounds per acre x 1.12	=	kilograms per hectare (kg/ha)
Tonnes per hectare x 0.45	=	tons per acre	Ounces per acre x 70	=	grams per hectare (g/ha)
Kilograms per 1000 L x 10	=	lbs per 1000 gallons	Pounds per ton x .5	=	kilograms per tonne (kg/t)

Many measurements in this book will be presented in metric values with imperial equivalents in parentheses. However, where common usage, common sense, space limitations or regulatory concerns dictate, one or the other may appear exclusively.

INTRODUCTION

A good portion of what's called nutrient management involves routine chores. Collecting and storing manure, and applying it along with other fertilizers to cropland are part-and-parcel of most livestock operations.

What hasn't been routine until recently is **planning** – specifically, accounting for and recording all the nutrients you have, which nutrients you'll need and when, and how much to apply to your land base.

In the last decade, greater societal awareness regarding water quality and a better understanding of how nutrients cycle through the environment have put the spotlight on all on-farm nutrients, but especially manure. Tools to help farmers balance nutrients based on agronomic requirements have been refined. As a result, nutrient handling has evolved into a more formal set of farm practices known as nutrient management planning.

> **Based on proven scientific principles, a nutrient management plan helps you match farm-generated and purchased nutrients to your crop's needs and your soil's fertility requirements.**

Nutrient management planning is a reality of farming life that's here to stay. Legislation may require you to develop a nutrient management plan or strategy, or both. Whether you're required to or not, the good news is that planning can protect water quality and save you money. (For more information on legislative requirements and nutrient management plans and strategies, please go to page 112.)

Since your farm is like no other, your plan will be unique, customized to your goals and circumstances. It's also very much a "living" document; one that can and should change with your operation.

In the nutrient management planning process:

- all nutrients are **inventoried** – including nutrients found in the soil and in a growing or harvested crop, and those considered to be deficient
- all nutrients are **managed** – according to land base, production goals, proximity to water resources, farmstead layout, equipment, and safety concerns.

Preparing nutrient management documents can give you greater insight into aspects of your operation that may not have received much scrutiny to date. In the process you can ensure that you are protecting air and water quality for the long term.

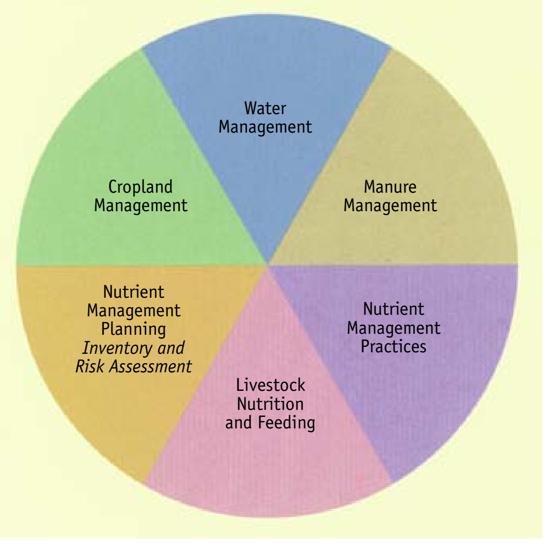
The process integrates the calculation of:

- application rates
- separation distances, and
- acreage needs

with

- farmstead planning
- odour issues and neighbourly relations
- application technology
- soil and water conservation practices, and
- contingency plans.

While your plan may be detailed, it's also "big picture." Nutrient management planning involves a systems approach – understanding that a change to any one component will affect other components and the entire system.



Nutrient management planning is most effective when producers integrate a systems approach to changes planned for their operation.

BENEFITS

Saves money

- you may be surprised to learn how many nutrients are present but unaccounted for in your operation's manure and soil, and how much money can be saved by reducing commercial fertilizer purchases

Optimizes crop yields

- allows recycling of nutrients over entire land base, supplying crops with commercial nutrients only when required
- improved soil health from addition of organic materials

Protects soil and water resources

- a risk assessment is part of the nutrient management planning process, so you can store, handle and apply manure and nutrients with greater assurance of environmental protection
- the risks of over-application and nutrient loss are reduced by accounting for all nutrients

Integrates best management practices

- many of the steps in nutrient management involve best management practices – meaning they're practical, proven, and protect the environment
- you'll focus on taking an integrated (or systems) approach to management – not just for nutrients, but all components of your operation

Increases options

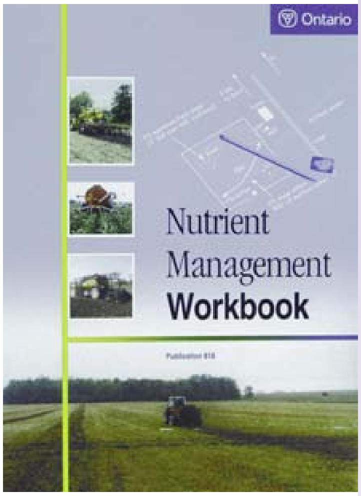
- by putting it all down on paper, you'll see a range of options

Avoids conflict

- the process shows ways to minimize farm-generated odours, and thus the potential for nuisance complaints from neighbours

Proves diligence

- your efforts are a testimony to your stewardship and reflect well on you and on the agriculture sector
- producing high quality products in environmentally responsible ways generates consumer confidence
- having a contingency plan demonstrates your preparedness for the unexpected



The *Nutrient Management Workbook* and NMAN computer software are tools to help develop your customized NM plan.

"There's a lot of negativity about nutrient management plans. I think most of it has to do with people not understanding it. But once you understand the purpose of it, how it helps you manage manure better, and the safety for the environment – personally, I think it's good."

Erwin Horst, Perth County

CHALLENGES

Generates paperwork

- you may be spending more time at your desk or on the computer – try to remember you're gathering some vital benchmark information about your operation that you can use
- as a living document, your plan needs to be flexible – to change with your operation

Incurs costs

- if you do the paperwork yourself, there will be a cost in terms of your time
- if you hire a consultant to help prepare your plan, the fee will depend on the size of your farm and the complexity of the plan

Preparing a nutrient management plan should be considered an essential part of farm business planning today.

10 STEPS TO NUTRIENT MANAGEMENT PLANNING

1. SET GOALS
2. TAKE INVENTORY
3. INPUT AND ANALYSE DATA
4. INTERPRET RESULTS
5. MAKE DECISIONS
6. ACT
7. KEEP RECORDS
8. MONITOR
9. ADJUST
10. PLAN FOR THE UNEXPECTED

Nutrient management planning is a 10-step process. It's also a continuous process – throughout the season, and from year to year, wherein you'll be re-evaluating your plan based on experience and new developments in your operation.

This book is laid out for easy reference to information regarding each of the 10 steps. Look for the step numbers in page margins.

WHERE THE ENVIRONMENTAL FARM PLAN FITS IN

If you've participated in the Environmental Farm Plan (EFP) program, you're already one step ahead. Nutrient management planning builds on the risk-assessment and planning process started with EFP, and continues to develop an action plan to deal with the identified nutrient management-related risks in a farming operation.

If you haven't yet completed an EFP, get involved! You'll be equipping yourself with risk-assessment and corrective tools that were developed by farmers for farmers. The plan covers a wide range of agricultural environmental issues – 23 topics in all.

To complete a farm plan, participants attend workshops facilitated by the Ontario Soil and Crop Improvement Association (OSCIA). Farmers, hired by OSCIA, review the environmental farm plans, and when "deemed appropriate" by OSCIA are often used as prerequisites for agri-environmental financial assistance programs.

A nutrient management plan is a more detailed plan, with a focus on fewer topics, namely those pertaining to fertility and manure management (i.e., seven of the above mentioned 23 topic areas).

Both programs give strong testimony to the proactive environmental stewardship of its participants.

The EFP program is voluntary. EFPs are confidential and are reviewed by farmers during peer review. EFPs and NMPs should be updated at least every five years to address changes in your farm operation.

The Ontario Farm Environmental Coalition and its partners promote the:

- **benefits to farmers who adopt nutrient management planning**
- **strategic utilization of on-farm nutrients**
- **adoption of soil, water and nutrient stewardship practices**
- **recognition by rural neighbours of the benefits of nutrient management planning, and**
- **acceptance of nutrient management planning by all residents of rural municipalities.**

PRINCIPLES

IN THIS CHAPTER, WE EXPLORE:

- nutrients required by crops
- sources of nutrients
- nutrient and water cycles
- the fate of nutrients in farming systems
- pathogens and sources of nutrients
- the Nitrogen and Phosphorus Indexes, and
- using the systems approach.

Many factors affect a crop's ability to obtain nutrients from the soil. To develop an effective nutrient management plan, you need to know what these factors are, how they interact, and how they influence your options.

MAJOR NUTRIENTS IN FARMING SYSTEMS

Most production systems in agriculture – both livestock and crop – depend on ample supplies of available nutrients. **Macronutrients (nitrogen, phosphorus** and **potassium)** plus **secondary nutrients (calcium, magnesium** and **sulphur)** are considered essential for plant and animal life. The primary biological function of each is described in the following chart.

In corn, a lack of phosphorus causes purpling of the leaves.

MACRO AND SECONDARY NUTRIENT FUNCTIONS		
NUTRIENT	**FUNCTION IN LIVESTOCK**	**FUNCTION IN PLANTS**
NITROGEN (N)	• proteins for muscle, skin, internal organs • enzymes for metabolic processes	• proteins for tissue growth • enzymes for metabolic processes • photosynthesis and respiration
PHOSPHORUS (P)	• bone growth • energy transfer • milk, meat or egg production	• photosynthesis and respiration • energy transfer • cell division
POTASSIUM (K)	• muscular activity • blood pressure regulation • pH buffering	• plant structure • photosynthesis and respiration • water uptake by roots
CALCIUM (Ca)	• bone growth and repair • milk or egg production • reproductive functions	• cell wall strength • cell formation • enzyme activation
MAGNESIUM (Mg)	• enzymes • muscle relaxant	• photosynthesis • protein and enzyme activation
SULPHUR (S)	• component of several amino acids in proteins and enzymes	• component of several amino acids in proteins and enzymes

SOURCES OF NUTRIENTS

Most of the nutrients taken up by plants are supplied by the soil itself. However, the levels of some nutrients in soil are inadequate to support optimal growth.

Nutrient materials that can be added to the soil come in two major forms:

- ▶ **inorganic,** e.g., commercial fertilizers
- ▶ **organic,** e.g., a major portion of manures, crop residues, biosolids.

Organic sources include:

- ▶ manure from your own farm or others' farms
- ▶ nutrients from incorporated legumes
- ▶ residual nitrogen from previous manure and biosolid applications
- ▶ washwaters and manure treatment by-products
- ▶ biosolids, or other non-agricultural source materials.

As you develop a nutrient management plan, use the nutrients that are most readily available to your operation.

A good way to account for crop nutrients in your operation is to begin with the ones already on your farm, such as manure and plowdown crops.

Off-farm nutrient sources, such as commercial fertilizers and biosolids, should be used to make up for the required nutrients not supplied by on-farm manure.

Using specific amounts of commercial fertilizer provides a consistent, balanced and reliable nutrient source. Examples include starter fertilizers and/or commercial sidedress of N for corn.

COMMERCIAL FERTILIZERS

Commercial fertilizer materials are one of the major sources of nutrients for crops. There are pros and cons with their use.

COMMERCIAL FERTILIZERS	
ADVANTAGES	**DISADVANTAGES**
• are in known and consistent concentrations and so allow for precise and timely applications • are readily available • can be blended to match crop requirements	• must be purchased off-farm • don't add organic matter to the soil • risk losing nitrogen portion outside of the growing season • carry a high energy cost associated with processing

How commercial fertilizers are produced

Nitrogen in the form of ammonia (NH_3) is manufactured by extracting the nitrogen gas from the atmosphere and hydrogen from natural gas. The initial product is **anhydrous ammonia** (82% N). All other commonly used nitrogen materials are then manufactured from ammonia. The forms most commonly used are urea (46%) and urea ammonium nitrate (28%) solution.

Common **phosphorus** fertilizer materials are made by treating rock phosphate (an unavailable form of phosphorus) with various acids in order to make the phosphates available for plant growth. Nitrogen can be added to the process to make nitrogen and phosphorus blends and to make phosphorus more available.

Potash fertilizer is made by crushing potassium chloride (muriate of potash) and washing the product to remove other salts.

Commercial fertilizers can be applied precisely – when crops need them.

Unlike organic sources of nutrients, commercial fertilizers can be blended to match crop requirements.

MANURE

Manure provides the same nutrients for crop production as commercial fertilizers. One of the main challenges with manure, however, is that we can't change the proportion of nutrients to meet crop needs. We must take the manure as it comes. Some forms of manure, such as solid poultry, are relatively concentrated compared to liquid veal manure, which is very dilute.

Some types of liquid manure are dilute. This makes them easy to handle with a wide variety of application equipment, but costly relative to the concentration of nutrients available.

MANURE

ADVANTAGES	DISADVANTAGES
• contains many required nutrients • provides nutrients for several years after application • supplies organic matter to soils	• has variable nutrient content • cannot always meet crop needs • produces odour • can lead to water contamination if not properly managed • can be difficult to apply to growing crops

Unchecked runoff from improperly applied manure can contaminate surface water with nutrients, bacteria and organic debris.

Erosion control structures, such as Water and Sediment Control Basins (WASCoBs), will help reduce sediment load from cropland runoff.

Nitrogen in manure is present in both ammonium (inorganic) and organic forms. The proportion of each depends on the type of manure, and the amount and type of bedding material added.

The organic nitrogen in manure is eventually converted to ammonium through microbial action, and then further converted to **nitrate**. Ultimately, all of this N may be taken up by plants either as ammonium or as nitrate.

Phosphorus is present in organic and inorganic forms in the solid fraction of the manure. Repeated manure applications will increase P levels. At low soil-test levels, manure P is only 40% available as fertilizer phosphorus in the year of application. The remainder becomes available over time. At higher soil-test levels, the full amount of manure P is considered available as fertilizer P to plants. As P levels increase, so does the potential for surface water pollution, and high enough levels will be detrimental to plant health.

The nutrient content of manure is influenced by many factors:

- nutrition – in general, a better feed-conversion ratio leads to lower excretion of N and minerals in manure
- feed additives – feed additives that promote growth may also reduce excretion of N and P
- dilution – manure storage and volumes of water collected can influence the concentration of nutrients in manure
- bedding – amount and type of bedding (e.g., wood shavings) that resists breakdown is prone to tying up manure nutrients (e.g., N) making them temporarily unavailable to crops.

BIOSOLIDS OR NON-AGRICULTURAL SOURCE MATERIALS

Biosolids, which originate from sewage treatment, pulp and paper, and other sources, provide many of the same nutrients for crop production as manures or commercial mineral fertilizers.

Certificates of Approval are required by the Ministry of the Environment before non-agricultural source materials (NASMs) can be applied. Application must be done in accordance with provincial guidelines.

Biosolids provide many of the same nutrients as manure and commercial fertilizer.

PATHOGEN SURVIVAL

Manure contains bacteria, viruses and parasites. The variety and numbers of these micro-organisms make manure a beneficial soil amendment. However, some are referred to as pathogens because they can infect other livestock and humans.

A pathogen is any virus, bacterium, or protozoa capable of causing infection or disease in other animals or humans. Pathogens range from parasites such as roundworms to bacterium such as salmonella and E. coli to protozoa such as Cryptosporidium parvum and Giardia. Most livestock viruses are not passed to humans.

Few pathogens survive for long when outside a livestock host. Most last only a few days. But some can last up to several months, depending on a number of environmental conditions. The following can limit pathogen survival:

- high temperatures – very high temperatures reached during composting
- freezing or freeze/thaw cycle – whereas moderate temperatures may extend the lifespan of pathogens
- low humidity, sunshine and dry field conditions
- manure decomposition – produces chemicals that kill some plant pathogens
- high and low pH – acidic soils and the use of liming materials will reduce pathogen survival
- absence of oxygen – liquid manure and the wettest part of stored solid manure are considered anaerobic environments (i.e., no oxygen).

Soil is good at trapping bacteria and other organisms, filtering out most protozoa and bacteria. Soils with high organic matter and clay content are more effective at filtering viruses. However, pathogens can bypass soil filters by following macropore flow or preferential flow to shallow aquifers or through tile drainage systems.

Pathogens can move to surface water via surface runoff or by livestock accessing streams and creeks. Livestock operations located upstream from municipal drinking water supplies or recreation areas should recognize the potential risks and develop their nutrient management plan accordingly. Pathogens are unlikely to directly contaminate groundwater.

Pathogenic bacteria found in livestock may infect humans if there's a direct pathway to drinking water supplies or recreational waters. In water wells, these bacteria can be controlled with chlorine or ultraviolet light filtration systems.

Manure treatment processes such as anaerobic digestion and composting can generate conditions required to reduce pathogens in manure.

Phytase can reduce excreted P from hogs by up to 50%.

LIVESTOCK NUTRITION AND NUTRIENT OUTPUT

Diet and feeding strategies are of critical importance to livestock and poultry health, performance and product quality. You can reduce feed wastage and improve performance by adhering to the general principles of animal nutrition, feed analysis and ration formulation.

Science-based nutritional strategies will improve the nutrient balances on livestock farms. These strategies are quite simple to implement and can have a significant impact on nutrient output and your operation's profitability. The most promising and practical of these strategies focus on two main principles: optimizing input and maximizing the efficiency of utilization.

Feeding more closely to the animals' requirements will reduce nutrients excreted for all livestock types. For **ruminants,** balancing P-containing mineral supplements will reduce P excretion. And by balancing ruminally degradable and undegradable protein sources, N excretion can be reduced. For **non-ruminants,** the biggest impacts will be realized by using phytase, reducing P-containing mineral supplements, or maximizing protein efficiency by balancing amino acids (potentially with synthetic amino acids). Using these strategies, N and P excretion can be reduced by up to 50% (see table).

Applying nutritional strategies to reduce excretion will increase the need for precise feed ingredient evaluation, feed formulation, manufacturing and delivery. Reducing water wastage from drinkers can also decrease manure volumes. Practices that improve performance and reduce feed wastage will help reduce nutrient levels in manure materials.

Nitrogen and phosphorus excreted in feces and urine are the main sources of water pollutants from livestock agriculture.

HOGS: POTENTIAL IMPACT OF NUTRITIONAL STRATEGIES ON EXCRETION OF NITROGEN AND PHOSPHORUS

STRATEGY USED	POTENTIAL REDUCTION IN NUTRIENT EXCRETION
Improve feed efficiency	3% for every 0.1 unit in improvement
Minimize feed wastage	1.5% for all nutrients for every 1% reduction
Match nutrient requirements	6–15% for N and P
Phase feeding	5–10% for N and P
Split-sex feeding	5–8% for N
Phytase	2–5% for N; 20-50% for P
Formulate on nutrient availability	10% for N and P
Amino acid balancing	9% for N for every 1% reduction in crude protein
Highly digestible feed ingredients	5% for N and P
Pelletize the ration	5% for N and P
700–1000 micron particle size	5% for N and P
Enzymes: cellulases, xylanases, etc.	5% for N and P for appropriate diet
Growth-promoting feed additives	5% for all nutrients
Low-phytase corn	25–50% for P

Note: The actual reduction in N and P will vary. The closer the feeding program is to recommendations, the lower the nutrient reduction in manure.

NUTRIENT AND WATER CYCLES

NUTRIENT CYCLE

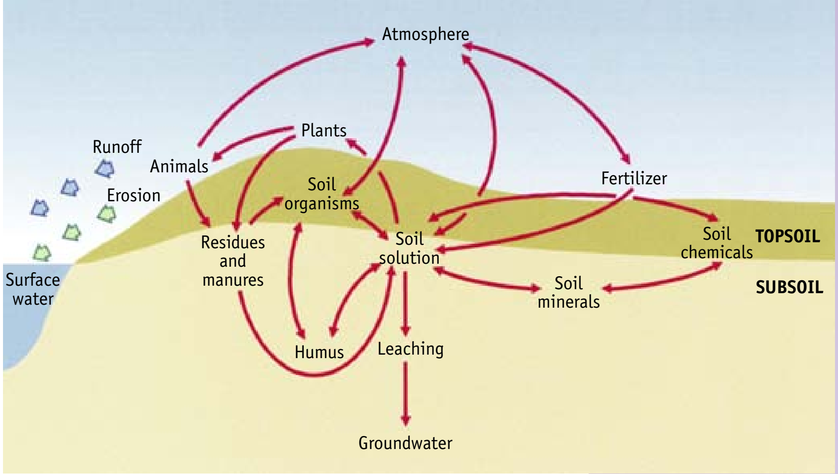
Nutrients are constantly cycling through the soil in different forms. As they do, nutrients are used by plants, lost from the soil, or converted to unavailable forms.

A basic understanding of the nutrient cycle and its interaction with the water cycle is the foundation of a sound nutrient management plan. It involves learning about the various forms in which nutrients exist, what influences the availability of specific nutrients, and how they're lost from the cycle.

Nutrients exist in soil in many forms, of which only a few are useful to plants. Regardless of whether you apply nutrients to soil in organic form (e.g., manures) or in inorganic form (e.g., commercial fertilizers), they must be in an inorganic form to be taken up by plants.

In soil that isn't frozen, chemical and biological activity is continually changing nutrients from one form to another, although a rough balance exists among them. Look at the nutrient cycle illustration for a general idea of the cycle through which nutrients flow.

NUTRIENT CYCLES



Nutrients exist in the soil in many forms. Chemical and biological processes change the chemical form of crop nutrients. Some nutrients move right through a cycle that consists of soil, crop, air, livestock and water components. Nutrient cycles consist of several components – soil, crops, livestock, manure, other nutrient materials, groundwater and surface water, and in the case of nitrogen and sulphur – the atmosphere.

Soil

- ▸ crop nutrients can be derived from weathering minerals in cropland soils
- ▸ nutrients can be added directly from the application of fertilizers, manure and other organic materials
- ▸ nutrients can be added indirectly to the soil from the breakdown of soil organic matter, soil animals, soil microbes, manure and crop residues
- ▸ soil microbes will break down soil organic matter, manure and crop residues for their own use or to transform to soluble forms – other microbes can transform some nutrients into gaseous forms that in turn escape into the atmosphere
- ▸ while in the soil solution, nutrients can be taken up by crops or microbes, exchanged with other nutrients from soil exchange sites, tied up by soil minerals (as unavailable forms) or leached to groundwater

Crops

- crops remove nutrients from soil solutions – when crop nutrients are harvested, they're lost from the system, fed to livestock or returned to soil as crop residues

Livestock

- livestock consume crops as feed or forages through grazing, use them for maintenance, production or reproduction, and return some portion of the nutrients directly or indirectly as manure additions

Manure and other nutrient materials

- when materials are incorporated:
  - organic portions are processed or tied up by soil microbes
  - inorganic portions go directly into the soil solution
- when materials are not incorporated:
  - certain nutrients may be directly lost to the atmosphere
  - others may be lost to surface runoff
  - remaining nutrients will go through the same process as incorporated nutrients

Water

- cropland runoff can remove nutrients from topsoil and deposit them downslope or into surface waters
- some nutrients in the soil solution are lost from the cropland system through leaching to tile drainage systems or to groundwater resources

Atmosphere

- atmospheric gases (e.g., nitrogen gas and methane) can be fixed by crops and soil microbes
- some nutrients in the soil solution can be transformed to atmospheric gases – some of which are harmful greenhouse gases (e.g., nitrous oxide, methane and carbon dioxide)

WATER CYCLE

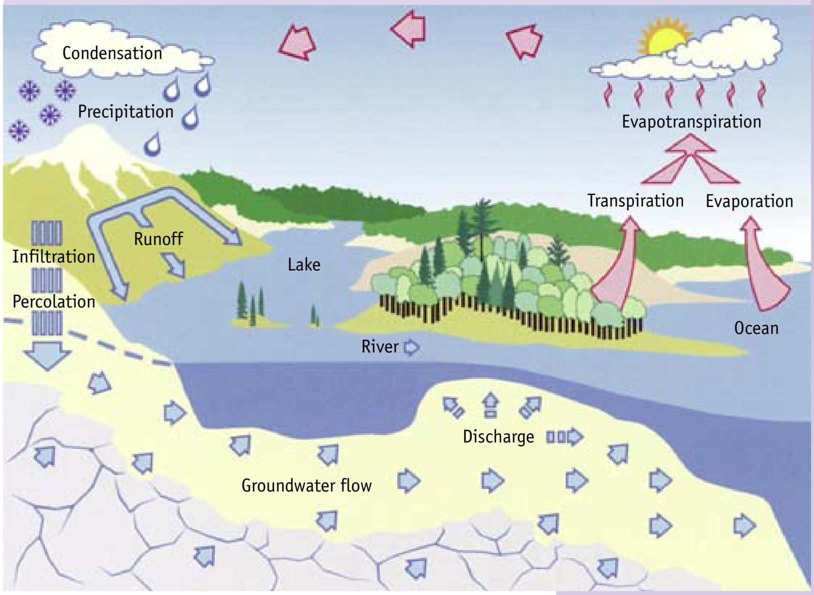
Water is in constant motion, continually recycling through the environment in a series of pathways called the **water cycle**.

Precipitation, mostly in the form of rain or snow, falls on land, buildings, and bodies of water. Precipitation can be temporarily stored in ponds, lakes and rivers, held by snow and vegetation, or stored as ice and snow.

Some of the water falling on land and buildings flows overland as runoff to bodies of surface water (e.g., lakes & rivers). Some of the water that's held by soil or vegetation will infiltrate through soil materials, to be stored as groundwater. Groundwater can then move to lakes, rivers, ponds, wetlands, wells, or to the soil surface. Groundwater flowing to the surface, or small surface water bodies, form part of a larger surface water system called a watershed.

At the soil surface, water can be evaporated directly to the atmosphere, or transpired (evapotranspiration) when plants release moisture during rapid growth.

THE WATER CYCLE



Water is in constant motion, continually recycling through the environment in a series of pathways called the water cycle.

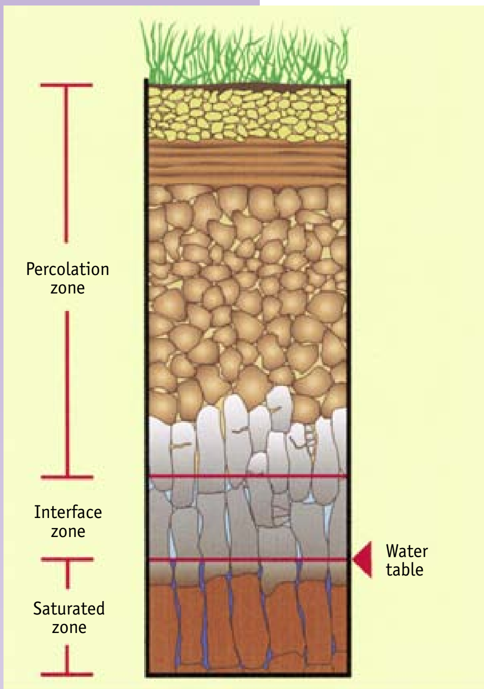
INTERACTIONS BETWEEN WATER AND NUTRIENT CYCLES

Pathways of water

In your fields, **precipitation** can:

- ▶ be stored on the surface as snow or ice
- ▶ evaporate at the soil surface
- ▶ infiltrate the soil
- ▶ be stored in the soil to be used by crops
- ▶ run off overland if precipitation exceeds the soil's infiltration capacity.

The proportion of water in any of these areas depends on soil characteristics (properties and quality), length and degree of slope, temperature and weather conditions, and the quality of cropland management.



Water moves – or percolates – through soil pores and cracks to a saturation zone known as the water table.

Nutrients and surface water

When water falls on a bare field in late spring, roughly two-thirds of it is evaporated back to the atmosphere, one-quarter runs off to ponds, watercourses, lakes and other depressional areas, and the remainder infiltrates the soil.

Continuous row-cropping, a decrease in forage-based cropping systems, and large equipment used in wet soil conditions can contribute to soil compaction, which reduces water's ability to percolate through soil. This can result in excess surface water in fields.

Excessive runoff is of particular concern, since it can take soil and the crop inputs in the soil (such as phosphates from applied commercial fertilizers or manure, and some pesticides) with it to pollute surface water. In addition to overland flow, excess surface water can lead to soil erosion. Erosion affects water quality because it can transfer high sediment loads to watercourses. That sediment will include topsoil, chemicals, nutrients (i.e., N and P) as well as microorganisms, including pathogens.

Nutrients and groundwater

Water enters soil through pores and cracks or holes and tunnels created by root channels, earthworms, insects and animals. Some of these pathways run continuously downward to the subsoil. These "macropores" can be direct channels for manure and nutrients applied at the surface to contaminate water. (tile and groundwater).

How much water enters will depend on your field's natural characteristics and your management choices.

Several natural characteristics affect the amount of water in soils, namely: soil type and structure, slope, depth to water table, depth to bedrock, precipitation, season and weather.

Management practices also affect soil moisture content. Soils with high amounts of crop residue will allow more infiltration and higher soil moisture. The same is true for soils with high organic matter content.

Soil type

The type of soil (e.g., sandy loam or clay) determines how much water is held in your soil, and how much is available for use by crops.

Your soil's water-holding capacity will also depend on the amount of organic matter and the number of soil layers. Soils with layers of various-textured soils (known as "stratified") will slow the speed with which water moves downward through soil profiles.

In uniform soils, the water table will move up and down with the seasons. If a layer of soil occurring naturally or caused by cultivation restricts water movement, a perched water table may be present.

Knowing your soil types is the first step to maintaining and improving them, and managing water effectively.

NUTRIENT LEACHING

Nutrients in solution will move with soil water. Leaching occurs when these nutrients, nitrates for example, move through soil pores and large cracks below the root zone. The amount of leaching is related to:

- **the concentration of nutrients in the soil solution**
- **the overall supply of available nutrients in the soil**
- **soil texture – water moves quickly through sandy soils, and cracked clay soils**
- **soil layering or stratification, which will slow the movement of water though the soil profile**
- **coarse fragments – soils with large volumes of stones and gravels are more prone to leaching**
- **soil depth to bedrock or water table – less soil depth means quicker travel time.**

The site features most connected to groundwater contamination are:

- soil texture
- depth to bedrock
- depth to groundwater.

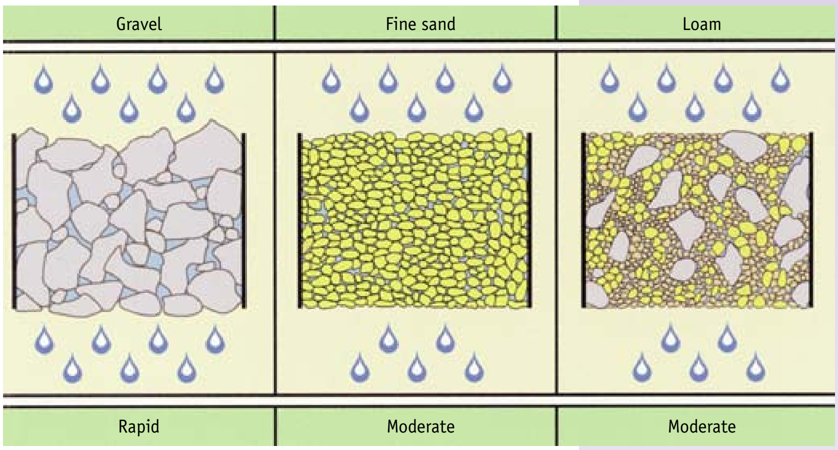
Soil texture

Soil texture, which is the relative coarseness or fineness of the soil particles, is the most important determining factor in measuring the ease and speed with which water and contaminants can move through the soil to groundwater.

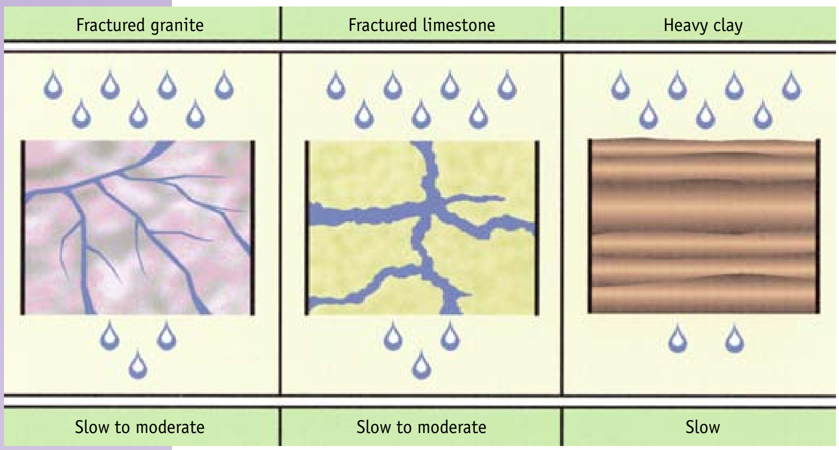
Coarse-textured soils such as gravels and sands have large pore spaces between the soil particles. This allows water to quickly percolate downward to the groundwater.

In fine-textured soils such as clays and clay loams, water and contaminants move through soil very slowly. They act as a natural filter and allow for biological and chemical breakdown of contaminants before they reach groundwater. Fine-textured soils provide better natural protection for groundwater.

Soil texture can be assessed using hand-texturing methods or with laboratory particle-size analyses. Soil maps can also help you identify soil texture at a particular site.



Water percolates quickly through sands and gravels and very slowly through clays.



Most bedrock types are not impenetrable. Water moves through cracks and fissures to shallow water tables.

Depth to bedrock

Shallow aquifers are often present in regions where bedrock is close to the surface. This is particularly true with fractured bedrock types such as limestone, dolomite, sandstone and weathered shales.

Open fractures in the bedrock allow rapid movement of water and contaminants to groundwater. If the depth of soil over the bedrock is shallow (less than 90 cm or 3 ft), there is little opportunity for filtration or restricting the flow of contaminants to the bedrock layer.

Depth to bedrock can be determined using hand or mechanical excavation equipment.

Soil maps and surface geology maps can give a general indication of bedrock depth. One simple visual clue of shallow bedrock depth is bedrock exposure at the soil surface. Also, if you've had experience with excavations or digging post-holes in the area, you'll have some indication if depth to bedrock is an issue.

Depth to groundwater or water table

Filtering and treatment of contaminated water by natural processes primarily takes place in soil above the water table in the unsaturated zone of soil. In a naturally occurring, high water table, water and contaminants have little time to move through unsaturated soil before reaching shallow aquifers.

Water table depths can fluctuate significantly, depending on the season. In Ontario, the water table is usually highest in the spring or fall.

Depth to water table can be assessed by:

- digging a hole in June or September and observing the depth to free water in the hole
- using soil colour features (rust spots and blue-grey colours in soil layers) and the soil drainage method by referring to a local soil map to assess drainage class (e.g., imperfect or poor drainage).

REDUCING THE RISK OF GROUNDWATER CONTAMINATION FROM MANURE APPLICATION ON SHALLOW SOILS

HYDROLOGIC SOIL GROUPS (HSGs):

Soils are classified into five Hydrologic Soil Groups based on the soil's runoff potential. These soil groups consider the water movement through the soils within a 90 cm (3 ft) soil profile rather than just the surface texture to a 20 cm (8 in.) depth. The HSGs are AA, A, B, C and D. AAs generally have the smallest runoff potential and Ds the greatest.

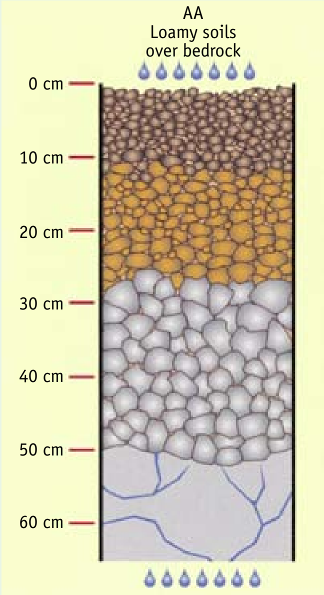
Soils that are shallow to bedrock would move up one category in HSG. For example, a clay loam soil that is shallow to bedrock on a HSG D would move up to HSG C.

All soils in Ontario have been rated into HSGs. These ratings help to determine N Index risk assessments and loading limitations for proposed nutrient application rates.

SHALLOW TO BEDROCK SOILS:

There are some locations where risk of contamination is so high that manure should never be applied. In other situations, risk may still be high, but management around manure type, application timing and incorporation may reduce those risks to acceptable levels.

- no manure should ever by applied on or within 3 metres (10 ft) of exposed bedrock
- where manure is applied without pre or post tillage, there should be no rain in the weather forecast
- where liquid manure is injected, the application band should disturb 50% of the surface area to reduce risk of a concentrated band moving downward



Group AA are all soils that are shallow to bedrock <60 cm (2 ft) and all group A soils that have a depth of less than 0.9 m (3 ft) to bedrock.

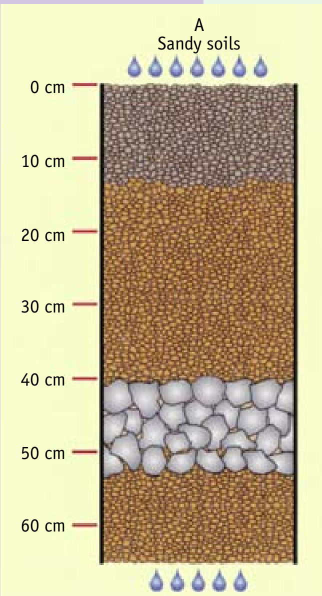
DEPTH TO BEDROCK	LIQUID MANURE	SOLID MANURE
0–15 cm (6 in)	no application	no application Oct–May; < 22 t/ha June–Sept (<10 ton/acre)
15–30 cm (6–12 in)	no application Oct.–May; pre-till, or <40 m^3/ha (<3600 gallons/acre)	pre-till, or <45 t/ha (<20 ton/acre)
30–90 cm (1–3 ft)	pre-till, or <40 m^3/ha (<3600 gallons/acre)	no restriction

SOILS WITH SHALLOW GROUNDWATER:

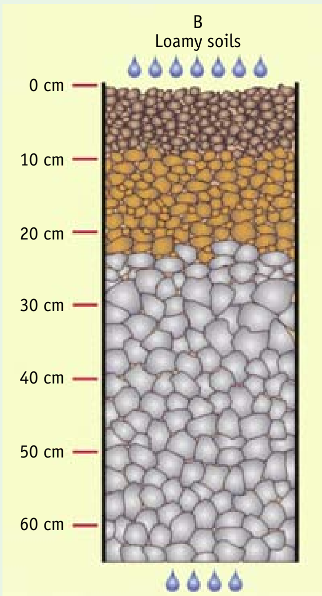
▶ when the water table is near the surface, saturated soils, wheel tracking and risk of getting stuck will discourage application – assess risk according to conditions at application time

POTENTIAL FOR GROUNDWATER CONTAMINATION

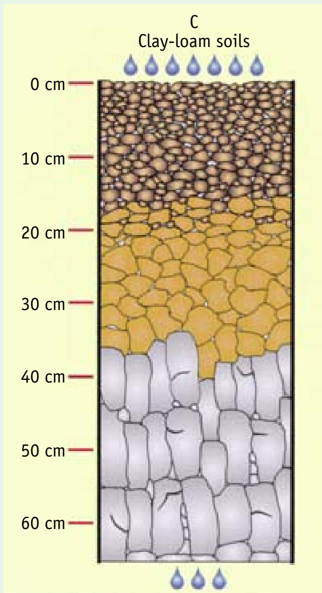
HYDROLOGIC SOIL GROUP	DEPTH OF UNSATURATED SOIL AT THE TIME OF APPLICATION		
	<30 cm (1 ft)	30–60 cm* (1–2 ft)	>60–90 cm* (>2–3 ft)
CATEGORY A: RAPID (SAND)	no application	high	moderate
CATEGORY B: MODERATE (LOAM)	no application	moderate	low
CATEGORY C: SLOW (CLAY/LOAM)	no application	low	very low
CATEGORY D: VERY SLOW (CLAY)	no application	low	very low



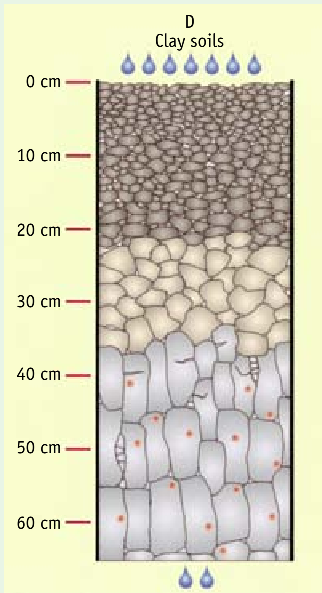
Group A is sand, loamy sand or sandy loam types of soils. They have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water infiltration.



Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well-drained soils.



Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.



Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Application guidelines are determined from the following table for the risk category identified:

GROUNDWATER CONTAMINATION POTENTIAL	LIQUID MANURE	SOLID MANURE
HIGH	No application	Pre-till, and <45 t/ha (<20 tons/acre)
MODERATE	Pre-till, and <40 m^3/ha (<3600 gallons/acre)	Pre-till
LOW	Pre-till or <40 m^3/ha (<3600 gallons/acre)	No restriction
VERY LOW	No restriction	No restriction

NITROGEN: ENVIRONMENTAL RISKS AND THE N INDEX

Some of the very same macronutrients that are essential for sustaining animal, crop and soil life are, in excessive quantities, harmful to water and air quality.

Regardless of how nitrogen is applied to the soil, much of it will eventually be converted to the nitrate form. Plants take up most of their nitrogen as nitrate, in part because it's the most common inorganic form in soil.

Nitrate-nitrogen is very soluble in water and moves with soil moisture. This allows roots to obtain the nitrogen from almost any part of the soil from which they draw water. However, because of its solubility, nitrate-nitrogen also leaches very easily.

High nitrogen and phosphorus levels in water allow excessive growth of aquatic plants.

Nitrogen, when in nitrate (NO_3^-) form, moves easily with soil water. As a result, it can travel through and below the root zone, and potentially enter groundwater.

The level of nitrate-nitrogen in soil can change quickly. In warm weather, large amounts can be released by the breakdown of organic matter. In wet weather, nitrate can be lost from well-drained soils through leaching, or from saturated soils, by conversion into nitrogen gas by soil bacteria through a process called denitrification.

In soil, the nitrogen in urea is converted to ammonium. However, under certain circumstances, the ammonium can be converted to ammonia gas. A significant portion of the nitrogen content of urea can be lost when urea is left on the soil surface or on crop residues under warm, humid conditions with high soil-moisture content.

The fate of manure nitrogen

In manure, nitrogen has two forms: inorganic and organic. The main form of nitrogen will vary, depending on the type of manure (liquid vs. solid).

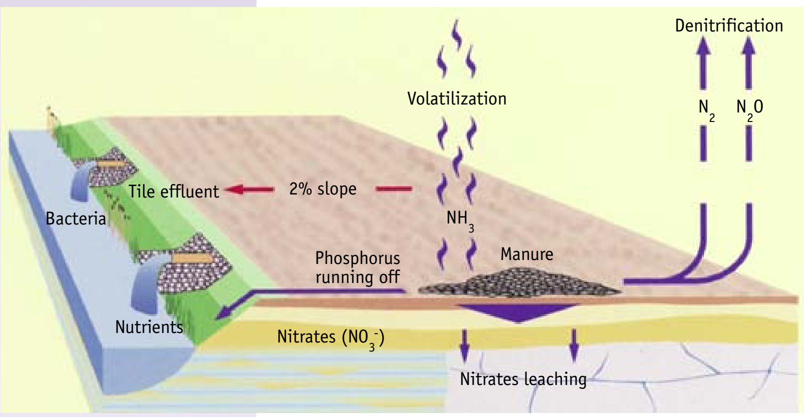
Manure runoff can harm aquatic habitat. Ammonia gas from manure runoff may cause fish kills.

A key inorganic form is **ammonium (NH_4^+)**. NH_4^+ is available for plant growth but highly volatile as it can convert to ammonia gas (NH_3). NH_4^+ can be a problem if raw manure runs off into surface water because the toxicity of the ammonia results in fish kills.

The organic nitrogen component in manure is quite stable and will eventually become converted to ammonium through a process known as mineralization. In soil, ammonium will be held to soil surfaces (clay and organic matter). It is available to plants and is subject to a process called nitrification – whereby soil microbes change ammonium to nitrite and nitrate (NO_3^-).

Nitrate in the soil is subject to several fates:

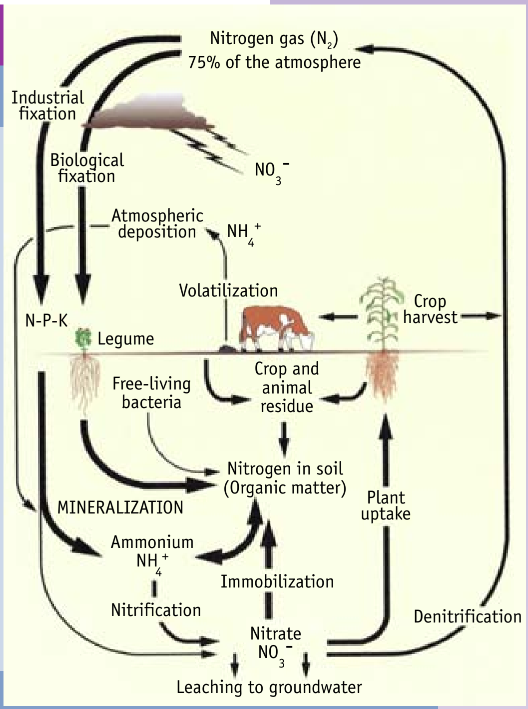
- taken up by plants
- absorbed by soil microbes (immobilized)
- leached through the soil beyond the root zone
- found in cropland runoff
- transformed, in wet soils, by soil microbes through denitrification to N gases such as nitrogen gas (N_2) and nitrous oxide(N_2O). Nitrogen gas makes up 78% of the atmosphere while nitrous oxide is a greenhouse gas that has about 300 times the warming capacity of carbon dioxide.



Applied manure nitrogen adds ammonium and nitrate to the soil N reserve. Some of this N is lost as ammonia (NH_3). Much of this ammonium and nitrate may be taken up by plants. Nitrate not taken up by plants can be leached or converted to nitrogen gas.

NITROGEN CYCLE – Here's what happens to the "key players" in the nitrogen cycle.

N-INPUT	PROCESS / FATE
COMMERCIAL FERTILIZERS	Nitrogen gas (N_2) is fixed to manufactured fertilizers with urea, ammonium and nitrate components
MANURES	Solid and liquid manure, wastewaters and biosolids add organic and inorganic nitrogen forms to the soil
LEGUMES	Nitrogen gas (N_2) is fixed by microbes in soil and legume plants and provides an organic N-form to the soil
CROP RESIDUES	Organic N is added from crop root systems and residues (including cover crops)
ATMOSPHERIC INPUTS	Some NO_3^- is added to soil by heat and lightning
N RESERVES IN THE SOIL	**PROCESS / FATE**
SOIL ORGANIC MATTER	Organic N is part of soil organic matter (humus)
AMMONIUM (NH_4^+)	NH_4^+ can be held on soil and humus particles on exchange sites
NITRATE (NO_3^-)	NO_3^- in soil solution and in moisture is held by soil particles
N CHANGES IN SOIL (by soil microbes)	**PROCESS / FATE**
MINERALIZATION	Organic N breaks down into ammonium
NITRIFICATION	Ammonium is converted to nitrate
IMMOBILIZATION	Ammonium and nitrate are tied up by soil organisms
VOLATILIZATION	Conversion of ammonium-N to ammonia gas
DENITRIFICATION	Conversion of nitrate to nitrogen gases, N_2 and N_2O
LEACHING	NO_3^- in soil solution moves downward out of root zone potentially into groundwater



As we saw earlier in this chapter, there are many factors that influence just how easy it is for nitrogen and phosphorus to follow pathways to surface water and groundwater. Soil type and slope, proximity of ground or surface water, the weather and the season, your management practices and the fertility levels will all affect risk.

To assess risk, those factors that influence nutrient movement off the field need to be looked at on a site-by-site basis. Factors are then weighed together to arrive at a risk "Index", better known as the Nitrogen or Phosophorus Index. The following section explains how these work.

The Nitrogen (N) Index

The Nitrogen Index is a tool for reducing the risk of nitrate contamination of groundwater. It evaluates the vulnerability of nutrient management practices with respect to the movement of nitrates. The N Index combines source and transport factors to assess the risk of nitrate movement to groundwater on a field-by-field basis.

The nitrogen cycle is complex, and factors contributing to both nitrate source and transport often interact. When manure nitrogen converts to the nitrate form, it will move through the soil with water rather than bind to soil particles.

Source risk factor

The net amount of nitrate in the soil following harvest may have come from:

- nitrogen applied for growing the current year's crop
- nutrients applied after crop harvest
- residual nitrogen in crop residues, especially legumes
- mineralized N and nitrified materials from soil organic matter.

In the case of nitrogen applied for this year's crop, it is the amount of N applied in excess of crop requirements that is of most concern.

For nutrients applied after harvest – as with fall application of manure – there is an increased risk of nitrate movement to groundwater. The timing and method of application and the type of manure will influence risk.

The risk of N movement is greatest on shallow soils.

Transport risk factor

The transport factor evaluates the opportunity for nitrate to move down, with water, through the soil to groundwater.

In Ontario, crops are normally removing more water from the soil during the growing season than is being added as precipitation, so there's no leaching during the growing season except under abnormally wet conditions.

The fall, winter and early spring usually brings more precipitation than evaporation, so water can move down through the soil profile. This is the reason we are concerned with the amount of nitrate in the soil after the growing season, when there is no crop to absorb the nitrate and the risk of loss is high. Cover crops grown after crop harvest help reduce this risk of loss by taking up nutrients and holding them in an organic form until spring.

PHOSPHORUS: ENVIRONMENTAL RISK AND THE P INDEX

In manure, phosphorus (P) is associated with the solid fractions; therefore a higher portion is present in solid manures.

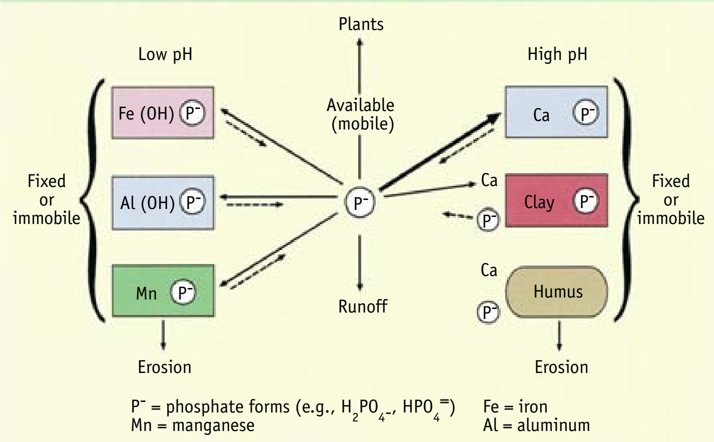
Inorganic P in solution is referred to as phosphates (PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$). Phosphates are very reactive in soil and combine with calcium, magnesium, iron, manganese, or aluminum, and become attached to the soil particles.

In soils with low pH, phosphorus is immobilized to form iron, manganese and aluminium compounds. In soils with a high pH, phosphorus can be found attached to clay and humus particles or tied up with calcium and magnesium compounds. Only a small amount (5%) is available to plants at any given time.

Phosphates in solution are very reactive. They can quickly be immobilized or taken up by plants. However, much of the phosphate remains in a reserve form and is released into solution to replenish what plants have removed. Since it doesn't move with soil moisture, phosphorus is unlikely to leach.

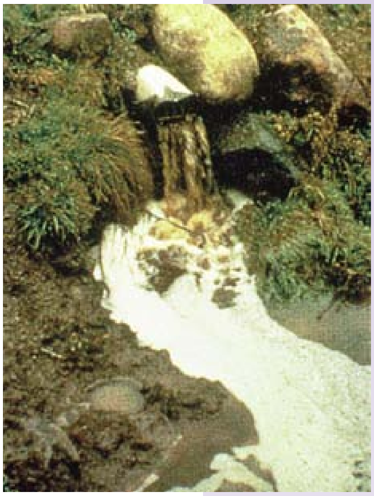
Because low temperatures slow root growth and nutrient absorption, plants are often unable to obtain sufficient phosphorus during cold weather, especially when plants are small.

SOIL PHOSPHOROUS – FORMS, FATE & AVAILABILITY



Phosphates are very reactive in soils. In acidic soils, it can be tied up by iron, aluminum and manganese compounds. In high pH soils, it can be tied up by calcium and magnesium compounds, as well as clay particles and soil organic matter.

Soil P is often attached to soil particles and will reach surface waters with cropland runoff.



Washwater containing phosphate-based detergents from some dairy farms reaches surface waters through direct hookups to tile lines.

In Ontario, phosphorus is the limiting factor for algal growth. If you reduce phosphorus in surface water, you'll have fewer algal blooms.

The fate of phosphorus

In the year of application, manure P is only 40% as available as fertilizer P. Therefore, 100 lbs of P_2O_5 from manure is equivalent to 40 lbs of P_2O_5 from fertilizer. When it comes to the long-term change in soil-available P (soil test P), manure P does not differ as much from fertilizer P. Over time, 80% of the P in manure is available for crop uptake.

In solution, phosphates can be taken up by plants, lost in soil runoff, or a very small amount may move through the root zone through soil cracks. Any phosphorus that ends up in surface water can promote algal blooms. As these aquatic plants die and decompose, oxygen levels in the water drop to levels that can kill fish and other aquatic life.

The Phosphorus (P) Index

The purpose of the Phosphorus Index (P Index) is to assign a value to the risk of surface water contamination through nutrient application to cropland. So, for example, on fields where soil phosphorus levels, as determined from soil tests, are very high and erosion potential is high, the risk of phosphorus contamination of surface water from manure application is also high. There may be a need to restrict P application, or to reduce erosion. The following chart lists the field and management practices that are considered when arriving at a P Index.

FACTORS CONSIDERED IN THE P INDEX TO ESTABLISH MINIMUM DISTANCE SEPARATIONS FOR MANURE APPLICATION ADJACENT TO WATERCOURSES

INFLUENCING FACTOR	FIELD MEASUREMENT OR INPUT NEEDED DETERMINING THE P INDEX
NATURAL FIELD CHARACTERISTICS account for a field's soil erosion potential and water runoff potential	• soil texture/erodibility • slope length • slope gradient (adjacent to watercourse) • rainfall energy • distance to the watercourse
FIELD MANAGEMENT PRACTICES adjust the field's soil erosion potential	• tillage system (e.g., no-till) • cross-slope/contour farming • crop rotation, forages, cover crops
NUTRIENT MANAGEMENT PRACTICES account for factors such as the current P levels in soil as well as how and how much P is being applied to a field	• soil fertility levels • manure and fertilizer application rates • method of manure and fertilizer application (e.g., incorporated vs. surface-applied)

Note: the P Index-based separation distances for P application do not need to be considered if the soil sample P test result is below 30 ppm.

Even if the P Index calculated for a particular field is high, it's often not necessary to restrict phosphorus application to the entire field, because only a portion of the field directly connected to the watercourse is likely to be "delivering" the phosphorus. As a result, only those areas adjacent to a watercourse or that have the highest risk of sediment delivery potential need to be avoided.

The P Index is higher on steeply sloping fields.

POTASSIUM

In manure, potassium (K) has two forms: inorganic and organic. Approximately 75% is in the liquid fraction and is readily available to plants. The remaining 25% can be found in the organic portion of manure solids.

In soil, K has three forms:

- unavailable K – as much as 90–98% is held by minerals
- slowly available K – up to 10% held by clay minerals
- available K – 1–2% in solution or held by minerals. K ions will leach in sandy soils.

Despite the relative low availability in soil, K maintains a dynamic equilibrium. Potassium ions that are taken up by plants are rapidly replaced by exchangeable potassium from reserves in the soil.

Potassium from farm sources does not lead to water quality issues in Ontario because the available potassium is in equilibrium with unavailable forms of potassium in the soil. Extremely little K leaches or is found in cropland runoff. Potassium is not a limiting factor for aquatic plant growth.

***Caution:* High soil-test levels of potash and high potash levels in manure can lead to high potassium (K) levels in forages, resulting in milk fever problems in dairy cows. Alternatives to high K forages include off-farm sources of low K hay and/or dilution with low K forages such as corn silage, or anion/cation balancing.**

SUMMARY OF MANURE NUTRIENT LOSSES AND INTERACTIONS WITH THE WATER CYCLE

PROCESS	DETAILS
VOLATILIZATION	• defined as the loss of free ammonia (NH_3) to the atmosphere • manure-based ammonium (NH_4^+) will readily convert to ammonia • manure with higher levels of NH_4^+ will more readily produce NH_3 • rate of loss depends on temperature, humidity, wind speed, soil moisture, pH, vegetative cover, rainfall and infiltration – loss is greatest in warm, sunny dry weather • loss increases with surface exposure – incorporation reduces loss
DENITRIFICATION	• manure-based nitrogen (ammonium) converts to nitrate and nitrite (nitrification) • in saturated soils, nitrates will be converted by microbes to nitrogen gas (N_2) • in semi-saturated soils and storages, nitrates will be converted by microbes to N_2O
RUNOFF AND EROSION	• surface-applied manure is at risk of runoff • manure-based P + N nutrients will be transported with eroding materials and runoff • rates of runoff and erosion increase with slope, low infiltration rates, compacted or frozen soils, low vegetative or crop cover, intense rainfall or snowmelt
LEACHING	• defined as the movement of soil solutions and their solutes out of the soil profile/rooting zone • for this to happen, there must be a high concentration of nitrate (and/or bacteria) in the rooting zone and a net movement of water through the soil profile • sandy and gravelly soils with high water tables are at greatest risk • prime sources of nitrate are: ○ improperly stored manure (e.g., uncovered solid or composted manure on bare soil) ○ nitrate fertilizers, and ○ mineralized applied manure and legumes
TILE EFFLUENT	• defined as the mass flow of applied liquids to tile outlets • all manure-based nutrients (N,P and K) and bacteria can end up in surface waters, as effluent seeps through cracks and continuous macropores (without pre-cultivation) • this is more often an issue with no-till soils and soils prone to cracking
IMMOBILIZATION	• nutrients are tied up by microbes in soil • soil microbial populations are large and diverse enough to remove available nitrate and phosphate from soil solutions before plants can use them • rate of immobilization depends on the ratio of carbon:nitrogen (C:N) of crop residues or manure added to the soil ○ if high carbon/low nitrogen material such as straw or sawdust bedding is added to soil, the microbes will tie up any available nitrates ○ in time the microbes will run out of food (carbon) and release the nitrogen following mineralization
FIXATION	• phosphates are very reactive in soil and combine with calcium, magnesium, iron, manganese or aluminum, and become attached to the soil particles • a small amount remains in solution at any given time – they are removed from the solution quickly • much of the phosphate remains in a reserve form and is released into solution to replenish what's been removed by plants

MICRONUTRIENTS AND TRACE ELEMENTS

Sheep have a low tolerance for copper in their diet – test your manure for micronutrients before applying to sheep pastures.

Manures are rich in crop-required micronutrients such as boron, chlorine, iron molybdenum and zinc. They are also a source of micronutrients required for animal health, including zinc, copper, selenium, chromium, iodine and cobalt.

Manure type and management directly affect plant and animal micronutrient levels. For example, zinc and copper levels from swine and poultry manure are most often higher than from other manure types. For soil fertility, this means that annual manure applications aimed at meeting P and N needs may result in higher-than-expected soil levels of certain micronutrients.

Some research studies have shown a buildup of elements such as copper and/or zinc in fields with a history of heavy manure application. However, recent studies of manure nutrient contents have not shown this to be a problem in Ontario when compared to biosolids standards. The take-home message is to be aware that feeding micronutrients over nutritional requirements in livestock feeds and medicines could have a negative impact on long-term soil quality.

To control soil levels of micronutrients:

- manage sources of micronutrients in livestock feeds and treatments
- test manure and soil for micronutrient levels (to provide a baseline)
- adjust your nutrient management plan and application operations if necessary.

SYSTEMS APPROACH TO NUTRIENT MANAGEMENT PLANNING

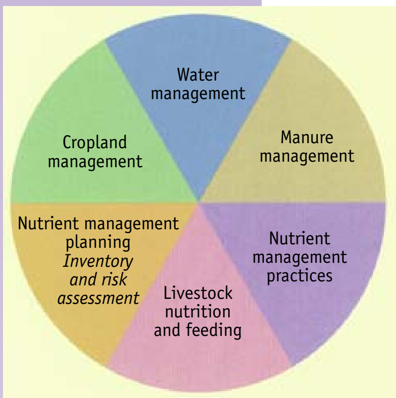
A general understanding of nutrient sources, changes and losses is the foundation of an effective **nutrient management plan.** The next step focuses on operation: accounting for the nutrients and assessing risks of losing them.

Before you get started, remember the big picture. Think of what you're assessing and planning for as a management system. A management system consists of a set of distinct yet interactive management practices (e.g., nutrient application) or groupings of practices (e.g., livestock nutrition and feeding) that affect management outcomes.

A comprehensive management system includes all key components that affect desired outcome. In a comprehensive management system, **a planned change will impact other components of the system as well as the system itself.**

When you use a management system to predict and assess the impact of a specific practice on management components, you're using the **systems approach.**

COMPONENTS



A systems approach to nutrient management planning includes the following components.

1. Water management

- ▶ proximity to surface waters, depth to water tables and aquifers, as well as drainage, irrigation and surface water management practices

2. Nutrient management – inventory and risk assessment

- ▶ accounting for all nutrient sources and levels in farm operation plus assessment of environmental risks and limitations for nutrient management

3. Nutrient management practices

- ▶ testing for nutrient levels, selecting nutrient sources, scheduling applications, calibrating application and assessing impact

4. Livestock nutrition and feeding

- ▶ focus on reducing, modifying, supplementing and targeting diets and feeding practices to improve use efficiency and reduce inputs

5. Manure management

- ▶ manure and other waste collection, transfer, storage and handling systems

6. Cropland management

- ▶ best management practices that protect soil and water plus reduce nutrient loss (includes cropping and tillage practices)

Using the systems approach is the most effective way to develop your nutrient management plan. A good example of this is the Environmental Farm Plan process.

A SYSTEMS APPROACH AT WORK IN A LIVESTOCK OPERATION

While developing an NMP (i.e., *Component 2: nutrient management – inventory and risk assessment)*, a livestock producer learns that he has excessive P levels in most of his fields. To address this, the producer:

- **▶ lowers manure P levels by reducing P supplements to his animals *(Component 4: livestock nutrition and feeding)***
- **▶ changes his manure application practices by incorporating surface-applied manure *(Component 3: nutrient management practices)*; and**
- **▶ complies with specified separation distances for application *(Component 1: water management)*.**

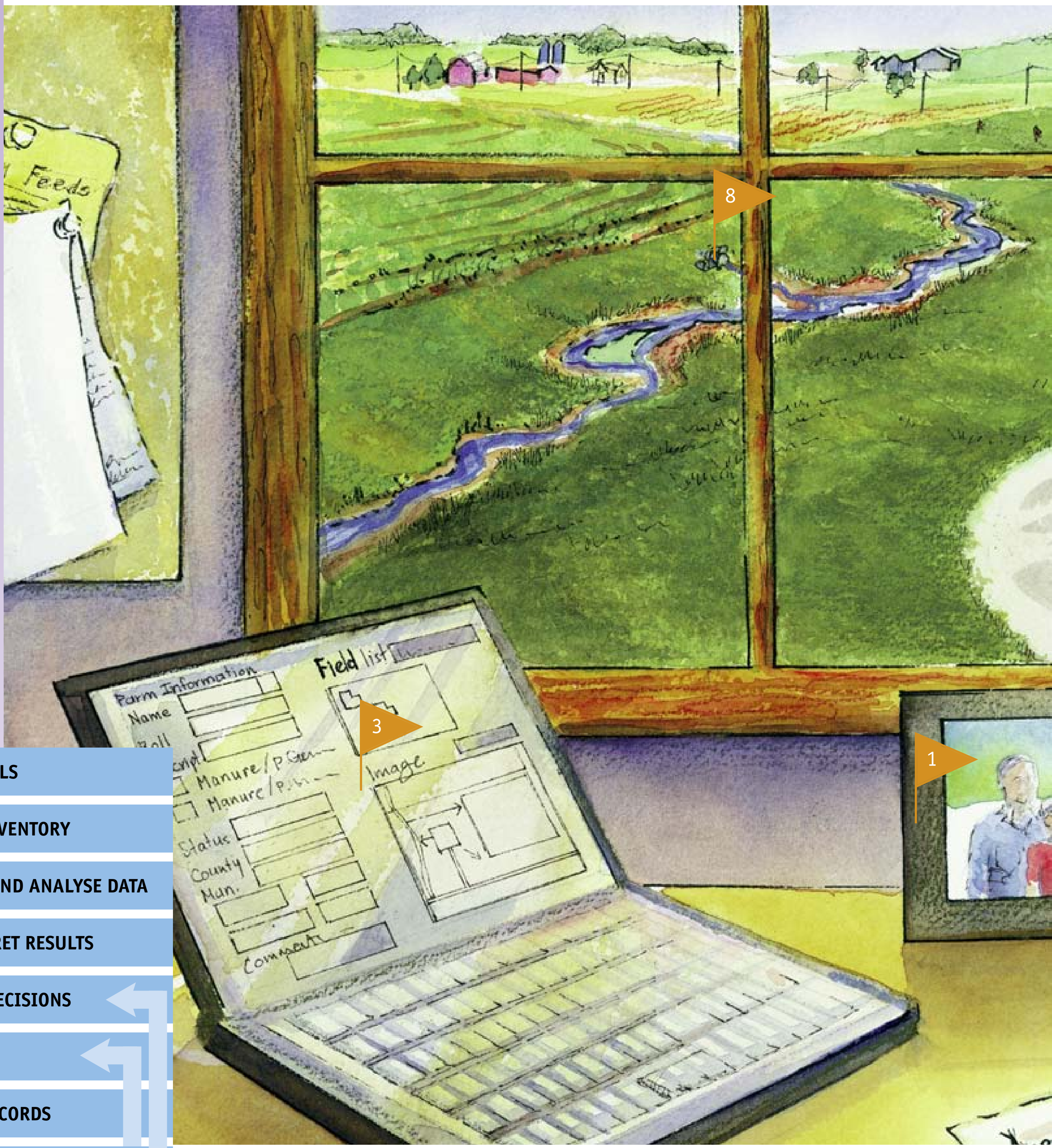
By using the systems approach, this livestock producer has saved money on production inputs and reduced impacts on surface water quality.

10 STEPS TO MAKING IT WORK

Nutrient management planning is an in-depth process. But it doesn't have to be overwhelming – especially when you take it step-by-step.

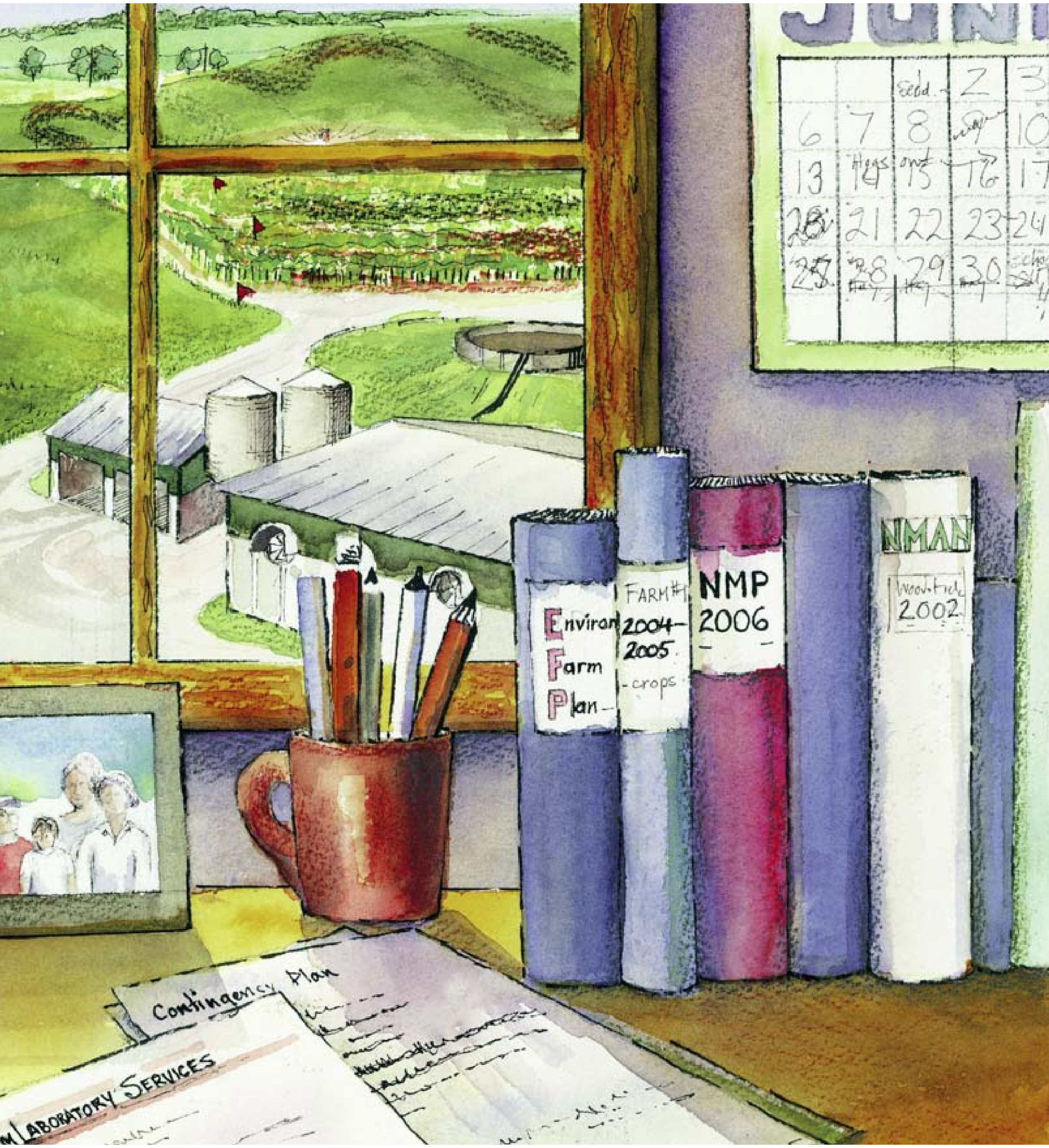
The illustration on the next two pages and the flow chart below give you a bird's-eye view of the process, so you'll know what to expect. In subsequent chapters, we'll explain how to develop each step and then put the entire plan into action.

STEPS	DESCRIPTION	KEY COMPONENTS
1 SET GOALS	State your direction for nutrient management planning – helps with decision-making	• Establish why you're doing the plan • Seek advice • Create a vision for what the plan will accomplish
2 TAKE INVENTORY	Create a picture in time of what's currently available within your operation – if you don't know what you've got, you don't know what you need	• Identify resources on the farm • Describe site characteristics • Detail current management practices
3 INPUT AND ANALYZE DATA	Apply what you have against what you need to do	• Use NMAN and MSTOR • Determine land base requirements • Conduct risk assessment
4 INTERPRET RESULTS	Develop options, based on your data analysis – to manage risk, decrease input costs, and handle all nutrients generated	• List possible management practices • Identify changes to structures, facilities and equipment • Remember the systems approach
5 MAKE DECISIONS	Select options to meet your goals	• Consider personal and business goals • Use available resources • Set proper application rates • Honour separation distances
6 ACT	"Walk the talk" to meet your goals	• Make an operational plan • Complete day-to-day activities • Account for the impact of outside forces (e.g., weather)
7 KEEP RECORDS	Document what actually takes place – develop your own information for future planning, while showing accountability for your actions	Maintain: • application records • livestock records • cropping records • monitoring records
8 MONITOR	Observe the impact of what you do to determine: • is production on track? • are ground and surface water protected? • are nutrients cycling properly	Monitor: • nutrient levels in soil and manure as they relate to crop performance • water quality in wells and tiles • livestock performance • nuisance impacts
9 ADJUST	Fine-tune your plan, and upgrade technology where appropriate	• Use information from record-keeping and monitoring • Modify plan by repeating Steps 3 to 6
10 PLAN FOR THE UNEXPECTED	Develop a contingency plan	• Identify resources • Communicate to others involved • Document actions



1. SET GOALS
2. TAKE INVENTORY
3. INPUT AND ANALYSE DATA
4. INTERPRET RESULTS
5. MAKE DECISIONS
6. ACT
7. KEEP RECORDS
8. MONITOR
9. ADJUST
10. PLAN FOR THE UNEXPECTED

Remember that your plan is not and should not be set in stone. Planning is a dynamic process, just as your operation is. That's why some steps are revisited, whether from season to season or year to year, as you evaluate your progress.


Environ
Farm
Plan
FARM #1
2004-
2005
crops
NMP
2006
NMAN
2002
Contingency Plan
LABORATORY SERVICES

1

Step 1. SET GOALS

Nutrient management plans are developed for many different reasons. Yours may include one or more of the following:

- ▶ evaluate land base needs because you're planning to expand your livestock operation
- ▶ optimize economic yields
- ▶ manage input costs
- ▶ protect soil and water resources
- ▶ comply with nutrient management regulations.

Identify which of these or other reasons relate to your farming operation now so that you can continue to focus on these throughout the planning process.

CONSIDERATIONS

Business

Ask yourself: where will the operation be in five and 10 years, and how will that impact the nutrient management plan goals?

If you're considering future expansion, can the nutrient management plan be proactive in addressing some of the requirements (e.g., calculating land base requirements or arranging manure agreements)?

Set goals with partners and family members.

Family

Who in the family will be directly involved in the nutrient management plan? When it comes to nutrient management planning, are your goals and the goals of family members in accord?

Practicality

A nutrient management plan has to be practical. If it costs too much to implement, or if it can't be followed because the farm lacks the infrastructure to carry out the plan (e.g., equipment can't meet the application requirements), then the plan must be reconsidered.

Stewardship

Which environmental goals are you seeking to address? Surface water or groundwater protection? Improved soil or air quality? Many planned best management practices will lead to environmental improvements for several resources. Others will only protect one resource. For example, runoff control is an important goal, but won't necessarily protect groundwater resources.

Experience of others

Who do you know who has already completed a nutrient management plan for some of the same reasons you're considering? Relying on others' experiences of the process could help you set realistic goals and actions for your plan.

Trusted advice

Some people quickly discover they don't have all the background or the time to complete a plan. Some operators use their time and expertise with the livestock portion of the operation, and rely on others for the cropping components of their operation. Who do you trust to help you complete the plan?

If you're less than comfortable with compiling the data required for your plan, or have a complex farm operation, you might consider hiring help or creating a team of advisors (e.g., livestock nutritionist, custom manure applicator, consultant, hired help) to assist you.

One of the biggest advantages of using a consultant is that they're a fresh pair of eyes and often able to see the big picture more quickly than someone involved in your day-to-day farm operation. Different levels of service are offered in nutrient management planning, and are often reflected in the cost. Decide what you need and how much you're willing to pay before hiring outside help.

Seek advice from the leading-edge producers and technical specialists you trust.

2

Step 2. TAKE INVENTORY

A complete inventory makes for an effective NMP.

CHECKLIST FOR INVENTORY

Having the following items on hand before getting started will speed up the process. Some of this information may have been compiled for an environmental farm plan.

- ✔ Contact names for laboratory services, sources for maps or aerial photos, consulting or engineering services if you plan to engage professional services
- ✔ County soil map and report – available on the Internet at http://sis.agr.gc.ca/cansis/nsdb/detailed/on/zipfiles.html
- ✔ Topographic maps or aerial photographs for your property – a place to start for a satellite image of your farm is at http://maps.google.ca/
- ✔ Tools for measuring slope in the field – clinometer, stake and string
- ✔ Building plans for livestock facilities
- ✔ Field measuring wheel or Global Positioning System (GPS)
- ✔ Distance measurements:
  - ► between facilities, farms or land bases, wells (all types), surface inlets, and surface water bodies (e.g., creeks, streams, ponds, etc.)
- ✔ Field slope measurements
- ✔ Depth to saturated soil (especially if non-agricultural sourced materials are being applied)
- ✔ Location of tile outlets, buffer strips, surface inlets, wells
- ✔ Crop records – crops grown, yield, manure rate applied, fertilizer applied, soil test results
- ✔ Livestock inventory – species, size class, and type (to determine manure volume generated)
- ✔ Soil sampling equipment – soil sample probe, bucket, soil test bags/boxes
- ✔ Manure sampling equipment – solid manure:
  - ► fork, plywood, plastic jar that will hold 1 L (32 oz) of sample
- ✔ Manure sampling equipment – liquid manure:
  - ► agitation equipment in place, clean plastic pail and laboratory-supplied plastic sample jar

Begin by identifying:

- ► all available nutrients on your farm – manure nutrients, nitrogen credits from forage crops, cover crops or past manure applications, available soil nutrients, other off-farm nutrient sources
- ► any site characteristics that could impact application rates and separation distances.

This is called completing an inventory of the farm operation. It establishes a baseline to which future plans can be compared. When monitoring the actions undertaken from a completed plan, you can look to your inventory for help in determining how well the plan is working. For example, if one of the goals of the plan is to maintain soil fertility levels, then future soil test results should remain close to baseline levels.

No two farms are identical: that's why the inventory process can be simple for some farms and very detailed for others.

Avail yourself of some public resources. Soil maps can be obtained on the Internet or from your nearest office of the Ontario Ministry of Agriculture, Food and Rural Affairs. Slope information can be found on topographical maps, sometimes on soil maps, or can be measured. Drainage maps are available at municipal offices, while water well records are available from Ministry of the Environment.

Often a consultant compiles the inventory information. Nevertheless, you as farm owner/operator will need to provide input regarding crop records, e.g., preferred rotation, tillage preferences, yield goals and more.

Your inventory and NMP will only be as good as the information you put into it. In this section you'll learn how to:

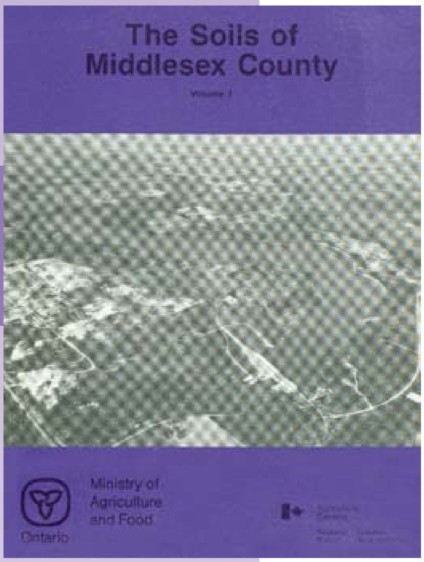
- **use and interpret soil information**
- **use soil hydrologic groups**
- **measure slope**
- **create maps for fields and farmsteads**
- **use crop inventory and yield information**
- **estimate how much manure you have**
- **take a soil sample**
- **take a manure sample.**

HOW TO USE AND INTERPRET SOIL INFORMATION

Soil maps are available for most counties in Ontario. Soils are mapped based on key properties such as surface and subsoil texture, natural drainage (before drainage tile installation), stoniness and slope. The amount of detail that can be included is limited; therefore your own experience of your farm's soils is important. Consider soil type and variability when developing your nutrient management plan.

What is meant by "soil information and interpretations"?

- soil information refers to local (county or district) soil maps and reports
- soil maps show the extent of soil types (series)
- soil interpretations are suitability or risk ratings of soil types for various uses, e.g., agricultural capability, limitations for soil management, suitability for specialty crops, erosion risk.



Soil maps and reports are essential tools for a proper inventory of your operation.

How can this information be useful for nutrient management planning?

- soil maps show your soil types, their properties (materials, slopes, natural drainage class, stoniness), and extent of these soils on your farm or area of concern
- soil information can provide important information on:
  - slope and erosion risk for P Index
  - hydrological groups for the N Index
  - liquid loading limits for application rates (in some cases)
- soil maps and information can also help you recognize unseen areas of your soil (subsoil and geology), the implications for soil management, and potential environmental risks

What are the limitations of this information?

- scale – most soil maps are mapped at a level of detail that is too general for intensive farm planning and development of a soil management program. Interpretations are based on experience and observation.

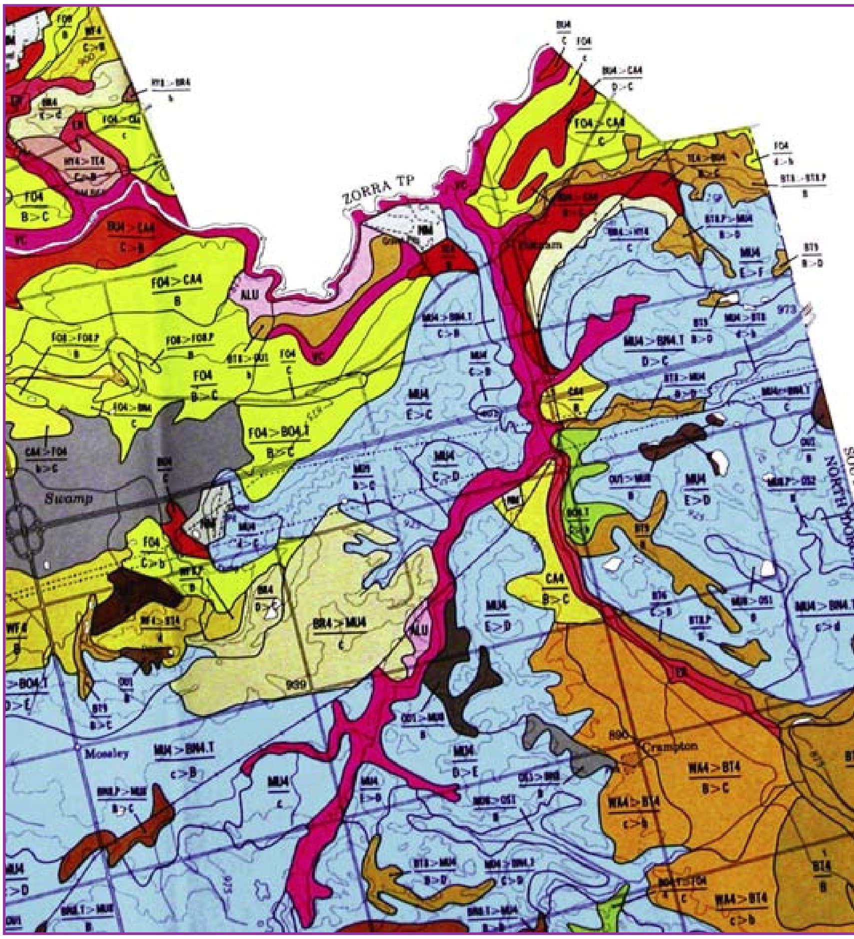
What do you do with the information on soil maps?

- property identification – use township, lots, concessions, and noticeable features like streams, woodlots, and buildings to locate property
- list – note the soil map unit codes (landscape units) on property
- soil map legend – use legend to look up soil type (e.g., Brookston clay) and soil properties of interest (slope, texture, subsoil features, natural drainage)
- soil report – if you need further information about soil properties and interpretations of your soil type, look them up in the Soil Survey Report that accompanies the soil map.

How can you obtain more soil information?

- contact your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs
- call the toll-free Agricultural Information Contact Centre, 1-877-424-1300
- visit the OMAFRA website at www.omafra.gov.on.ca
- contact your local conservation authority or municipal office

Example of a soil map and legend



SOIL SERIES	SOIL SERIES MEMBERS & DRAINAGE	USUAL SURFACE TEXTURE	SOIL MATERIAL DESCRIPTION	LANDSCAPE UNITS*	DOMINANT SOIL DRAINAGE COMPONENT	SIGNIFICANT SOIL DRAINAGE COMPONENT
Bennington (BN)	Bennington – Well Tavistock – Imperfect Maplewood – Poor	Silt loam, loam	40–100 cm of glaciolacustrine loam, silt loam and occasionally very fine sandy loam overlying clayey glaciolacustrine deposits	BN4	Well to imperfect	—
				BN6	Well to imperfect	Poor
				BN8	Poor	—
				BN9	Poor	Well to imperfect
Muriel (MU)	Muriel – Moderately well Gobles – Imperfect Kelvin – Poor	Silt loam, loam, silty clay loam	Silty clay loam, silty clay, and occasionally clay loam glacial till deposited by glaciation from the Lake Erie Basin	MU4	Moderately well to imperfect	—
				MU6	Moderately well to imperfect	Poor
				MU8	Poor	—
				MU9	Poor	Moderately well to imperfect

* landscape units are the soil map unit code found on soil maps

SOIL MAP SYMBOLS

Numerator	single soil	multiple soils
Denominator	single slope	multiple slopes

Example (single soil / single slope): Busl / B

Example (multiple soils / multiple slopes): Hosil-G / B>C=D

SOIL TEXTURE ABBREVIATIONS

l	=	loam
sl	=	sandy loam
ls	=	loamy sand
cl	=	clay loam
sil	=	silt loam
s	=	sand
c	=	clay
si	=	silt

SLOPE CLASSES

A, a......0 to 0.5% slope	Level
B, b......0.5 to 2% slope	Level to nearly level
C, c ......2 to 5% slope	Very gently sloping
D, d......5 to 9% slope	Gently sloping
E, e ......9 to 15% slope	Moderately sloping

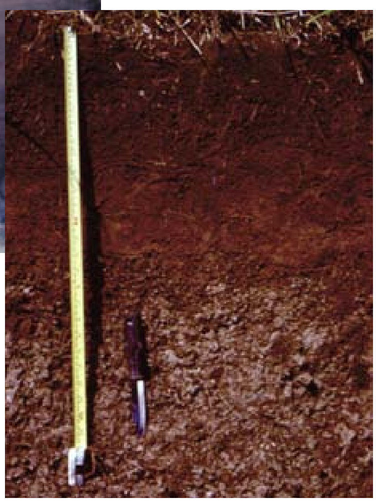
Upper case = Long (>50 m) simple slopes

Lower case = Short (<50 m) complex slopes that intersect each other

HOW TO USE SOIL HYDROLOGIC GROUPS

As explained in the Principles chapter, the rate of water movement down through the soil depends on the soil's permeability. The permeability of soils with layers of contrasting textures will be determined by the most flow-restricting layer. This property of soils is summarized in the Hydrologic Soil Group (HSG), which places soils into one of four categories (A, B, C or D).

To illustrate: shallow soils over bedrock provide less protection for groundwater, because contaminants aren't filtered once they reach the fractures in bedrock. Soils with a shallow bedrock phase are considered to be one category higher in Hydrologic Soil Group than the same soil without shallow bedrock (e.g., C becomes B, or A becomes AA). The permeability of the soil also influences the aeration, so the fine-textured soils (i.e., C or D category soils) stay saturated longer and therefore have much greater denitrification potential than the coarse-textured soils.



Water percolates quickly through sandy soils (HSG A) and slowly through clay soils (HSG D).

SOIL SERIES APPROACH TO EVALUATING LEACHING RISK

MAXIMUM N INDEX VALUE RELATED TO SOIL/SITE RISK

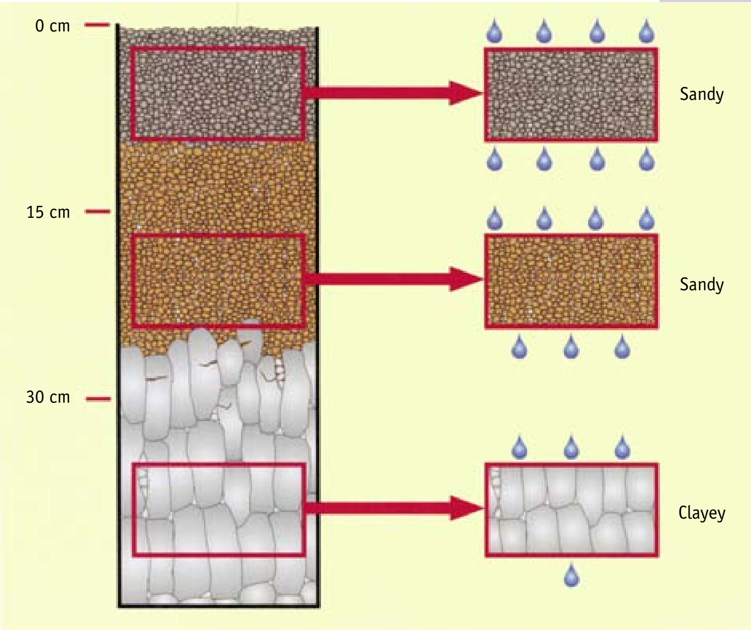
HYDROLOGIC SOIL GROUP	LEACHING RISK	MAXIMUM N-INDEX VALUE
AA	Very high	1
A	High	3
B	Medium	4
C	Low	6
D	Very low	9

Soils shallow to bedrock (<3”) move up one risk level; A soils with shallow bedrock become AA

Source: Publication 29 – *Drainage Guide for Ontario*

SOIL GROUP	FINAL INFILTRATION RATE (mm/hr)
A	8 – 12
B	4 – 8
C	1 – 4
D	0 – 1

Source: U.S. Soil Conservation Service, *National Engineering Handbook: Hydrology,* Section 4 (1972)



The illustration on the right shows how the clay layer slows the movement of water in loam soil. The water can move laterally through the loam but not downward through the clay layer.

2

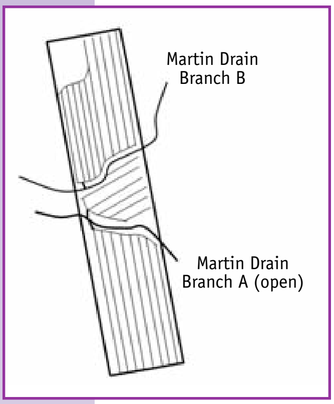
HOW TO MEASURE SLOPE

Rod and level

Using a rod and level is the most accurate method for measuring slope. Surveyors and professional engineers use these tools.

Topographic map or soil maps

These maps are great tools to estimate slope, a good place to start. Topographic maps show intervals of 3 metres (10 ft) or less, depending on scale. Intervals of 10 feet are not helpful in flat areas. When using a soil map, the soil unit slopes are in a range. In a nutrient management plan, the most conservative estimate of slope should be used (e.g., a local 5% knoll should be used – even if most of the slope is only 3%).



A tile drainage installation map for M&M farm as provided by the contractor indicates the location of municipal drains, systematic tile lines, header tiles and outlets.

Stake and string

1. Cut one stake to 5 feet and the other to 12 feet; acquire string level.
2. Make a 4-ft mark on the 5-ft stake and notch the 12-ft stake at 1-ft intervals from the 5-ft mark to the 12-ft mark.
3. Cut 110 feet of string. Mark the 100-ft point.
4. Place 5-ft stake at the top of slope and long stake at bottom of slope to be measured.
5. Tie string to both stakes at the 4-ft mark.
6. Move string up the lower stake until level – difference beyond 4 feet is the rise and the 100-ft string is the run.
7. Use the following formula to determine slope: RISE (FT) ÷ RUN (FT) X 100 = SLOPE %

Use fence posts or the top strand of wire as a guide when using a clinometer to estimate slope.

Clinometer

A clinometer is a slope angle and height meter. When using a clinometer, you must consider the height from which your partner is measuring and measure to that same height (i.e., eye-level to eye-level). Aim the instrument at the object by raising or lowering it until the hairline is sighted against the point to be measured. At the same time, the position of the hairline against the scales gives the reading.

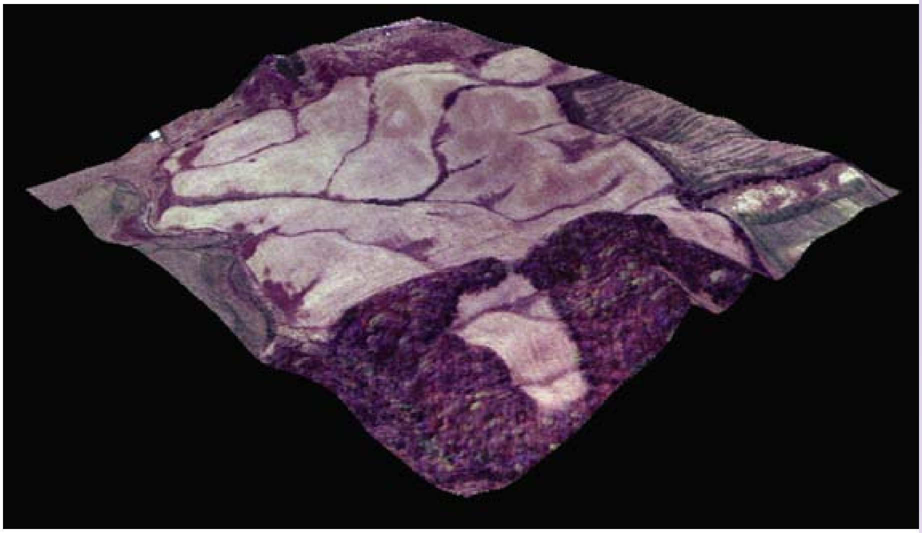
There are also orientation compasses that have slope indicators.

Clinometer

Hand-held GPS unit

Some global positioning systems (GPS) predominantly used to provide site-specific soil testing and field coordinates can also estimate slope. If an elevation measurement is taken at two points with a known distance between the two, then elevation can be calculated.

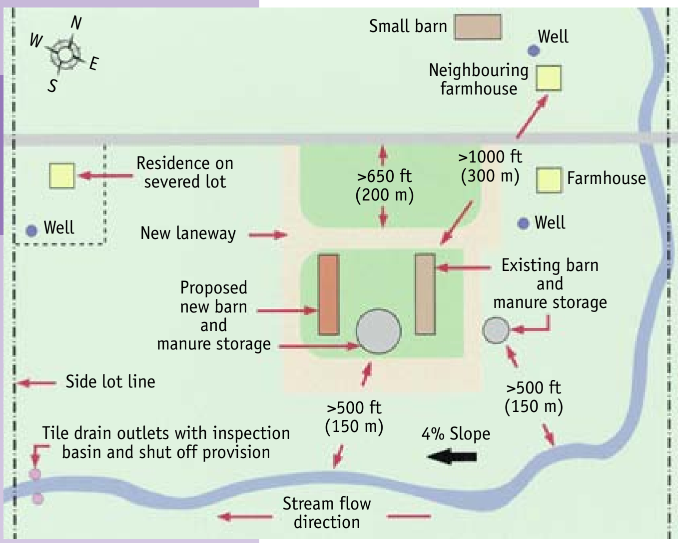
The accuracy of a GPS unit is usually within a metre. Thus, the greater the slope distance, the more accurate this system.



Geographic Information Systems or GIS maps can show precise detail and integrate several layers of information.

2

HOW TO CREATE MAPS



Farmstead sketch

Maps are documents that are easy to read and follow. A farm map will allow a person unfamiliar with the property to be oriented quickly. A map can be hand-drawn and simple or can be layered over an aerial photograph.

For our purposes, we're defining "sketch" and "map" as follows. A sketch is a hand-drawn aerial depiction that is not necessarily to scale. A map is an aerial depiction that is drawn to scale or is based on existing maps or aerial photos.

FARMSTEAD

A farmstead sketch should include the following:

▶ north direction arrow

▶ property identifier (i.e., home farm), lot, concession, municipality

▶ road names, municipal boundaries if applicable, neighbours, and other local features

▶ permanent, temporary and proposed livestock facilities

▶ locations of:

- ▷ surface water
- ▷ tile inlets and catchbasins
- ▷ wells (includes gas, oil, test and water wells)
- ▷ municipal wells and adjacent private wells
- ▷ other non-agricultural land uses (i.e., woodlots, wetlands)
- ▷ flow paths and physical barriers.

If you're expanding and applying to a municipality for a building permit with Minimum Distance Separation (MDS) information, the sketch should show:

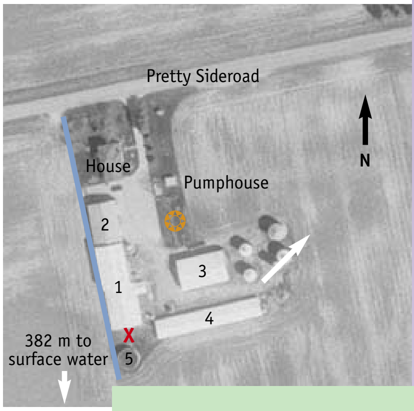
▶ dimensions of all livestock housing and manure storage facilities

▶ setback distances between facilities, lot lines, adjacent neighbours' residences.

Sample farmstead map

As we proceed through the steps, we'll present a case study farm to shed some light on the thought and decision-making process that a farmer may go through to complete a nutrient management plan. The case study cannot possibly cover all of the options or decisions that could be part of a plan, but does attempt to follow the process.

Our case study is a hog operation in southwestern Ontario, the details of which have been borrowed from an actual farm. Names and locations have been changed to "protect the innocent."



FARMSTEAD MAP LEGEND

Location: Home Farm, Lot 1, Conc. 10, Somewhere County

1 = Sow barn, 45′ x 110′
2 = Equipment shed, 45′ x 60′
3 = Equipment shed, 45′ x 75′ under-barn manure storage
4 = Finishing barn, 30′ x 135′ under-barn manure storage
5 = Uncovered 30′ x 12′ manure storage
X = Catchbasin (goes to municipal drain)
= Drilled capped well
= Lot line
= Slope direction

A farmer recently expanded to 100 sows farrow-to-finish. He realizes that his land base is limited and as a result is surveying his neighbours to find someone interested in a manure agreement.

LOCATION: Somewhere County, 2850 crop heat unit area.

ANNUAL MANURE PRODUCTION: 688,720 gallons (MSTOR 2005).

OWNED LAND: 44 workable acres, systematically tiled; 990 ft to nearest neighbour to the west; 1000 ft to nearest neighbour (hamlet) to the east.

LIQUID MANURE STORAGE: Open circular tank (12'x 30').

FIELD

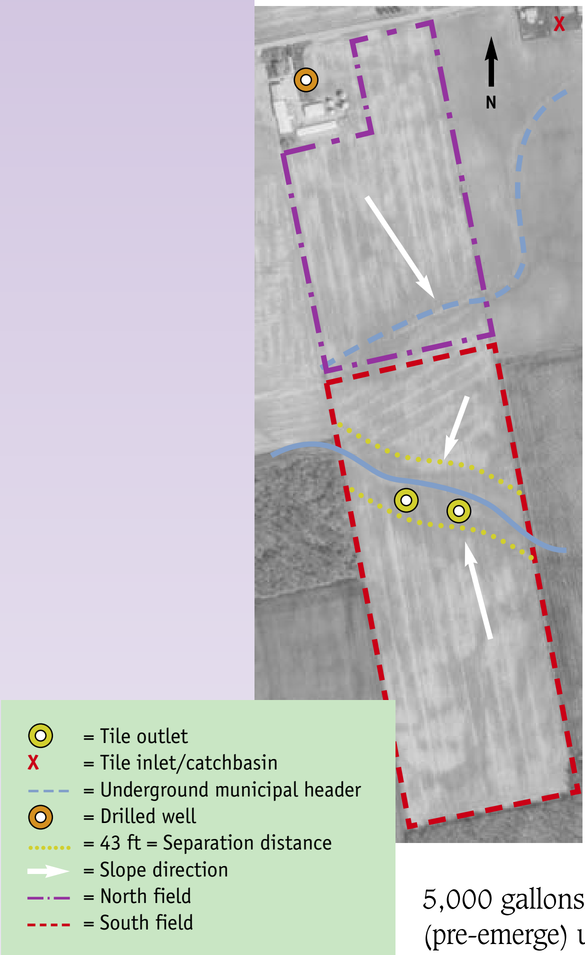
Your field sketch should identify the following:

- ▶ lot and concession; municipal roll number
- ▶ sections of field being managed differently
- ▶ tile drains
- ▶ tile outlets and surface water inlets
- ▶ surface water within 150 metres (500 ft) of the field
- ▶ non-agricultural land uses (i.e., schools, cemetery)
- ▶ private wells and municipal wells within 100 metres (330 ft) of a field boundary.

Some field sketches and maps are most useful during application when the applicator (yourself or someone hired) can see where materials will and will not be applied. Some sketches will have separation distances highlighted. Some of the distances could include:

- ▶ setback distances required from all wells
  - ▷ 90 metres (300 ft) from all known wells where a field is receiving biosolids (non-agricultural source material)
  - ▷ 15 metres (50 ft) from drilled wells
  - ▷ 30 metres (100 ft) from all other wells near where manure is being applied

- minimum depth to saturated soil conditions at time of application
  - areas of a field where deep rutting occurs would be considered saturated
  - 30 cm (1 ft) depth of unsaturated soil is required for fields where biosolids are applied and is easiest to find from soil maps
  - if a soil map shows poorly drained soils, this would indicate risk of saturated soil in the 30–60 cm (1–2 ft) range, while a soil map that indicates imperfectly drained soils would suggest a risk of saturated soils in the 60–90 cm (2–3 ft) range
  - saturated soil depth can also be determined by digging test holes
- direction of maximum sustained field slope
- direction of maximum sustained field slope within 150 m (500 ft) of watercourses
- setback distances from surface water (established by the minimum separation distance and/or the phosphorus index)
- location of all permanently vegetated buffer zones.



Sample field map

LOCATION: L14 C10 Somewhere County, 2850 crop heat units.

LAND BASE: 44 workable acres owned, systematically tiled. North field: 20 acres, no surface water. South field: 24 acres, open municipal drain with maximum slope of 3% on north side and 5% on south side. 990 ft to nearest neighbour to the west; 870 ft to nearest neighbour (hamlet) to the east.

PHYTASE USED IN FEED RATION: 20% phosphorus reduction.

SOIL SERIES: Muriel silty clay loam.

SOIL HYDROLOGIC GROUP: C.

ROTATION: corn/corn–soybean rotation with manure applied to fields yearly (fall and/or spring) depending on crop. Fall plowing occurs after corn harvest; mulch till occurs in spring on soybean residue.

Crop inventory

NORTH FIELD: 20 acres, continuous corn with average corn yield 130 bu/ac. Manure applied with drag hose at 7,000 gallons every fall after corn harvest – injected or surface-applied and plowed within 12 hours.

SOUTH FIELD: 24 acres, corn (2005) – soybean (2006) rotation with average soybean yield 42 bu/ac. Manure applied at 5,000 gallons/acre (soybeans) or 7000 gal/ac (corn) every spring after planting (pre-emerge) using drag hose injection system for corn or surface-applied on soybeans.

CROP INVENTORY AND YIELDS

You must have accurate crop and yield information to develop an effective nutrient management plan. You'll need to know:

- crop rotation
- average yield (5-year average to cover weather impact)
  - crop yields are important because they help determine fertilizer recommendations for a given crop
  - yield also helps estimate the nutrients removed from the field – in nutrient management planning, when soil fertility levels are high, application rates are determined by matching rates with nutrients removed by the crop
  - for crops such as corn silage, haylage etc., it is recommended that a "typical" wagonload be weighed and the number of loads counted in order to establish yield potential
- management variations across the field (zones or areas treated differently due to poorer or better than average yield)
- previous crop (are there any nitrogen credits?)
- how much manure was applied to that field from previous applications
- predominant soil series
- field soil test results
- commercial fertilizer applied or planned.

Crop yield is variable across most fields – due to moisture conditions, slope position and changes to soil quality. Crop yield monitors and weigh wagons can be used with conventional harvest equipment to pinpoint variation in crop yield within mapped fields.

CALCULATING MANURE VOLUME

Calculation of manure production is an important factor when determining storage capacity, application rates, timing and contingency planning. Choose from several methods to determine how much manure is produced.

MSTOR is part of the nutrient management software package that helps you calculate:

- ▶ how much manure is produced (based on average manure produced per animal per day)
- ▶ additional water usage (e.g., milking centre washwater, cleaning water, loafing areas)
- ▶ additional water from rainfall for uncovered storages
- ▶ calculates volume or capacity of existing storages and dimensions for new storage requirements.

MSTOR is available from the Ontario Ministry of Agriculture, Food and Rural Affairs.

The challenge for most producers when determining total manure volume is to account for all sources of contaminated liquids that are or should be stored with manure.

Manure storage sizing data is based on the parameters in the chart below.

DAILY MANURE PRODUCTION

ANIMAL TYPE	NUMBER IN BARN	AVERAGE WEIGHT PER ANIMAL (LB)	CUBIC FEET OF MANURE PER LB PER DAY	CUBIC FEET OF MANURE PRODUCED PER DAY
	x	x	x	=

Actual records should be used where manure volume is measured on a regular basis. (See format in the Record-Keeping section on page 96.) Documentation from a custom applicator or broker is useful because payment is generally on the volume of manure moved from the storage.

HOW TO TAKE SOIL SAMPLES

A fundamental part of any nutrient management plan is knowing how much nutrient is present in the soil to start with. Only then can a plan be developed to properly manage the nutrients that have been generated on-farm, as well as nutrients that are being imported onto the property as biosolids or commercial fertilizer.

Soil testing is really a four-step process:

- ▶ collecting a representative sample from each field or section
- ▶ sending the samples to an accredited laboratory for analysis to determine the levels of available nutrients
- ▶ incorporating the analytical results into a nutrient management plan
- ▶ keeping a record of results, to determine if soil test levels are increasing, decreasing or being maintained over time.

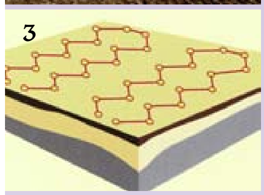
As part of your nutrient management plan, test soils from all farms and fields in your operation. Analyses should be done by an Ontario-accredited laboratory.

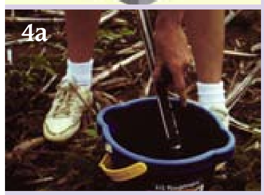
The most recent soil test results serve as a benchmark or starting point for measuring the effectiveness of nutrient applications and cropping practices. Samples taken every three years or at the same point in the crop rotation and time of year will provide a comparison to the benchmark samples. GPS reference points or detailed maps can help you reduce sample variability by ensuring soil samples are taken from the same field location each time the field is sampled.

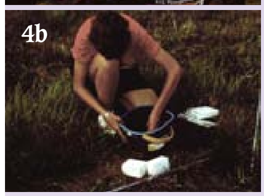
The ideal time to sample is before the nutrient applications occur. In a corn–soy–wheat rotation, the samples can be taken after the wheat crop before nutrient applications to the corn crop. In a rotation that includes forages, soil should be sampled when the forage crop ends (plowed down or sprayed). It's best to develop a rhythm or pattern of sampling each field at a particular point in the rotation, i.e., September after wheat harvest or in the fall after the soybean harvest.

Here is how to obtain the actual samples.

1. Take only 6-inch soil cores. A consistent depth is important.
2. A minimum of one core per acre should be collected from random points over the field area. The recommended maximum sampling area is 25 acres (10 ha) to account for variation in soil fertility within and between fields.
3. Use a zig-zag pattern across the field, avoiding previous starter fertilizer bands if possible.
4. Use clean plastic pails and take the time to break up lumps of soil.
5. Place thoroughly mixed samples directly into clean sample bag in the field.
6. Label samples according to field name to be used in your nutrient management plan.







HOW TO TAKE MANURE SAMPLES

One of the least desirable tasks on the farm – manure sampling and testing – is one of the most profitable! Analysis will give a tangible depiction of the amount of nutrients available.

You need to know the nutrient content of each type of manure generated or received because of the variability of livestock manure from farm to farm. Livestock genetics, feed ingredients, type of bedding, and amount of washwater or other liquid used can affect the amount of N, P and K in the manure.

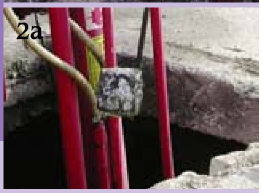
Take a new sample each time the storage is emptied for several years until you are satisfied that results are consistent. This will also help create a database of the nutrient content generated in your farm operation.

Analysis should include total nitrogen, ammonium nitrogen, phosphorus, potassium and dry matter content. Copper and zinc analysis are also useful for operations supplementing these micronutrients in the ration.

Here is how to sample liquid manure.


1

1. Agitate manure storage thoroughly.


2a

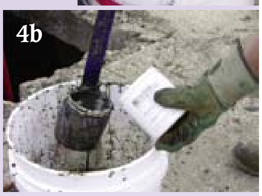

2b

2. Collect random sub-samples of manure from various depths in the storage. The sampling should take place while the storage is being emptied (i.e., every 10 loads or every 30–60 minutes from a drag hose pump).


3

3. Use a clean plastic pail to collect samples.

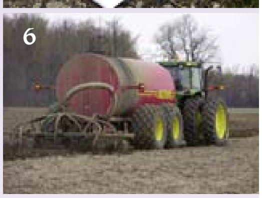

4a


4b

4. Mix 10–20 sub-samples thoroughly in a larger pail and transfer a small sample to a plastic jar (supplied by laboratory). Fill jar only half full to allow room for gas buildup.


5

5. Store in a cool place until sending the sample to the lab.


6

6. Consider taking another sample when applying to a different field to document the analysis for each field.

Here is how to sample solid manure.

1. Samples of solid manure can be taken from the spreaders during application or from the top, middle and bottom of the storage.
2. On concrete or clean plywood surface, take sub-samples (a forkful) of manure from several different loads throughout the application or from the different areas of storage.
3. Chop and mix the sub-samples together using a fork or shovel.
4. Divide the larger sample into four equal parts and discard three.
5. Continue to mix and subdivide until you have a sample that will fit into a plastic sample jar holding one-half litre.
6. Place sample jar into a plastic bag and ship to lab as per liquid sample.
7. Repeat sampling procedure if a portion of the manure will be applied to a different field.
8. Each storage system (or areas within the same storage with different dry matter contents) should have its own sample taken to reflect dry matter and specific nutrient content.

Ship or deliver immediately to the laboratory! Manure samples should be stored in a cool place until then. Try to schedule shipping or delivery to the lab on a weekday to ensure immediate processing. Sending samples through the post office is not recommended.


1


2


3


4


5


6

NMAN

3

Step 3. INPUT AND ANALYZE DATA

Step 3 aims to:

- ▶ establish, on a field-by-field basis, the nutrients required for the planned crop
- ▶ determine land base requirements.

This analysis process accounts for the amount of nutrients left from previous crops (soil test results and credits) and nutrients available from manure based on specific management practices. The process also uses inventory information (soil and slopes) to establish potential restrictions and/or setbacks from surface water sources.

With Step 3 completed, you'll have the information from which to determine the risks as well as the opportunities within your plan. The analysis step should indicate the red and yellow flags – warnings that should be addressed – in your plan.

The analysis process requires working through the NMAN software or the *Nutrient Management Workbook* (Publication 818). This is a comprehensive field-by-field approach that incorporates site characteristics, with information about crop rotation, tillage, and timing of operations.

The result will be only as good as the information entered. Analysis depends on a thorough understanding of the cropping management on your farm. It requires a commonsense approach to timing of nutrient application, in light of the soil and cropping characteristics. Some of the information will be based on long-term knowledge of the land base, the fields, site conditions and on personal observations.

You may be confronted with a red flag if you propose to apply more manure than is needed or that the field can handle.

RED AND YELLOW FLAGS – WHAT ARE THEY?

There are several types of flags.

GREEN flags indicate that the data is within an acceptable range

YELLOW flags (identified by a yield sign containing an "i") indicate a missing information caution on the printout. Additional documentation may be required to justify missing information flags when submitting a NMS or NMP for registration or approval. The flag will show up in a printout.

YELLOW flags (identified by a yield sign containing an "!") indicate a data caution. For example, data is approaching a limit or restriction (as indicated below by a red flag). This flag will not show up in a printout.

YELLOW flags (identified by a yellow circle containing a $) indicate an economic caution. For example, nutrients could be used in another way more cost effectively. No explanation is required when submitting a NMP with an economic caution.

RED best management practice (BMP) flags (identified by a lighter red colour or by a stop sign containing an "!") represent an area of environmental concern. Changes may be needed in the nutrient planning system to eliminate these flags.

STOP ARRÊT **RED** legislative flags (identified by a deep red colour and a stop sign) indicate a legislative infraction according to Ontario Regulation 267/03, as amended. A regulated NMS/P submitted for approval with warning flags may not be acceptable.

Red flag triggers:

Manure application rate in one application exceeds the maximum liquid loading rate.

Total amount of nitrogen applied in one crop year exceeds 200 lbs/ac and exceeds the agronomic recommendation.

STOP ARRÊT The P_2O_5 crop removal balance exceeds 70 lbs/ac per year.

The nitrogen crop removal balance after crop harvest exceeds the maximum N Index value based on the field's hydrologic soil group.

The nitrogen available for loss from fall-applied manure exceeds the lower of 120 lbs/ac or the maximum N Index value based on the field's hydrologic soil group.

The combined nitrogen crop removal balance from the harvested crop combined with the nitrogen available for loss from fall-applied manure exceeds the maximum N Index value based on the field's hydrologic soil group.

STOP ARRÊT Manure and nutrients are applied within 3 m (10 ft) of surface water.

Manure and nutrients are applied within the separation distance determined by runoff potential and/or P Index.

Inadequate land base availability for the manure produced, unless manure is being transferred via broker or agreement.

Cropland buffers are a sure way to avoid red flag triggers.

3

Inputs in the process stem from the inventory you compiled. For example:

- ▶ soil test results will be combined with the nutrient credits to determine additional nutrient needs for the planned crop
- ▶ manure test results will be considered with planned management practices to determine approximate nutrient value and application rate for the crop
- ▶ mapping information will help determine where there could be limitations to manure and/or nutrient application
- ▶ the field-by-field nutrient application results will provide an indication of how much land base is required for the livestock base or the nutrients available.

The type of outputs include:

- ▶ application rates and timing
- ▶ additional nutrient requirements
- ▶ setbacks and separation distances
- ▶ environmental limitations (red and yellow flags)
- ▶ land base requirements
- ▶ annual manure volumes.

Considerations for Step 3 will vary from farm to farm, according to the goals set for your plan and some of your farm's site characteristics. Farms with adequate land base will have more flexibility with application rates and opportunities for application, while farms with a small land base will more likely consider environmental maximums. For example, what's the maximum application rate that can be applied without triggering a red flag or "stop"?

Another consideration is the use of default information. When some of the inventory information is unavailable, then default values are used, e.g., for slope values and soil test values. The default values are generally conservative and will most often result in greater restrictions. For some nutrient management plans, it will be worth the effort to obtain the actual inventory numbers.

One of the key outputs of the NMAN program is the calculation of the land required to apply all of your manure volume.

The information entered in the inventory section will be used to develop options for application rates based on individual crop needs. Rate options are then screened through the NMAN program (software or workbook), which is pre-programmed with limits for application rates and required separation distances. This first "run" through the plan is done with proposed application rates that can be fine-tuned later. Other options are proposed by the plan developer if red or yellow flags are triggered.

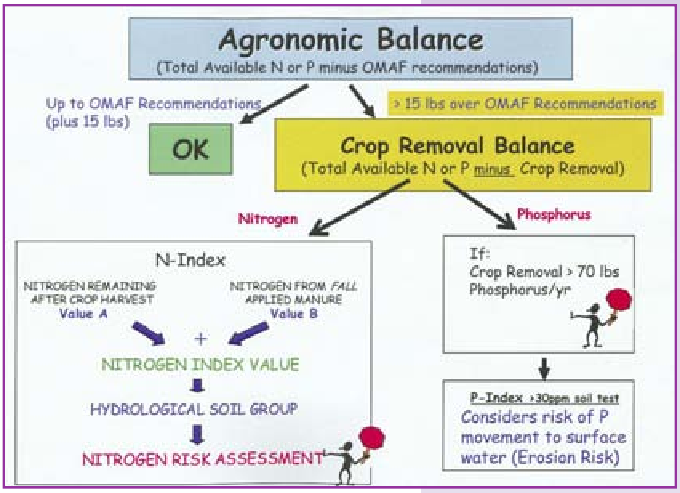
HOW THE NUTRIENT MANAGEMENT SOFTWARE/ WORKBOOK WORKS

Using livestock production data storage type and bedding information, **MSTOR** estimates manure volumes produced and typical dry matter content to calculate required manure storage size or capacity of an existing storage.

The NMAN software or workbook takes the available nutrients from manure and calculates an application rate based on crop requirements and/or on nutrients removed by the crop. Environmental risk could reduce that application rate (or require split applications).

A nutrient management planning year runs from harvest until the following harvest (generally autumn to autumn).

Agronomic balance is achieved when the macronutrients available to a crop (from all sources) is within 15 lbs/ac of the nutrients recommended for that crop. Agronomic balance takes the nitrogen and phosphorus available to a crop (from all sources) and subtracts the N and P required (based on research) for the planned crop. When the available nutrients are within 15 lbs of recommendations/requirements, then manure application rate is based on crop recommendations. When the available nutrients are more than 15 lbs over what is recommended (e.g., when a soil test is high and gives a 0 lb/ac recommendation), then the program automatically calculates crop removal balance.



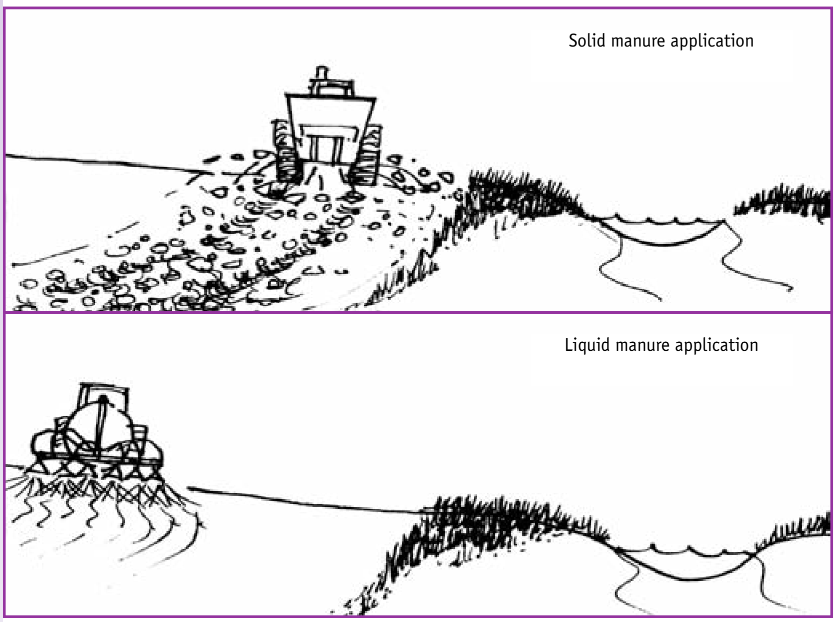
Crop removal balance is achieved when the macronutrients available to a crop (from all sources) are close to the amount of nutrients removed by that crop at harvest. Crop removal balance takes the nitrogen and phosphorus available to a crop (from all sources) and subtracts the nutrients (estimated based on average yield) to be removed by the crop at harvest. The manure application rate matches the P or N (whichever is lower) removed by the crop. Rates that match crop nutrient removal for P or K should in theory allow soil test levels to be maintained. In order to build up P levels in the soil, a phosphorus application rate of up to 70 lbs above what the crop removes per year is allowed before red flags appear. This represents approximately a 2 ppm (or mg/L) per year soil buildup for P.

If the P soil test is 30 ppm (mg /L) or higher, the P Index should be completed. The environmental impacts of P transport to surface water will be greater if the P Index is 30 ppm or higher, and significant erosion occurs. The P Index takes erosion potential and level of P in the soil to calculate a phosphorus separation distance.

When the N applied to a crop exceeds the N removed by the crop, then the N Index should be calculated to limit potential N loss by leaching during the non-growing season. When N left over at crop harvest is combined with N from manure applied in late summer or early fall, the potential loss of N from the soil through leaching or denitrification could be significant.

P and N Indexes are calculated as part of the NMAN software. They must be calculated manually when using the NMAN workbook.

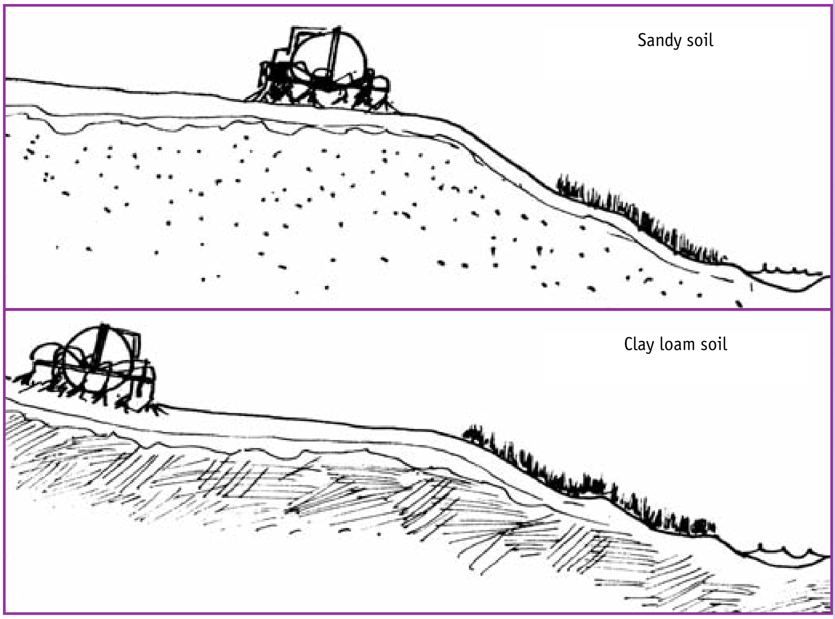
Manure separation distance is a limit set in NMAN that is based on runoff potential. The relationship is straightforward: the higher the runoff potential, the greater the distance separating manure application and surface water. Surface-applied liquid manure requires a larger distance than solid manure or liquid manure pre-tilled, injected or immediately incorporated.



Surface-applied liquid manure requires a larger distance from surface waters than surface-applied solid.

Liquid loading limit is the maximum rate that liquid manure can be applied without moving over the surface. It's determined from the runoff potential (slope and soil texture) and limits the application rate to one that can be absorbed by the soil. This loading limit can result in a requirement for split manure applications (e.g., several days apart).

The workbook version (OMAFRA Publication 818) provides the tables and calculations that are done in the background of the relatively user-friendly software. The software is available by calling the OMAFRA Nutrient Management Branch Information Line, 1-866-242-4460.



A higher application rate is possible with sandy soils that have a higher liquid loading limit, i.e., the ability for applied liquids to infiltrate and percolate into the soil.

3

INTERPRETING SOIL TEST RESULTS

In Ontario, crop fertilizer recommendations are based on the results of field trials conducted for each crop to determine the optimum rate for each level of soil fertility.

Agronomic nutrient requirements for P and K are based on soil test results. OMAFRA recommendations are based on the “nutrient sufficiency” approach.

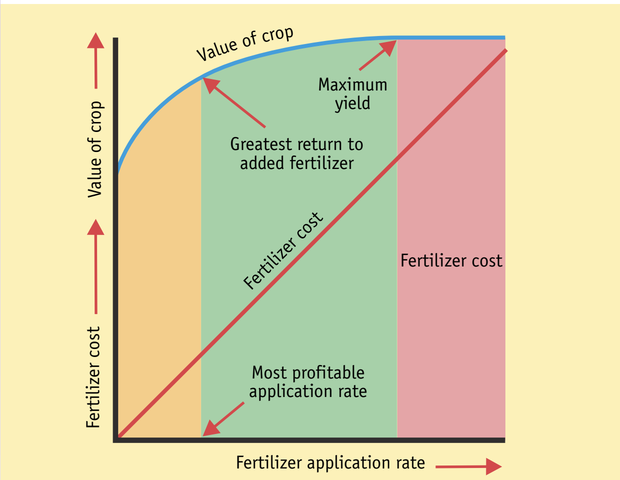
Agronomic N requirements are based on researched response curves for highest economic yield.

The recommended approach to nutrient application is applying nutrients at rates that optimize profitability while considering environmental risk. As fertility levels increase, crop response to added nutrients will decrease. When nutrients are applied in excess of crop utilization, then over time nutrient levels will gradually build up in the soil, or in the case of nitrogen, move out of the root zone.

There are two distinct goals for interpreting soil tests.

For lower-testing soils: aim to ensure adequate nutrient levels to optimize production, crop quality and returns.

For higher-testing soils: plan nutrient applications to protect water quality. For example, when planting a corn or wheat crop into soils with adequate but not extreme fertility levels, applying a liquid “pop-up” with the seed provides required nutrients closer to the seed, but at much lower volumes and incorporated into the soil.



Crop yields show a diminishing return to increasing soil fertility beyond the point of maximum economic yield.

EXAMPLE SOIL ANALYSIS RESULTS

ONTARIO ACCREDITED SOIL TEST LABORATORIES LTD.
Farm Soil Report

Report 62269
Received 07/10/05
Printed 15/10/05

Analytical values					Parts Per Million			
I.D.	Lab #	pH	BpH	O.M. %	Phosphorus NaHCO$_3$	Phosphorus Bray P	K	Mg
field 1 North half	998701	7.1		3.5	28 H		187 VH	112
field 1 South half	998702	7.2		3.2	33 VH		220 VH	167
field 2 North half	998703	6.9		4.0	35 VH		210 VH	127
field 2 South half	998704	5.9	6.8	2.8	25 H		175 VH	158
field 3 North half	998705	7.0		3.8	28 H		168 VH	118
field 3 South half	998706	7.1		3.3	26 H		160 VH	120
field 1 eroded knoll	998707	7.8		1.8	50 VH		235 VH	150

Most soil test results contain the following important information:

- **sample number** is important as a reference in case a sample needs to be re-analyzed
- **pH** is always given, and buffer pH is given when a soil sample has a pH of 6 or lower
  - buffer pH is an indication of how much lime is required to bring the pH of the soil back to 6.5 or higher – the closer the buffer pH is to 7, the less lime it will take to bring soil back to ideal pH levels
- **organic matter** can be provided for an additional cost, but is useful for establishing a baseline. Maintaining or slowly increasing organic matter levels can result in improved nutrient cycling, water-holding capacity and soil structure.
- nutrients like **P** and **K** have numbers and symbols
  - the symbols are L for low, M for medium, H for high, VH for very high and E for excessive
  - soils are considered excessive where additional nutrients will not give any economic yield return. This occurs at 60 ppm for P (for most crops) and 250 ppm for K. Soil test values over these levels could reduce crop yield or quality, e.g., phosphate applications may induce zinc deficiency on soils low in zinc and may increase the risk of water pollution.
- sometimes both the **sodium bicarbonate** and the **bray phosphorus** test numbers are given
  - some labs used the bray test until 1999
  - since there's no direct conversion (no number to multiply one result to get the other) between the two tests, the only way to compare results from previous years is to have a direct comparison of fields using both methods
  - you need the sodium bicarbonate test in order to run NMAN.

Nutrient contents of organic materials are usually reported as percentage by weight (%N, %P, %K, etc.).

Phosphorus and potassium must be converted to P_2O_5 and K_2O respectively.

Ammonium-nitrogen and micronutrient contents are usually reported in:

- **milligrams per kilogram (mg/kg) or,**
- **milligrams per litre (mg/L).**

To convert:

- **mg/kg to pounds/ton, divide mg/kg by 500**
- **mg/L to pounds/1000 gal. (imp.), divide mg/L by 100.**

Organic nitrogen is found by subtracting ammonium nitrogen from total nitrogen.

Ammonium = NH_4

Org N = Total N–NH_4

Org N (available) = Org N x available factors listed below

NH_4 (available) = NH_4 x (100–ammonium loss%)

Total (available) N = NH_4 (available) + Org N (available)

Soil nitrate levels are generally determined in May to early June by taking a soil sample from a 12-inch depth. The results can indicate how much nitrogen is present in the soil and can reduce N-inputs applied at side dress. (In Ontario, nitrate soil tests aren't routinely used for nitrogen fertilizer recommendations, but they can yield useful information.)

Testing for **micronutrients** such as zinc and manganese is sometimes done, but usually for diagnostic purposes only, i.e., comparing poor and good growing areas to identify a problem.

INTERPRETING MANURE TEST RESULTS

Manure test results will provide nutrient levels using the same numerical values as a soil test, but will **not** provide recommended rates of application. Manure test results should be used to help determine total available nutrients and overall nutrient application rates.

Several commercially available nutrient management planning tools incorporate soil and manure test results to calculate manure and other nutrient application rates.

The following principles must be addressed when interpreting manure test results:

- only a portion of the organic nitrogen is available for crop uptake (from ~5% in solid cattle manure with a high amount of bedding material to ~30% of poultry manure) in the year of application
  - organic nitrogen will build up in the soil with repeated manure applications
- residual N is derived from the organic fraction of manure, so we expect there is more from solid manure
- at least 40% of the P from manure is available as fertilizer P to crops in the year of application – at least 80% (the remaining 40%) will become available over the longer term, and adds to the total available soil P pool
- about 90% of the K is available in the year of application.

Using the inventory information from the case study farm on page 45-46, input the data into the nutrient management program (NMAN software or *Nutrient Management Workbook,* Publication 818) to come up with application rates for the planned crops. This is a first run through the plan, based on planned or normal application rates. Adjustments may have to be made if red or yellow flags are triggered.

3

SOIL TEST RESULTS – CASE STUDY FARM

SAMPLE MAY 2005

	PH	% OM	P (mg/L)	K (mg/L)	Mg (mg/L)
NORTH FIELD	6.8	2.8	57	300	180
SOUTH FIELD	6.7	2.6	43	258	155

MANURE TEST RESULTS – CASE STUDY FARM

MANURE SAMPLES – LIQUID HOG – FARROW TO FINISH
SAMPLED MAY 2004 TO OCTOBER 2005

AS IS BASIS	D.M.%	TOTAL N %	NH_4^+N ppm	P %	K %	ZN ppm	Cu ppm
SPRING 2004	2.7	.33	2600	.11	.15	36	22
FALL 2004	3.0	.37	2350	.11	.18	37	25
SPRING 2005	2.6	.32	2550	.11	.16	34	26
FALL 2005	2.9	.36	2475	.11	.16	35	23

FROM THE MANURE ANALYSIS

Spring manure, May 2004

Nitrogen

- 33 lbs/1000 gallons of total nitrogen: 26 lbs/1000 gallons in the ammonium form (quickly available assuming no volatilization loss) and 7 lbs/1000 gallons in the organic (slow release) form.

When manure is not incorporated, then some of the ammonium nitrogen will disappear (volatilize) into the atmosphere. When manure is applied in fall, some of the N will be lost through leaching or denitrification.

Phosphorus

The phosphorus portion of the manure provides about 20 lbs/1000 gallons of P_2O_5. However, not all of the 20 lbs will be available in the year of application.

Potash

Almost 17 lbs/1000 gallons of K_2O will be provided from the manure.

Copper and zinc

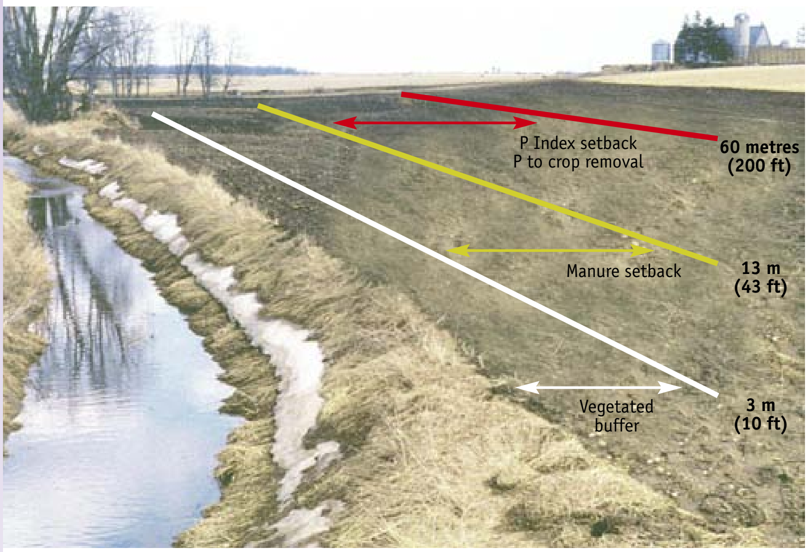
Some analyses will provide copper, zinc and other micronutrients found in the manure. These numbers normally reflect ration and supplements. If a micronutrient number is high, then a livestock nutritionist should be consulted to determine if the micronutrient is required at the rate being fed.

SOME OF THE ANALYSIS INFORMATION FOR THE CASE STUDY FARM

MANURE DESTINATION SUMMARY

TYPE	DATE	FIELD	DETAILS	AREA	CROP	RATE	SETBACK
FALL	Nov 2004	North	Drag hose – surface – incorp. 24 hrs	20	Corn	7000 gal/ac	n/a
SPRING	May 2005	South	Drag hose – surface – pre-tilled	23	Soybeans	5000 gal/ac	200 ft
FALL	Nov 2005	North	Drag Hose – surface – incorp. 24 hrs	20	Corn	7000 gal/ac	n/a
SPRING	May 2006	South	Drag hose – injected	23	Corn	7000 gal/ac	200 ft

The manure destination summary shows when application is planned to designated fields and at what rate. Setback distances are also determined from the slope and runoff potential information, and can be found in the Minimum Distance Separation Table on page 83.



A high P Index result will mean that a minimum separation distance of 60 metres (200 ft) will be required for manure application.

A Phosphorus Index of "37" for South field results in a restriction on application rate to phosphorus crop removal up to 200 ft from surface water.

Phosphorus Index   South Field 2004-2005

P-Index Factor	Value	Weight	Rating	Description
1. Soil Erosion	8	2.0	16.0	31.74 ton/ac
2. Water Runoff Class	4	1.0	4.0	C, 5% slope
3. Phosphorus Soil Test	4	2.0	8.0	43 ppm
4. Fertilizer Application Rate	4	0.5	2.0	64 lb/ac
5. Fertilizer Application Method	1	1.5	1.5	Placed with planter
6. Manure Application Rate	8	0.5	4.0	101 lb/ac
7. Manure Application Method	1	1.5	1.5	Injected
Total:			37.0	

P Index for South field

Field/Section Information (Fall 2004 – Fall 2005: Farm 1, south field, All)

General | Properties | Cropping/Tillage | Fertizer | Manure/P.Mat'l | Balance | Economic | Heavy Metal

AGRONOMIC NUTRIENT BALANCE

[lb/ac]	N	P_2O_5	K_2O
Commercial Fertilizer:	4	16	4
Nitrogen Credit:	18		
This Season's Manure:	189	71	121
Production Requirements:	-165	0	0
Agronomic Balance:	46	87	125

CROP REMOVAL BALANCE

[lb/ac]	N	P_2O_5	K_2O
Field Inputs:	22	16	4
This Season's Manure:	189	142	121
Crop Removal:	-108	-55	-38
Crop Removal Balance:	104	103	88
Nutrient Indices:	5.0	36	

Add Fertilizer [to meet agronomic requirements] | N-Index | P-Index

APPLICATION RATES

Description	Applied Date	Type	Rate	Applied [N,P,K]	Surface Water
Fert App 1	01-May-2005	6-24-6	5.0 gal/ac	4,16,4 lb/ac	200 ft
Manure App 3	20-May-2005	spring	7000 gal/ac	189,71,121 lb/ac	200 ft

Agronomic and crop removal balance summary, South field 2004–2005

Field/Section Information (Fall 2005 – Fall 2006: Farm 1, north field, All)

General | Properties | Cropping/Tillage | Fertizer | Manure/P.Mat'l | Balance | Economic | Heavy Metal

AGRONOMIC NUTRIENT BALANCE

[lb/ac]	N	P_2O_5	K_2O
Commercial Fertilizer:	4	16	4
Nitrogen Credit:	14		
This Season's Manure:	125	71	129
Production Requirements:	-165	0	0
Agronomic Balance:	-23	87	133

CROP REMOVAL BALANCE

[lb/ac]	N	P_2O_5	K_2O
Field Inputs:	18	16	4
This Season's Manure:	125	142	129
Crop Removal:	-108	-55	-38
Crop Removal Balance:	35	103	95
Nutrient Indices:	5.0	21	

Add Fertilizer [to meet agronomic requirements] | N-Index | P-Index

APPLICATION RATES

Description	Applied Date	Type	Rate	Applied [N,P,K]	Surface Water
Manure App 3	21-May-2005	fall	7000 gal/ac	125,71,129 lb/ac	N/A
Fert App 3	01-May-2006	6-24-6	5.0 gal/ac	4,16,4 lb/ac	N/A

Agronomic and crop removal balance summary, North field 2004–2005

3

3

SUMMARY OF FLAGS AFTER COMPLETING STEP 4: INTERPRET RESULTS	
(USING NMAN SOFTWARE)	FLAG
1. greater than 200 lbs/ac nitrogen applied to crop	!
2. application rate is greater than 6700 gallons (maximum rate on silt loam soil with a 5% slope)	!
3. P_2O_5 and K_2O are applied above agronomic requirements (economic)	$
4. additional nitrogen is required to meet agronomic recommendation (economic)	$
5. manure remaining (maximum of 52% of manure produced yearly is utilized)	⚠
6. projected land base requirement of 105 acres (yellow flag)	⚠
7. P_2O_5 is applied above crop removal limit (applied 87 lbs where limit is 70 lbs)	STOP ARRÊT
8. N over agronomic rate + fall application = N Index trigger	!

The farmer will have to adjust the planned nutrient application to eliminate the risks triggered by the red flags.

Using the inventory information and the soil test and manure analysis results, a number of red flags and caution flags have been triggered.

1. South field has 189 lbs in manure N and 22 lbs in starter N applied to a corn crop. This exceeds the 200 lbs N allowed per acre unless recommended (as per *Agronomy Guide*).

2. Application rate is greater than 6700 gallons. The proposed 7000 gal/ac to the South field exceeds the liquid loading limit for surface-applied manure to a 5% slope, with silt loam soil.

3. P_2O_5 and K_2O are applied above agronomic guidelines, which could have a negative yield/economic impact. If the additional nutrients will not boost yield, then the use of starter fertilizer could be re-evaluated.

4. For North field, additional N is required to meet the recommendations. 165 lbs/ac N is recommended, while 142 lbs/ac N is planned for application.

5. The amount of manure produced is greater than what can be utilized in the current year (just over half) on the planned fields. This would become a red flag if there were no available rented land or manure agreements.

6. A land base of 104 acres is required, based on the crop rotation, manure rate and frequency of application on the owned 44 acres. This would become a red flag if there were no available rented land or manure agreements.

7. P_2O_5 is applied at a rate higher than what the crop removes plus the allowed soil buildup. At this application rate, the soil phosphorus levels would rise quickly, resulting in increased environmental risk and higher separation distances.

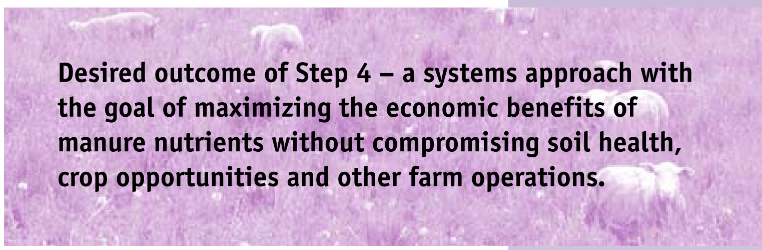
8. Nitrogen Index is triggered for North field. The amount of N applied to harvested corn crop exceeded the recommended rate by over 15 lbs/ac, plus the amount of N supplied in the application of liquid hog manure in fall adds up to a potential loss that exceeds N Index limits for a hydrologic soil group C.

Step 4. INTERPRET RESULTS

In Step 4, you interpret the information and flags you received following the initial run through the nutrient management planning model. You'll develop and assess the options to come up with the best possible decisions for your farm operation.

Here you have the opportunity to explore options, comparing the impacts of different management practices (e.g., on nutrient availability, application rates, environmental restrictions). For example, you may ask: Will some of the options result in reduced land base requirements? Or will the options result in higher application rates, and/or reduced setback distances?

Here are some of the areas you may wish to explore.



Desired outcome of Step 4 – a systems approach with the goal of maximizing the economic benefits of manure nutrients without compromising soil health, crop opportunities and other farm operations.

AREA	OPTIONS/CONSIDERATIONS	POTENTIAL IMPACT
MANURE STORAGE	type of storage – covered, concrete, earthen and management of liquids	• storage size • volume to handle • liquid loading, application rates
APPLICATION RATES	reducing or eliminating starter fertilizer	• application rate increase
	high soil test levels	• application rate limited • crop growth and quality affected • fertilizer rates reduced
CROP ROTATION	specific crop nutrient requirements	• application opportunities • acreage adjustments
MANURE NUTRIENT VALUE	method of application (e.g., incorporation vs surface application)	• available nutrients (reduced nitrogen loss) • operational concerns – workload and equipment requirement and setup • reduced P Index
PHOSPHORUS INDEX	tillage – cross-slope	• reduced P Index
	strip cropping and buffers	• reduced P Index
SEASON OF APPLICATION	late fall application	• application rates increased (compared to late summer application)
	use of cover crops with fall application	• application rate increased • nitrogen retention for spring increased
APPLICATION EQUIPMENT	time required to apply recommended rates	• feasibility with existing equipment and time
	new equipment vs. custom application	• timing of application • custom applicator flexibility and equipment selection • cost of application (what is your current cost and how does it compare?)

Size and type of manure storage will have a direct impact on the volume and nutrient value of manure to be applied.

Cross-slope tillage will reduce P Index value and allow for slightly higher application rates.

The key to a workable NMP is a commonsense approach that incorporates your entire livestock or crop production system: site features, management practices, equipment types and sizes, available labour, etc. For example, a farm operation on heavy clay soils would not plan to apply all the manure in the spring, prior to planting, on fields planned for corn.

The use of cover crops will help make fall applications feasible.

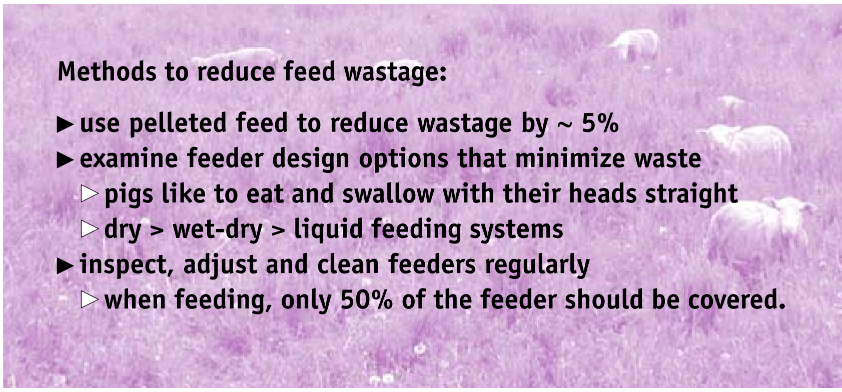
MANAGEMENT OPTIONS TO ADDRESS RED FLAGS

LIVESTOCK NUTRITION

Improve feed efficiency by reducing nutrient excretion. This can be done by decreasing feed wastage, improving feed digestibility (e.g., pelleting increases energy and protein digestibility) and improving animal productivity (e.g., genetic improvements, improving herd health status, feed additives). Consult with a livestock nutritionist to determine if your ration ingredients are being fed at rates recommended by the National Research Council.

1. If the land base required for manure application is tight or application rates are limited by high P content in manure, consider adding the enzyme phytase to the ration to improve P digestion in monogastric livestock. Adding phytase will reduce the P in manure up to 20%. However, this must be done in combination with the reduction of phosphorus supplements in feed.
2. Match the supply of available nutrient to requirements. This can be done by split-sex feeding and phase feeding.
3. Balance amino acids to help reduce the nitrogen in manure. New techniques include replacing protein with synthetic amino acids.

Reducing the nutrients in manure can often reduce the acreage requirements, since application rates often increase with reduced nutrient concentration.



Methods to reduce feed wastage:

- ► use pelleted feed to reduce wastage by ~ 5%
- ► examine feeder design options that minimize waste
  - ▷ pigs like to eat and swallow with their heads straight
  - ▷ dry > wet-dry > liquid feeding systems
- ► inspect, adjust and clean feeders regularly
  - ▷ when feeding, only 50% of the feeder should be covered.

MANURE AGITATION

Phosphorus is tied up with the solids, while potassium and ammonium N are highest in the liquids. So, proper manure agitation is usually recommended for uniform nutrient application on a field.

However, there are times when unagitated manure can be managed to make the highest use of the N without the P. This can be achieved when the liquids are skimmed off the top before agitation, and applied to fields closest to the storage that are already testing high for P.

When using this method, it's extremely important to take regular manure samples to determine when the P level begins increasing. Also be sure to document manure nutrients at different levels in the storage for record-keeping purposes.

	NON-AGITATED MANURE		WELL-AGITATED MANURE STORAGE 3/4 EMPTY
	FINISHER HOG MANURE	(AS IS BASIS)	FINISHER HOG MANURE
DRY MATTER	1.9	%	4.7
TOTAL NITROGEN	44	lbs/1000 gallons	61
AMMONIUM NITROGEN	36.2	lbs/1000 gallons	39.2
PHOSPHORUS	1.8	lbs/1000 gallons	14.7
PHOSPHORUS (LONG TERM)	3.6	lbs/1000 gallons	29.4
POTASH	25.9	lbs/1000 gallons	30.2

Is there an opportunity to take the top portion of the liquid manure storage and apply the manure – without agitation – to the fields with the highest phosphorus soil test levels? (These are usually the fields closest to the barn.)

COMMERCIAL FERTILIZER

In most cases where manure is applied, commercial fertilizer is still required for economic crop growth. This is especially true for corn crops where with most manure types, N needs can't be met: phosphorus is the nutrient that limits application rate.

Management strategies for improving N utilization often concern starter fertilizers. Ask yourself:

- is the starter fertilizer required – is it giving any yield benefit?
  - are there opportunities to reduce the starter fertilizer, e.g., instead of 200 lbs/ac of MAP(11-52-0) through the corn planter fertilizer boxes in a 2X2 band, can MAP be applied at 25 lbs/ac in-row through the insecticide boxes?
- is there a benefit to using a low-rate liquid starter?
  - will a lower rate increase my manure application rate?
- is there an opportunity to do a side-by-side comparison to determine if there is a benefit of using starter fertilizer – especially if soil P test is greater than 30 ppm or 30 mg/L?

TILLAGE

Type and timing of tillage will have an impact on nutrient utilization. To maximize nutrients for the crop, consider:

- incorporation of manure immediately after application to minimize odour and volatilization loss
- pre-tillage to break macropores, reduce risk of preferential flow, and increase soil infiltration capacity
- injecting manure to reduce odour and maximize N utilization
  - however, depending on injection tooth design and spacing, the risk of higher volumes in a more concentrated band closer to tiles will increase the risk of preferential flow
- that reduced tillage (or no-till) practices reduce erosion potential by increasing soil residue cover – this will lower the P Index
- that tillage for liquid manure applied in early fall does increase conversion of ammonium N to nitrate, which increases the risk of nitrate moving below the root zone – less tillage will result in volatilization loss
- that direction of tillage will impact water movement across a slope
  - near surface water, tillage usually occurs parallel to the watercourse, which is generally across the slope.

Pre-tilling will break macropores, reduce risk of preferential flow, and increase soil infiltration capacity.

What's meant by "incorporation"?

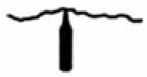
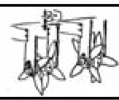
- **20–30 rule: 20–30 minutes for manure to infiltrate after application**
- **30% or less manure residue on the surface**

Does aeration tillage meet these requirements? The answer depends on application volume and setup.

MORE ABOUT NO-TILL

No-till is an excellent system and manure is an excellent resource, but using manure in a no-till system requires some compromise. Expect to do some limited tillage, or lose some nutrients.

The benefits are many, including use of natural nutrients, increased organic matter, and improved soil health and water-holding capacity. The main drawback is that you will have to pay closer attention to equipment modification, soil moisture conditions, and the potential for preferential flow. The chart below summarizes some of the advantages and disadvantages of using various forms of manure.

	PLACEMENT OF MANURE	INCORPORATION IMPLEMENT
Shallow incorporation S-tine cultivator		
Horizontal sweep injection		
Knife injection		
Shallow incorporation concave disks		
Slot injection		
Aeration technology		

4

+ ADVANTAGES – DISADVANTAGES

LIQUID MANURE	SOLID MANURE	COMPOST
+ opportunity to combine with cover crops – higher risk of runoff, compaction and preferential flow (requires attention to rates or lower rates) – compromise with some tillage (to improve N utilization; reduce odour issues)	+ higher organic N content = less NH_4-N for volatilization + higher solids contribute more organic material to soil + higher solids = less risk of runoff and preferential flow – greater time and labour requirement for application – less crop-available N (short-term)	+ completed process means little environmental risk (leaching, denitrification, volatilization) + soil health benefit from increased organic matter + lower volume and less odour compared to uncomposted manure – little crop-available nitrogen, high phosphorus and potash – more labour and close attention to composting process is required

CONSERVATION PRACTICES

Several conservation practices and structures will reduce the risk of erosion, runoff and nutrient loss.

- Manage residues. Reduce tillage operations to increase the percentage of the soil's surface covered by the residue of the previous crop. This reduces risk of erosion and runoff.
- Practise contour and cross-slope tillage and planting (including strip cropping) to, in effect, reduce the impact of cropland slope.
- Use erosion control structures such as field terraces, water diversions and water and sediment control basins to reduce the energy of overland flow.
- Establish buffer strips along streams.

NUTRIENT APPLICATION

Injection methods place the nutrients in the root zone to improve availability for crop use.

The method and timing of nutrient application will reduce odours and environmental risk.

- Incorporate to reduce odour and risk for runoff.
- Inject liquid manure to place nutrients in or near the root zone.
- Side-dress with injection or dribble-bar type applicators and use pre- or post-application tillage practices to reduce odours and provide nutrients when crop requires them.

CROPPING SYSTEMS

Cover crops will help to mitigate N Index flags. Cover crops take up and hold N in organic form during a season when annual crops aren't growing. This helps reduce the N available for leaching or denitrification.

Inter-row application is the application of manure into a growing crop. This system applies the N when the crop needs are highest, and when risk of loss is lowest. When applied at a rate to meet crop needs, this is also a greenhouse gas mitigation BMP.

Crop rotation will generate more opportunities for manure application.

OTHER OPTIONS

No two farms are the same. That's why no recommendation will suit every situation. Here are some ideas for alternatives that may fit into a whole farm management program.

RECENTLY EXPANDED LIVESTOCK OPERATIONS

For many recently expanded farms, there's a large volume of manure to land apply. In the past, manure was likely applied to cornfields just prior to planting.

However, in most of Ontario, there's a narrow window of opportunity for planting corn before impacting negatively on yield. Generally, fields are wetter than ideal (compaction issue) and most farmers have a heavy workload at this time of year (i.e., time is worth more than at any other time of year). This may result in higher manure application rates to fields closest to the manure storage.

Recently expanded livestock operations may face the challenge of managing extra volume of manure during the planting season.

ALTERNATIVES

Sometimes compromises must be made between highest nutrient availability for crops and managing workload and site conditions. The following options may not be the best economic choices (e.g., manure application to legume crops) or provide the most available nutrients for the growing crop (e.g., spring vs. fall application). But they do spread out the workload and allow application to all fields over the period of the rotation.

Early spring

Winter wheat – apply liquid manure (ideally with a drag hose system) at the same time that commercial nitrogen would be applied. Compaction is reduced and natural incorporation enhanced if application is done on frozen soils that thaw during the day, and freeze again in the evening. Avoid surface application on steep slopes where runoff could be an issue. Knowing the amount of nitrogen in the manure and paying attention to application rate uniformity is critical to avoid lodging. Hard red varieties are graded by their protein levels and have a higher N requirement than soft red or white varieties. High protein is easier to achieve for fields that have had regular manure application.

Pastures – often are not regularly rejuvenated with nutrients. Applying manure to pastures with conditions similar to winter wheat is one option. When manure is applied later in the season, slot injection systems will reduce contamination of new growth.

Canola – has a high N requirement and is planted at the same time as spring grains. Compaction is the biggest issue.

Canola has a high N requirement and will help to use manure nitrogen.

Row-crops such as corn provide an opportunity for side-dress applications.

Corn – is still the best crop to target with manure. Consider predetermining a percentage of acreage that will get manure and planting shorter-day varieties in those fields to compensate for realistic later planting, or plan manure application for corn silage fields. Surface application of manure can also take place after planting but with a compromise to some nitrogen.

Soybeans – have a longer planting window before significant yield losses. Later planting means more opportunity for better soil conditions to apply manure. Note, however, that too high a manure rate could result in taller and more dense beans that have an increased risk for lodging and white mould. Consult with a seed dealer for shorter, less bushy varieties and/or varieties that have some resistance to white mould.

Manure application on spring grains works in regions where additional nitrogen is recommended.

Spring grains – not recommended for manure application in southwestern Ontario since the amount of required N is so low (35 lbs) that a less-than-uniform application or too high a rate can result in a badly lodged crop. In other regions of Ontario where N recommendations for spring grains are higher, there is an opportunity for manure.

Late spring / early summer

Side-dress – into standing crop (i.e., liquid hog manure into corn).

Edible beans (coloured beans) – are usually planted near the beginning of June when risk of frost has passed and soil conditions are drier. Because they are a legume crop, coloured beans don't generally require nitrogen. However, where bronzing and root rots reduce yield, 40–60 lbs of nitrogen will often be recommended. Too high a rate of nitrogen from manure would delay crop maturity.

Liquid manure application following forage harvests works best with older forage stands.

Following forage harvest – after first, second or third cut, as close to harvest before regrowth. Keep rates under 4000 gal (50–75 lbs ammonium N) to minimize N burn. Applications give the greatest benefit to older forage stands with higher grass content (grasses need the N more than legumes) and where crown damage caused by wheel traffic will have less impact. Irrigation of low dry matter (<1%) liquids is an option for some that will also give a much-needed moisture benefit to the second and third cut forage crops.

Late summer / fall

After wheat harvest – on heavy clay soils prone to compaction, this time of year is the best option for application. The ability to apply manure on wheat makes wheat a good crop in the rotation since wheat allows the workload to be spread out, and makes it easier to apply manure to fields farther from the storage (sometimes once every three years at a higher application rate). Cover crops will minimize impact of nitrogen leaching (N Index).

Cover crops – are considered a benefit for fall manure application. Oats, barley, oilseed radish, turnips, oat/rye mix, red clover and red clover and/or peas are all acceptable cover crops. When spread uniformly over the field, volunteer wheat is also acceptable, as is wheat planted as a crop after soybeans. Cover crops take up the nitrogen and hold it in organic form until spring. Some cover crops will release their nutrients earlier or later than needed by the following crop. Red clover seems to release its nitrogen closest to corn crop needs.

Early fall after silage corn harvest – when soil conditions are dry, before the bulk of soybean and corn harvest. Nutrient loss and compaction can be minimized.

Apply manure in early fall after corn silage harvest to reduce the risk of compaction.

Alfalfa that will be plowed down – especially when the next crop will be corn. Drier soil conditions and workload flexibility make this a common practice. Keep in mind that a high percentage of legumes in the plowdown will result in a 100 lb N credit in addition to manure N, which should result in lower manure application rates.

Prior to planting winter wheat – may work better after edible bean harvest than soybean harvest since many seed drills follow the soybean combine. Manure applied after the wheat crop is emerged will often result in some tracking damage.

After corn and soybean harvest – the later that manure is applied in the fall, when conditions are cooler, the lower the likelihood of nitrogen loss from volatilization and leaching.

Winter application should never be part of the plan – but may be part of a contingency plan.

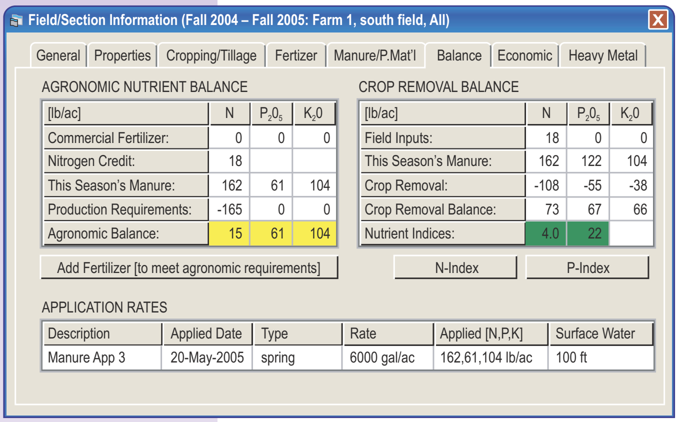
ACREAGE REQUIREMENTS BASED ON SETBACKS

If acreage is in short supply, try to keep P soil test levels under 30 ppm so that P Index doesn't become a trigger. Where soil test levels already exceed 30 ppm, treat the area near surface water as a separate section of the field to avoid lower rates to the whole field. Observe fields during rain events or snowmelt to see where water enters streams, and steer clear of those areas during manure application. Incorporate, inject or pre-till manure to allow application closer to watercourses.

CASE STUDY

For the case study farm, the chart below interprets some of the causes for the flags and seeks alternative strategies that will resolve the problems and improve the nutrient management plan. As always, the changes must be practical and fit with the overall management of the farm operation.

POTENTIAL CHANGES FOR NEXT SEASON (to resolve flags)	RESULTS
Consider not using starter fertilizer; apply additional N as carrier in herbicide	• Allows increased manure application (over 1000 gal/ac) based on P_2O_5 • Removes N Index red flag from fall manure application since N over crop balance is reduced
Reduce manure application rate for corn from 7000 to 6,000 gal/ac	• Reduces phosphorus applied over crop removal by 36 lbs and removes the red flag for P_2O_5 crop removal balance • Removes the red flag for N greater than 200 lbs/ac
Change tillage from moldboard plow to mulch till and direction from up and down slope to cross slope and measure slope length to show actual 800 ft	• Changes P Index from 36 to 22 in South field • Reduces P Index separation distance by 100 ft
Realize that more acreage is required	• Look for neighbour interested in manure agreement


Field/Section Information (Fall 2004 – Fall 2005: Farm 1, south field, All)

General | Properties | Cropping/Tillage | Fertizer | Manure/P.Mat'l | Balance | Economic | Heavy Metal

AGRONOMIC NUTRIENT BALANCE

[lb/ac]	N	P_2O_5	K_2O
Commercial Fertilizer:	0	0	0
Nitrogen Credit:	18		
This Season's Manure:	162	61	104
Production Requirements:	-165	0	0
Agronomic Balance:	15	61	104

CROP REMOVAL BALANCE

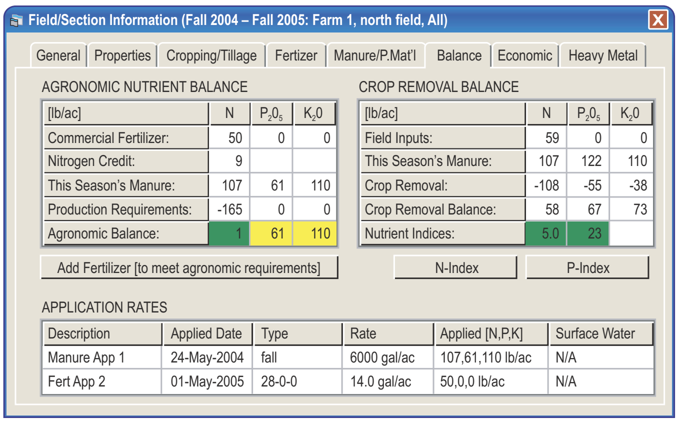
[lb/ac]	N	P_2O_5	K_2O
Field Inputs:	18	0	0
This Season's Manure:	162	122	104
Crop Removal:	-108	-55	-38
Crop Removal Balance:	73	67	66
Nutrient Indices:	4.0	22	

Add Fertilizer [to meet agronomic requirements] | N-Index | P-Index

APPLICATION RATES

Description	Applied Date	Type	Rate	Applied [N,P,K]	Surface Water
Manure App 3	20-May-2005	spring	6000 gal/ac	162,61,104 lb/ac	100 ft

Agronomic and crop removal balance after analysis (Step 3) for South field (2004–2005)


Field/Section Information (Fall 2004 – Fall 2005: Farm 1, north field, All)

General | Properties | Cropping/Tillage | Fertizer | Manure/P.Mat'l | Balance | Economic | Heavy Metal

AGRONOMIC NUTRIENT BALANCE

[lb/ac]	N	P_2O_5	K_2O
Commercial Fertilizer:	50	0	0
Nitrogen Credit:	9		
This Season's Manure:	107	61	110
Production Requirements:	-165	0	0
Agronomic Balance:	1	61	110

CROP REMOVAL BALANCE

[lb/ac]	N	P_2O_5	K_2O
Field Inputs:	59	0	0
This Season's Manure:	107	122	110
Crop Removal:	-108	-55	-38
Crop Removal Balance:	58	67	73
Nutrient Indices:	5.0	23	

Add Fertilizer [to meet agronomic requirements] | N-Index | P-Index

APPLICATION RATES

Description	Applied Date	Type	Rate	Applied [N,P,K]	Surface Water
Manure App 1	24-May-2004	fall	6000 gal/ac	107,61,110 lb/ac	N/A
Fert App 2	01-May-2005	28-0-0	14.0 gal/ac	50,0,0 lb/ac	N/A

Agronomic and crop removal balance after analysis (Step 3) for North field (2004–2005)

Phosphorus Index

P-Index Factor	Value	Weight	Rating	Description
1. Soil Erosion	2	2.0	4.0	10.10 ton/ac
2. Water Runoff Class	4	1.0	4.0	C, 5% slope
3. Phosphorus Soil Test	4	2.0	8.0	43 ppm
4. Fertilizer Application Rate	0	0.5	0.0	0 lb/ac
5. Fertilizer Application Method	0	1.5	0.0	
6. Manure Application Rate	8	0.5	4.0	122 lb/ac
7. Manure Application Method	1	1.5	1.5	Injected
Total:			21.5	

South field (2004-2005) after analysis (Step 3)

Reducing P Index results

P Index can be reduced by making several changes:

- ▶ changing tillage from moldboard plow to mulch till
- ▶ changing direction from up and down slope to cross slope
- ▶ measuring slope length to show actual 800 ft (instead of guessing)
- ▶ reducing application rate from 7000 to 6000 gal/ac
- ▶ eliminating the starter fertilizer.

The result of these changes is a reduction in the P Index from 37 to 21.5. This means a 43-ft manure setback from the surface water, and a P_2O_5 setback distance of 100 ft. To meet the crop removal rate of P_2O_5, just under 3,000 gal/ac of manure could be applied from 43 to 100 ft from surface water.

The land base owned by the farm is not sufficient to handle the manure produced. Alternative arrangements include:

- ▶ land purchase
- ▶ land rental
- ▶ manure agreements (or transfer out – as with NMAN terms)
- ▶ manure broker agreement to take manure to alternative location (more common with solid manure).

When land base requirements exceed owned acres, you must consider additional factors, including:

travel distance and route to alternative land base
- ▶ additional time, fuel, cost of transporting water in manure, road wear, odour issues
- ▶ whether manure can be managed so that the more concentrated manure is transported the farthest distance – this would lower the handling cost per unit of nutrient

competition for land rentals and/or manure agreements.

The owner of the case study farm approached his neighbours. They agreed to enter into a manure agreement.

MANURE APPLICATION AGREEMENT

MANURE GENERATOR INFORMATION:

Generator Farm Name: M & M Farms Ltd
Generator Owner Name: Mr. I. C. Money
Address: R.R. #2, 540 Concession 10
Anytown ON. N0N 0N0
Telephone: (555) 555-1234

LAND OWNER/RECEIVER OF MANURE INFORMATION:

Farm Name of Receiver: Green Acres Farm Ltd.
Legal Name of Receiver: Mr. U. B. Green
Address: R.R. #2, 555 Concession 10
Anytown ON. N0N 0N0
Telephone: (555) 555-9876

AGREEMENT INFORMATION:

Term of Agreement: 3 years
Agreement commences on: September 1, 2006
Agreement ceases on: August 31, 2009

This agreement between the parties named above, allows for the following fields to be included in the farm unit operator's 'Farm Unit Declaration' and for application of manure to these fields under the farm unit's nutrient management plan.

List each field/section under this agreement:

Field/Section	Lot	Concession	Township	County	Tillable Acres	Roll Number
North Field	13	10	Anywhere	Somewhere	25	355335555003555
South Field	13	10	Anywhere	Somewhere	35	355335555003555

I, U. B. Green (land owner) give permission to I. C. Money (manure generator) to declare the above lands as part of the farm unit covered by the nutrient management strategy/plan for the period covered by this agreement.

I also give permission to the farm unit operator to do soil sampling on the properties listed to determine the condition of the soil. I also agree that the land identified in this agreement will not be used for the application of any other prescribed material, originating from any other operation, including my own during the term of this agreement.

I also agree that the manure covered in this agreement will be applied in accordance to the nutrient management plan that applies to the farm unit into which these lands are incorporated.

A spill contingency plan was developed and fully reviewed by both parties.

U. B. Green **Land Owner (print)**	UBGreen **Signature**	March 31, 2006 **Date**
I. C. Money **Manure Generator (print)**	ICMoney **Signature**	March 31, 2006 **Date**
C. M. Ecry **Witness (print)**	CMEcry **Signature**	March 31, 2006 **Date**

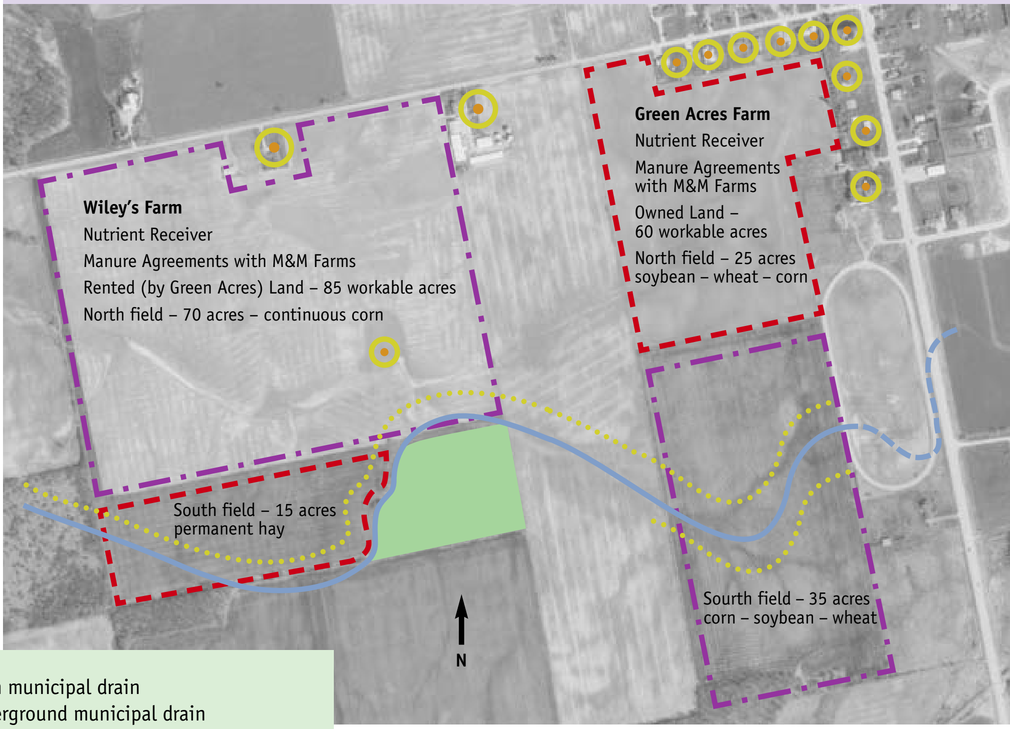
Note: Permission to use these lands is required from all property owners listed on title to the land.

For further information about and examples of manure agreements with brokers and neighbours, see factsheet Order No. 06-041 (April 2006) AGDEX 720/538.

4

Below is a field map for both neighbouring farms. The Green Acres field is to the east of the case study farm; Wiley's Farm is directly west.

FIELD MAP FOR MANURE AGREEMENT FARM(S)



Manure agreement details to handle remaining manure from case study farm.

Step 5. MAKE DECISIONS

Before finalizing decisions, consider the need for new application equipment.

By completing the NMAN software portion of the nutrient management plan, you've completed most of the analysis (Step 3). And by developing options to address the implications of this analysis, you've completed the fourth step.

It's decision-making time. The prime focus for this step is to figure out how the prescribed application rates will work, considering all of the other variables affecting the operation. Your NMP should reflect decisions in all aspects of livestock and crop management.

On paper, your plan may make sense. But making it work means that the infrastructure must be in place, or resources available to allow the decisions to be implemented. Can you get the job done – considering the combined constraints of weather, labour and time?

Many of these decisions are not a direct part of the plan, but are important in carrying out the plan. You may have similar questions or issues to those of the case study farm, as outlined in the following chart.

CASE STUDY FARM

QUESTION OR ISSUE	CONSIDERATIONS FOR DECISION-MAKING
Will changing my crop rotation provide adequate feed?	• Including wheat and soybeans in the rotation will increase overall corn yield average • Could substitute wheat into ration? • Will have to purchase additional corn to meet feed needs (this was required anyway due to small acreage)
Will the 3000-gallon tanker with 30-ft spread width along with 175-hp tractor be adequate to apply 138,000 gallons of manure in one week in spring?	• Approximately 50 loads • 20 minutes (avg) between loads • 17 hours to spread spring manure (~ 2 days) • 8 hrs/day for field work (rest for barn work)
Will the landowner(s) with whom case study farm has manure agreement expect that case study farm landowner will apply manure?	• Green Acres – November, applied 163,000 gal • Wiley Farm – May, injected 350,000 gal • Approximately 120 loads (5-6 days) • Will likely require custom applicator or custom corn planting
How will the application rate of 6000 gal/ac be applied to a field that is 1740 ft (530 m) long and is 681 ft (208 m) wide and tank must go to the fence row and back?	• At 6000 gal/ac, one load would go about 700 ft • One load could be spread going width-wise across the field instead of lengthwise
How will manure be incorporated on the same day it is applied?	• 25-ft cultivator on a 125-hp tractor with hired help as driver • Using EFP financial incentive program, could purchase an incorporation tool for behind tanker

Two key decisions that affect the overall development and implementation of the NMP are:

- rate to be applied
- setback and/or separation distance(s).

One of the key decisions driving the development of NMPs is a proposed new or upgraded manure storage.

DETERMINING THE MAXIMUM RATE OF MANURE TO SPREAD

The maximum rate of manure application can be limited by one of the following factors to reduce environmental impact:

- soil absorption capacity – manure should infiltrate cropland, not run off
- phosphorus requirements – rates should reflect crop P needs and account for P buildup
- nitrogen requirements – rates should reflect no more than 75% of crop N needs.

The following section describes how these factors limit application rates for manure.

SOIL ABSORPTION CAPACITY

- liquid manure must be applied at rates that "stick" to the soil surface – rather than run off of it
- in some cases, soils will become saturated and manure will run off before desired nutrient application rates are reached
- the ability for cropland to absorb liquids is referred to as **liquid loading** – the **liquid loading limit** is the maximum rate of applied liquid before the soil becomes saturated and runs off
- liquid loading varies with existing soil moisture levels, soil texture, drainage class and slope steepness and length
- in the Runoff Potential table on page 80, soil (i.e., Hydrologic Soil Groups) and slope combinations are ranked in terms of their risk for runoff (note: no application is recommended for steeply sloping lands with slow to very slow drainage)
- in the second table on page 80, maximum rates for each runoff potential ranking are provided for both surface-applied or incorporated / pre-tilled soils

TABLE 1: RUNOFF POTENTIAL

HYDROLOGIC SOIL GROUP (DRAINAGE CLASS)	MAXIMUM FIELD SLOPE WITHIN 150 M (492 FT) OF SURFACE WATER <3%	3–<6 %	6–<9%	9–12%
A (RAPID)	Very low	Very low	Low	High
B (MODERATE)	Very low	Low	Moderate	High
C (SLOW)	Low	Moderate	High	No application
D (VERY SLOW)	Moderate	High	High	No application

Hydrologic Soil Group source: *Drainage Guide for Ontario* Pub. 29
Group A is often associated with sand, Group B with loam, Group C with clay loam and Group D with clay soil textures.

TABLE 2: MAXIMUM RATE PER APPLICATION

RUNOFF POTENTIAL	SURFACE-APPLIED m^3/ha (gal/ac)	INCORPORATED OR PRE-TILLED m^3/ha (gal/ac)
HIGH	50 (4450)	75 (6700)
MODERATE	75 (6700)	100 (8900)
LOW	100 (8900)	130 (11600)
VERY LOW	130 (11600)	150 (13400)

5

STOP ARRÊT The application rate should not exceed the numbers in Table 2 Note: $1m^3$ = 1000 L

Here's an example of how the liquid loading concept could be used.

A single application of 10,000 gal/ac of a very diluted (low nutrient content) liquid, such as those from a runoff storage or manure from a dairy barn with earthen storages

- would not be recommended for surface applications to anything heavier than a loam soil with less than 3% slope, or
- injected applications to anything heavier than a loam soil with less than 6% slope.

However, two applications of 5,000 gal/ac at least 24 hours apart may work on heavier soils with steeper slopes depending upon soil conditions.

To improve absorption capacity, apply manure several times a year. Plan crop rotations accordingly.

To improve absorption capacity:

✔ apply liquid manure several times a year – instead of all at once
✔ pre-cultivate soil before application – to increase surface area for absorption
✔ apply manure on residues, cover crops or forages before plowdown to reduce runoff

To ensure that suitable volumes of liquid manure are applied:

✔ address crop fertility needs
✔ calibrate equipment to ensure targeted rate will be applied
✔ monitor field surface following first 30 minutes of application – if you see surface movement or tile runoff, reduce the application rate

Apply manure into crop residues to increase soil absorption capacity.

Precultivate soil before application to improve infiltration rates of applied manure.

As you determine application rates, remember that **phosphorus** that goes unused by the crop remains in the soil and builds up. Take care to avoid accumulation of excess P over time, especially in areas prone to erosion.

In determining application rates to meet **nitrogen** needs, remember that nitrate is mobile and, if not *quickly* used by the crop, will be lost to the air or groundwater. It's recommended that no more than 75% of the crop needs for N should come from manure. Include some nitrogen from mineral fertilizers, for the following reasons:

► N release from organic materials depends on the weather, and in cool, damp seasons, the crop may not have enough N available at the required time from organic sources for optimum growth and yield

► manure application is often uneven, so parts of the field receive insufficient manure to meet crop requirements – a uniform application of mineral N fertilizer helps to increase overall yields in areas missed by the spreader

► reducing the N application rate from manure also reduces the amount of P and K being applied – in situations where P doesn't exceed current recommendations, use manure P to furnish all P requirements, provided N requirements are not exceeded.

Where manure is applied once in a rotation (i.e., once every three years) or onto legume crops such as forages or soybeans, manure applications should not exceed total P removal for the rotation *and* should not exceed 200 lbs/ac N.

Separation distances for manure application should take all surface water sources, including surface water inlets, into account.

DETERMINING SETBACK DISTANCES FOR MANURE APPLICATION

Separation distances for manure application should take all surface water sources into account. Include surface water inlets such as catchbasins.

The most effective setback from any surface water is a vegetated buffer. The broader the buffer, the more effective it is in preventing nutrients and pathogens from entering the water. Vegetated buffers have many purposes, ranging from streambank stabilization to sediment filtration.

For more information about vegetated buffers, see another title in this Best Management Practices series: *Buffer Strips,* Order no. BMP-15.

The following two methods provide recommended distances for separation between manure application and surface water sources. Selection for the more appropriate method depends on the soil test P value.

POTENTIAL FOR SURFACE WATER CONTAMINATION FROM MANURE RUNOFF

Manure contains nutrients and pathogens, both of which should stay out of water. Determining how far from watercourses manure should be applied depends on many factors: soil moisture absorption capacity at the time of application, slope near the watercourse, soil texture and manure type, application method and volume.

When manure is incorporated a few days before planting, the separation distance may not need to be as wide as surface-applied manure in early spring (assuming same slope and texture). Where surface water enters a watercourse as a stream of concentrated flow, a separation distance that includes the path of flow would be more logical than a constant width along a watercourse.

The following method will provide some general guidance in determining what distance should be left between watercourses (including surface inlets) and manure application. Site-specific characteristics of your farm at time of application should, of course, be taken into account.

Cropland buffers help to keep runoff – soil, nutrients and pathogens – from entering surface waters. Wider buffer strips are more effective.

To determine a site's potential for surface water contamination from manure runoff, use the runoff potential rating from the upper table on page 80. Then, using the table below, determine the recommended separation distance between surface water and manure application.

MINIMUM SEPARATION DISTANCES BETWEEN SURFACE WATER AND MANURE APPLICATION

	MINIMUM SEPARATION DISTANCE (with established buffer zone)			
RUNOFF POTENTIAL	SURFACE-APPLIED		IMMEDIATELY INCORPORATED OR PRE-TILLED	
	LIQUID	SOLID	LIQUID	SOLID
HIGH	30.5 m (100 ft)	15.2 m (50 ft)	18.3 m (60 ft)	9.1 m (30 ft)
MODERATE	22.9 m (75 ft)	13 m (43 ft)	13.7 m (45 ft)	6.1 m (20 ft)
LOW	15.2 m (50 ft)	13 m (43 ft)*	9.1 m (30 ft)	4.6 m (15 ft)
VERY LOW	13 m (43 ft)*	13 m (43 ft)*	3.0 m (10 ft)	3.0 m (10 ft)

*Application can be made within the same distance as the incorporated values, if applied to a living crop or to greater than 30% residue cover.

Farms should have a minimum 3 metre (10 ft) vegetated buffer adjacent to all surface water if nutrients are to be applied to adjacent fields.

Note: NMAN software will generate separation distances for each field. Red flags will be generated where problems arise.

For soils with lower P soil test results (< 30 ppm)

Soils with a soil test phosphorus result of <30 ppm are limited to P applications of crop removal plus 78 kg/ha (70 lbs/ac) to facilitate planned P buildup. Although the manure separation distance must be observed, commercial P sources can be applied.

For soils with higher P soil test results (> 30 ppm)

Use the Phosphorus Index to determine separation distances based on the risk of surface water contamination when applying P, either as manure or as commercial fertilizers. The P Index can also be used as a management tool to help determine how to reduce the risk of P runoff. High soil test phosphorus combined with high risk of soil erosion gives the highest P Index values.

To determine the P Index for each field with a soil test result for P of >30 ppm, refer to any one of these publications from the Ontario Ministry of Agriculture, Food and Rural Affairs: the *NMAN Workbook* (Publication 818), *Determining the Phosphorus Index for a Field,* Order No. 03-109, or the *Agronomy Guide for Field Crops,* Publication 811.

Try strip cropping to reduce P Index results.

Use your P Index rating and note the recommended separation distances from the table below.

NUTRIENT APPLICATION LIMITATION AS DETERMINED BY P INDEX AND PROXIMITY OF TILLABLE LAND TO SURFACE WATER SOURCES

P INDEX	<3 m (<10 ft)	3–30.5 m (10–100 ft)	>30.5–61 m (>100–200 ft)	>61 m (>200 ft)
LOW <15	no application	crop removal	no restriction	no restriction
MEDIUM 15–30	no application	crop removal	no restriction	no restriction
HIGH 31–50	no application	crop removal	crop removal	no restriction
VERY HIGH >50	no application	no application	crop removal	crop removal

Note: Where separation distances, in combination with the P Index, restrict nutrient application, consider changing management practices (application rates, application methods, and soil and water conservation practices), to decrease your P Index value.

Step 6. TAKE ACTION

It's time to put your nutrient management plan to work. It may not be followed exactly as planned due to unforeseen circumstances, change in conditions and so forth. But now you have a solid framework for nutrient use in your operation, and a path to meet the goals set out at the beginning of the process.

- Write down or obtain a computer printout of your plan.
- If a consultant or third party prepared the plan, have them go over the details of the plan with you and anyone else involved in the farm operation.
- Keep the plan in a location where it can be easily accessed for review.
- Prioritize the actions and prepare to acquire resources that are not yet in place (e.g., if manure is to be custom-applied, but no custom applicator has been contacted yet).

No two farms are the same, which is why no simple recommendation will fit every situation.

And remember, before you add nutrients to your cropland, that proper application includes a consideration of **all** of the following:

- crop needs
- field conditions
- weather
- season
- neighbour concerns.

Have your NMP advisor review the operational details of your plan with you.

PLANNING YOUR NUTRIENT APPLICATION

Calibrate to ensure that you're applying at the planned rate.

Ensure that application equipment matches your storage and handling system.

How many days – whether between harvest and winter, or between snowmelt and spring planting – are available for applying manure? How many days will you need, considering the number of loads you can handle in a day?

Calibrate manure application equipment.

Often overlooked, calibrating your nutrient application equipment is an essential step in supplying the recommended levels of nutrients to your crops.

Spreader calibration works in combination with soil and manure testing and nutrient management planning to ensure proper application rates of manure and commercial fertilizers.

Many farmers estimate how much manure is spread by counting the number of loads being applied to a field, based on the spreader capacity. Although a good place to start, it does not take into account uniformity of application or the different densities of the manure or whether the spreader is being filled to meet the manufacturer's specifications.

The table below presents estimated densities of the manure to convert volume of the spreader to weight of manure. A better option is to weigh several typical load(s) of manure and use this measurement for your calculations.

An accurate estimate of manure application rates requires more than simply counting the loads.

DENSITIES OF DIFFERENT TYPES OF MANURE

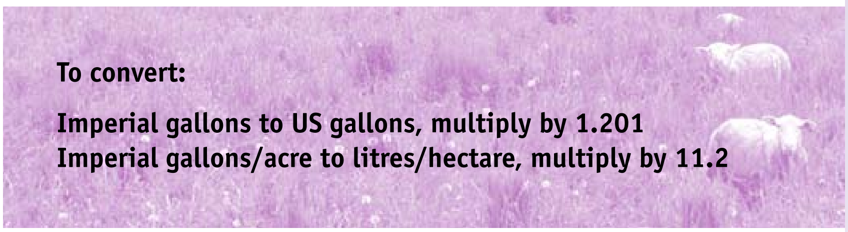
TYPE OF MANURE	WEIGHT PER CUBIC FOOT (LBS)	WEIGHT PER BUSHEL (LBS)
LIQUID	62.4	80
SEMI-SOLID	60	76
THICK SOLID MANURE	50	64
LIGHT SOLID MANURE	35	45
DRY POULTRY LITTER	25	30

You can use several methods to measure your spreading rates. One quick method for solid manure involves weighing the manure applied onto a sheet of plastic placed in the path of the spreader. A method for liquid manure uses a straight-walled pail to measure depth of application. The following table on Calibrating Manure Spreaders shows how to convert the measurements to application.

New methods are being introduced to quickly and accurately determine what's being applied. For liquid manure, in-line flow-meters are available that can instantly give you an application rate in gallons per hour. GPS technology is available to combine flow-meter information with application width and groundspeed information to give an instant gallons-per-acre readout.

CALIBRATING MANURE SPREADERS

SOLID MANURE Calibrations Using a 40 x 48 in. Sheet (Opened Feedbag)		LIQUID MANURE Calibrations Using a Straight-Walled Pail	
MANURE PER SHEET (lbs)	APPLICATION RATE (tons/acre)	DEPTH OF MANURE IN PAIL (inches)	APPLICATION RATE (gallons/acre)
1	1.6	1/10	2,265
2	3.2	1/8	2,825
3	4.8	1/4	5,650
4	6.4	1/3	7,550
5	8.0	3/8	8,500
7	11.2	1/2	11,325
10	16	5/8	14,150
15	24	3/4	17,000
20	32	1	22,650



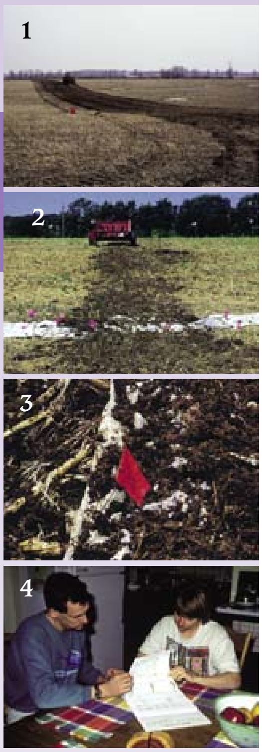
To convert:

Imperial gallons to US gallons, multiply by 1.201
Imperial gallons/acre to litres/hectare, multiply by 11.2

An alternative method for calibrating liquid manure is to weigh the manure and use the same method as the sheet. When using a round straight-walled container, the area is calculated from the inside rim diameter. The formula for area is pi r2 (3.1417 X square of radius) and assumes that a gallon of liquid manure weighs 10 lbs.

Calibrating liquid manure applicators

1. Set a series of straight-walled pails in the path of application of the spreader.
2. Measure depth of liquid in pails. Take an average.
3. See the table on page 87 to estimate application rate.



Calibrating solid manure spreaders

1. Spread several plastic sheets (40 x 48 in.) within spread pattern of spreader.
2. Drive by the plastic sheets at normal speed.
3. Collect the sheets and weigh them. Note the average.
4. Use the table on page 87 to determine the application rate in tons/acre.

For more detailed information, see the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on how to calibrate a liquid manure spreader. It shows equations to calculate travel speed based on application rate required, width of application, and time it takes to apply a load. See also the Best Management Practices book, *Manure Management,* Order no. BMP-16.

All nutrient application equipment needs to be checked regularly to assess uniformity of spread pattern and proper rates of application.

Calibrating nutrient applicators (spreaders)

1. Assess the uniformity of spread pattern from commercial fertilizer applied with:

- ▶ **drills/planters** – rate delivered should be uniform across equipment width
- ▶ **broadcast equipment** – typically, relative delivery rates should be higher immediately behind spreader, and drop steadily as the distance from point of spreading increases
  - ▷ where delivery rates are inconsistent, consult operator's manual for adjustment.

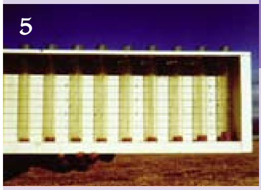
2. Determine effective spreading width:

- ▶ for drills/planters, the effective spreading width is the width of the equipment
- ▶ for equipment with spread patterns where delivery rates drop off as the distance from the point of spreading increases
  - ▷ the spreading width is determined by the distance between the point on the right and left side of the swath, where the application rate is one-half the rate through the centre section of the swath.

3. Calibrate:

- ▶ method #1
  - ▷ fill the equipment to a given level
  - ▷ travel a distance until area covered is equal to one acre
  - ▷ determine amount of nutrients required to refill to the given level
- ▶ method #2
  - ▷ weigh the equipment
  - ▷ spread several acres
  - ▷ reweigh the equipment
  - ▷ divide weight difference by number of acres covered.

Note: area covered is determined by multiplying the effective spreading width by the distance traveled.



If wet weather is forecast, delay application or restrict to areas with the least risk of runoff.

Pay attention to the weather forecast.

Weather plays an important role in determining the number of days available for application. Weather, combined with soil moisture and drying conditions, impact manure nutrient (especially nitrogen) availability. Weather forecasts are useful when planning manure application.

Other weather considerations could include wind direction (especially if there are residences downwind), wind speed (irrigation of <1% dry matter materials), relative humidity and of course, probability of precipitation. This information should be recorded at the time of application (see record-keeping section). Local weather forecasts, though not always reliable, are more accurate than in the past.

Thunderstorms are often forecast in spring, but frequently don't materialize. Grower experience in following weather patterns has always been important in farm task management. If thunderstorms or rain are forecast when you're planning a manure application, consider a change in approach. For example, have a second tractor begin incorporating behind the manure tanker as soon as conditions allow, instead of waiting an extra day. Or, in a no-till situation, apply manure to a field with least risk of surface runoff.

Although there are many weather sources, an online source for farm weather can be found at: www.farmzone.com/report/LongTerm (weathernetwork.com).

Fall spreading will reduce N-value in manure.

WINTER APPLICATION

Winter application of manure cannot always be avoided. When storage sizing is less than adequate or when conditions occur that result in the storage being full before spring application, then winter application becomes a contingency.

The challenge is to find where manure can be applied that will result in the least risk of manure entering watercourses. When applying manure in winter, consider:

- ▶ are there any alternative storages in the neighbourhood that could be utilized?
- ▶ is there any land base where manure could be incorporated immediately?
- ▶ where owned equipment is not adequate, could manure be incorporated using a custom applicator?
- ▶ if solid manure must be surface-applied (on snow), where is the field with the least runoff potential to a watercourse?
- ▶ have separation distances been doubled when manure is applied in winter conditions?

6

The specific requirements for winter spreading are set out in section 48 of the Nutrient Management Act Regulation.

When fields are near rural residences, avoid application approaching and during weekends and other community events.

Good neighbour policy: notifying your neighbours of your intent to apply will ease concerns.

Many farm operations emit odours. Most conflicts occur between livestock operations and neighbours. Unfortunately, such conflicts are not always handled as constructively as they might. Conflict can be prevented: it takes a little know-how, a few skills and techniques, plus the right attitude.

The key to preventing problems is **good planning, careful management and neighbourly relations.**

The Kaisers address their neighbours' concerns with good rapport and communications. They back up what they say with comprehensive planning and BMPs for manure and other nutrients.

Site planning

By following planning principles that take neighbours' concerns into consideration, livestock odours are less likely to become a point of contention.

Principles to consider:

- meet MDS distance formula
- locate storage system and lanes downwind from rural neighbours where possible
- keep storage out of main view – plant trees to remove dust and aerosol particulates from air and increase dilution.

For more information, see the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on odour control in livestock and poultry farms.

Keep trees 30 metres (100 ft) from fan barns and 60 metres (200 ft) from naturally ventilated barns to avoid impacting ventilation systems.

Neighbourly communications

Get to know your neighbours. Help them feel comfortable enough to talk to you directly about their concern. This will help prevent the need for third-party involvement. Also,

- try to limit spreading to two or possibly three times a year: the less often odour is noticed, the less likely the concern
- where possible, incorporate manure immediately after spreading
- avoid application on hot, humid days to reduce the chance that their windows are open – morning spreading is often the best time
- avoid spreading manure on weekends, or just before the weekend
- take wind direction and speed into account when spreading near neighbours
- notify neighbours (by telephone and/or through a note in their mailbox) to let them know in advance of your manure spreading plans, so they can plan around the event accordingly if they so wish (e.g., not hang their laundry outside)
- participate in and host special events in the neighbourhood (e.g., a summer barbecue).

With these considerations, many of today's livestock producers are building respect and fostering unity within the rural community.

For more ideas, see the ministry factsheet on farm and neighbour relations, Order no. 05-001.

When it comes to manure and neighbours, the good news is that BMPs for retaining manure nutrients, such as immediate incorporation and spreading on cooler days, will also reduce odours during application.

HOW TO APPLY

There are some key considerations when applying nutrients.

If a custom applicator is applying manure, review your nutrient management plan with the applicator (specifically rates, separation distances and special site features).

Where suitable, pre-till tile-drained lands before applying liquid manure – it will break up large pores and reduce infiltration to tiles. Care and consideration should be given to soil conservation. Maintain as much residue cover as possible.

Incorporate manure as soon as possible following application (ideally the same day as application).

Surface-applied liquid manure should be pre-tilled or immediately incorporated to reduce nutrient loss.

Conduct tile drain inspections to assess manure losses. If manure becomes visible at the tile outlets, stop application immediately.

PREVENTING PREFERENTIAL FLOW

For manure on tile-drained soils, choose one or more of the following options.

- ▶ Monitor tile drains and take appropriate action – stop application, block outlets (for at least 72 hrs) and remove contaminated water (e.g., with a vacuum tanker).
- ▶ Pre-till to break macropores.
- ▶ Apply at a rate of less than 3,600 gal/ac (40 m^3/ha).
- ▶ Apply liquid manure/organic material over a "representative" tile and observe the tile outlet for manure.
- ▶ Treat tile effluent to remove contaminant (e.g., biofilter, dispersion sandwich).
- ▶ Note that solid manure in tiles can also become an issue when rainfall occurs shortly after application.
- ▶ **Stop application immediately** if discolouration is observed, then implement contingency plan.

Step 7. KEEP RECORDS

In order to review and revise a plan, you must know what was done. Record-keeping is the process of recording what **actually** took place.

Record-keeping is already a key component of many aspects of farming, such as financial book-keeping and recording crop and livestock yields. For nutrient management plans, there are two main reasons for keeping records:

- they provide the information you'll need to fine-tune your NMP during the review process, and you can determine how closely the plan fits with reality
- they demonstrate accountability and diligence, should something go wrong, or if someone questions what was done (e.g., a nuisance complaint). Having the records of what was done and when will help resolve questions and conflicts.

Keep the nutrient management plan as simple as possible, but preserve the details in the record-keeping.

WHAT TO INCLUDE

Although the following list gives more record-keeping ideas than may be required on your farm, this is the type of information that will simplify the updating of your nutrient management plan and the evaluation of what worked and what didn't and why.

FIELD AND CROPPING PRACTICES

- Soil test results
- Nutrients types applied and application dates, rates, and methods
- Manure analysis records – if manure is being managed differently, or samples were taken at different levels in the storage
- Records of equipment calibration
- Incorporation method and date
- Weather conditions at time of application and incorporation
- Rainfall records to determine water content changes from the norm (i.e., more rainfall than normal = less concentrated manure, resulting in adjusted application rate)
- For spreading: date, time, location, quantity, setbacks
- Date and times of tile outlet monitoring including observations (on application dates) if applicable
- Commercial fertilizer invoices showing volume and timing of application
- Crop type and planting date and planting details

7

Record-keeping can be used to fine-tune your plan.

- ▶ Tillage method and date
- ▶ Herbicides applied and date
- ▶ Scouting notes
- ▶ Harvest date
- ▶ Yield
- ▶ Side-by-side comparison results

GPS systems, especially in tandem with flow meters, are useful in recording where manure has been applied, and where it hasn't. This system allows a commercial fertilizer applicator to come in later to apply nutrients where manure application equipment couldn't.

LIVESTOCK INFORMATION

- ▶ Feed records, especially to justify or monitor manure nutrient reductions
- ▶ Inventory of livestock on the farm (monthly basis)
- ▶ Inventory of feed
- ▶ Record of livestock groupings and batch feeding
- ▶ Biosecurity protocols for the operation
- ▶ Manure volume generated – an accurate measurement of the nutrients generated on a farm is an important aspect of manure storage planning
- ▶ Manure analysis results

OTHER INFORMATION

- ▶ Documentation of any other time/conditions when a contingency plan is deployed, including location, estimated volumes and remediation measures
- ▶ What was done to resolve any complaints
- ▶ Imported nutrient-containing materials, date, tons or volume, description of the material (i.e., agreements)
- ▶ Biosecurity protocols for the operation

When you keep proper records, you'll generate a considerable volume of information. It does take time to set up a system that allows the information to be readily reviewed and used. There are many different systems: software options, GPS-type, hand-held personal computers, and field books.

It's an old saying but it's still true: farmers are the first stewards of the land. Record-keeping is part of environmental stewardship, demonstrating on-farm diligence to the local community.

RECORD-KEEPING DOCUMENT FOR CASE STUDY FARM

EXAMPLE OF MANURE INVENTORY RECORD

PRODUCER: CM Farms	TANK I.D.	HARVESTORE® ~ 200,000 GALLON CAPACITY		
TANK DIMENSION:	Depth: 24'	Diameter: 42'	Length:	Width:
GALLON PER FOOT OF DEPTH: 8,654		GALLONS PER INCH OF DEPTH: 721		

Date/Year	Depth (inches)	Top to surface	= Depth of manure	X Gallons/inch	= Gallons
May 1, 2004	288	275	13	721	9,373
June 1, 2004	288	251	37	721	26,677
July 1, 2004	288	231	57	721	41,097
August 1, 2004	288	22	68	721	49,028
September 1, 2004	288	190	98	721	70,658
October 1, 2004	288	160	12	721	92,288
November 1, 2004	288	260	28	721	20,188
December 1, 2004	288	232	56	721	40,376
January 1, 2005	288	208	80	721	57,680
February 1, 2005	288	188	100	721	72,100
March 1, 2005	288	164	124	721	89,404
April 1, 2005	288	133	155	721	111,755
May 1, 2005	288	272	16	721	11,536

Amount Removed	Amount	No. of Loads	Destination
October 15, 2004	72,100 gal	25	Smith South field
April 20, 2005	100,219 gal	35	Brown Farm

FIELD SUMMARY AND RECORD KEEPER (Farm 1, South field, all)

Cropping Information

Status	Crop	Yield	Plant Date	Havest Date	Notes
Planned	Soybeans	42 bu/ac	15-May-2005	01-Oct-2005	
Actual	Soybeans	47 bu/ac	28-May-2005	09-Oct-2005	NK RR 10T1

Tillage Information

Status	Tillage Date	Method	Practice	Notes
Planned	01-May-2005	Mulch-Till	Cross Slope	
Actual	25-May-2005	AerWay®	Cross Slope	Pre-till ahead of manure application
Actual	28-May-2005	No Till		International 5100 Drill® with coulters

Fertilizer Application

Status	Description	App Date	Blend	Rate	Method	Applied	Surface Water
Actual							

Manure Application

Status	Description	App Date	Type	Rate	Speed	Method	Incorporation	Surface Water
Planned	Manure App 2	22-May-2005	Spring	5000 gal/ac		Drag Hose	Not incorp. Pre-tilled	200 ft

FIELD SUMMARY AND RECORD KEEPER (Farm 1, North field, all)

Cropping Information

Status	Crop	Yield	Plant Date	Havest Date	Notes
Planned	Grain Corn	130 bu/ac	01-May-2005	01-Oct-2005	
Actual	Grain Corn	156 bu/ac	19-May-2005	13-Nov-2005	West Spring Pioneer 38P04® @ 30,000 ppa

Tillage Information

Status	Tillage Date	Method	Practice	Notes
Planned	17-Nov-2004	Mulch-Till	Cross Slope	
Actual	29-Nov-2004	Soil Saver	Cross Slope	Sweep tooth, cloudy windy, 2°C. conditions ideal

Fertilizer Application

Status	Description	App Date	Blend	Rate	Method	Applied	Surface Water
Planned	Fert App 4	01-May-2005	28-0-0	12.0 gal/ac	Not Incorp. Standing	43. 0. 0. lb/ac	N/A
Panned	Fert App 3	01-May-2005	6-24-6	4.0 gal/ac	Placed with planter	3. 13. 3. lb/ac	N/A
Actual	Starter	19-May-2005	6-24-6	4 gal/ac	Placed with planter	3. 13. 3. lb/ac	
Actual	28% N	23-May-2005	28-0-0	10 gal/ac	Carrier, pre-emerge herbicide	36. 0. 0. lab/ac	

Manure Application

Status	Description	App Date	Type	Rate	Speed	Method	Incorporation	Surface Water
Planned	Manure App 2	24-Nov-2004	Fall	6000 gal/ac		Tanker	Incorp. 1 day	N/A
Actual	Manure	28-Nov-2004	Liquid Hog	6000 gal/ac	2.8 mph	Tanker	5 C; NW winds	N/A

LONG-TERM FORECAST

	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY
	Cloudy periods	Mainly sunny	Mainly sunny	Mainly sunny	Cloudy periods	Scattered showers
HIGH	29°C	32°C	32°C	30°C	26°C	25°C
LOW	17°C	21°C	20°C	22°C	15°C	16°C
P.O.P.	0%	20%	0%	0%	10%	40%
PRECIP ACCUM	–	–	–	–	–	close to 10 mm
WIND	SW 10 km/h	W 10 km/h	SW 10 km/h	SW 15 km/h	SW 25 km/h	NE 5 km/h

PLANNING FORECAST

	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY
DRYING INDEX	High (56)	High (59)	Very high (63)	Very high (63)	Very high (61)	Average
HRS SUNSHINE	14 h	14 h	14 h	14 h	13 h	6 h
GROWING DEG DAYS	18	22	21	21	16	16
CROP HEAT UNITS	28	31	30	32	25	26

Source: www.farmzone.com/report/LongTerm (the weathernetwork.com)

Step 8. MONITOR

Monitoring is the process of observing and recording. By using the records you've collected as a base, you can monitor your management practices for trends in your operation.

Monitoring helps you to determine if crops and livestock are receiving the proper nutrients. Paying attention to what monitoring reveals will help you adjust inputs and reduce negative environmental impact. Monitoring will also increase your confidence in the value of nutrient cycling within your operation.

Over time, you'll find a balance and can settle into a routine of closely monitoring important items while having confidence that other items are taking care of themselves. For example, monitoring soil conditions, manure and application rates for several years will give you confidence in what application rate your soils and crops will handle without negative yield impact or runoff issues.

WHAT TO MONITOR FOR	
SOIL	• Increasing or decreasing soil phosphorus and potassium levels over a 10-year period • Pre side-dress nitrogen tests to indicate nitrogen available for uptake by crops • Compacted soils caused by application method or timing
CROPS	• Yields and whether they are increasing or being maintained • Side-by-side comparisons are put in place and evaluated
WATER	• Monitoring tile outlets before, during and after liquid application at 1-hr intervals 24-48 hrs after application to ensure that water is not contaminated with manure • Regular water sampling of wells (testing for fecal coliform, nitrates)
MANURE	• Manure analysis consistency each time the storage is emptied • Seasonal variability of manure analysis • Effect of manure/feed additives on dry matter, nitrogen and/or phosphorus content of manure
FEED	• Feed additives and whether they are changing the nitrogen, phosphorus and/or micronutrients composition in the manure – feed ration analysis will detect changes in nutrient content of feed
LIVESTOCK	• Livestock production numbers, weight gains, milk or meat production per cycle or changes in reproduction rates – changes in predicted numbers or changes in production will have an effect on nutrients generated • Change in production due to management changes such as phase feeding
BUFFER STRIPS	• Effectiveness of buffer strips – look for evidence of erosion and/or sedimentation or evidence of concentrated flow to show that a grassed waterway may be more effective • Intense or high rainfall events result in surface runoff, contaminating water
RURAL NEIGHBOURS	• Comments/complaints from neighbours (positive or negative) • Odour comparisons – whether odours from storage and application are acceptable
CONTINGENCY PLANS	• The response(s) of those involved in the operation to a problem • Whether everyone involved in the operation knows where to find the list of contact numbers in the event of a spill
ECONOMICS	• Economical feasibility of the management practices required for the NMP • Reduction in commercial fertilizer costs • Cost share and/or realize partial nutrient value of manure in manure agreements

Monitoring should take place whenever nutrients are applied to land. Most often, monitoring is simply a visual inspection just to make sure things are happening as planned.

HOW TO MONITOR

STORAGE VOLUME

Monitoring storage volume will make it much easier to determine acreage requirements. Manure production is estimated from MSTOR, but like all averages, differences in water usage and production often result in an overestimate or underestimate of manure produced.

Monitor volume as storage builds. For a sample format, see the record-keeping chapter, page 96.

Keep yearly records of volume applied by custom applicators, or removed by manure brokers.

Manure in tile effluent will show up as discoloured water. Generally, the more discolouration, the more manure in the effluent.

Manure storages should be routinely inspected for cracks and structural integrity.

APPLICATION RATE AND UNIFORMITY

It's wise to periodically monitor manure application rates and uniformity. Here are some tips.

- One way to get a good look at spread pattern is to use a plastic sheet, then take a picture.
- Generally, a 10 to 15% overlap is required with irrigation guns when used with washwaters and other materials of less than 1% dry matter. On a reel, the width of spread pattern will become narrower as the hose winds around the reel.
- To get uniform application across a field, traditional box spreaders must go wheel to wheel.
- Depending on distance of a splash plate to the nozzle, a tanker will often spread higher volumes at each edge of the spread pattern and lower volumes behind the tanker
  - this spray pattern is similar to what happens when your thumb is too close to the opening of a garden hose.
- With injection units, look to see whether the volume increases in the other injection units if one of the units is plugged
  - do you know when an injection unit is plugged?
- Your equipment dealer may be able to assist in improving uniformity, e.g., splash plate setup, or the right incorporation or injection tooth for your soil types.

For more information, see the Best Management Practices book, *Manure Management.*

MANURE APPLICATION ON TILED LAND – TILE OUTLETS

Monitor tile outlets to ensure that manure is not entering surface water through preferential flow.

When applying liquid manure to tile-drained land, **monitor tile outlets to ensure that manure is not entering surface water through preferential flow.** Look for discolouration of tile flow, relative to pre-application condition.

Tiles should be observed on a regular basis. Here's a suggested schedule for observation:

- prior to application to determine the quality and quantity of flow (ideally there will be no flow)
- 10–20 minutes after start of application
- once each hour, if rate is greater than 20,000 gal/hr
- once each 20,000 gallons if hourly application rate is less.

As an alternative to having a person monitor, consider using automated continuous monitors.

ODOUR

Monitor for:

▶ wind direction
▶ smell (how bad is the smell and how long does it last?)
▶ complaints (family, neighbours).

Side-by-side comparisons are a great way to test new practices.

CROP RESPONSE

Side-by-side comparison is one of the best methods of testing new practices. In side-by-sides, you can measure crop response using plot comparisons of yield and economics to assess:

▶ requirement of starter fertilizer when soil test levels are high
▶ impact of timing on incorporation for nitrogen utilization
▶ impact of additional nitrogen over that provided by manure (testing different rates)
▶ impact of crop rotation and/or cover crops.

Set up and assess trials.

For side-by-sides, each plot should:

▶ have at least two replications in the field

▶ compare only one practice at a time (comparing more than one change will make it difficult to assess effectiveness of any one change)

▶ be in an area of the field where the site characteristics (slope, soil type, etc.) are similar

▶ be harvested and have yield data recorded

▶ be subjected to economic analyses to compare the plots.

Monitoring doesn't take much effort, but it can minimize problems and allow you to respond quickly in case of an accident.

Field trials are a great way to verify BMPs for your operation and site conditions. Follow guidelines for on-farm trials to generate reliable and transferable information.

It is best to monitor for runoff from fields and farmsteads during or immediately after storm events.

Step 9. MAKE ADJUSTMENTS

After you've put your nutrient management plan into action, and completed the monitoring and record-keeping, you're in a position to determine which decisions in the plan worked well and which did not.

If significant cropping or livestock management changes are planned, you're advised to rerun NMAN so that the nutrient management plan will reflect these changes.

A nutrient management plan is a living document intended to change with time and technological advances, and with a better understanding of the processes involved. It is most important to evaluate how well the plan met the goals you set for it (Step 1).

As you contemplate making adjustments, remember to follow the systems approach to management.

Making adjustments to the plan is similar to repeating Steps 3 to 6 – the analysis, interpretation, decision and action processes. The end result will be a revised plan, ready for implementation.

When reviewing or making changes to your plan, bear in mind the factors that may affect where changes are made. Consider:

- ▶ personal changes that may affect long-term goals, labour availability, etc.
- ▶ greater understanding of the principles that may affect whether you or a consultant revises the plan
- ▶ market forces that may affect the livestock raised, crops grown, end use of products generated (including manure), acres of various crops, etc.
- ▶ changes in the community (e.g., urban growth closer to the farm), bylaw changes and new regulations that may affect your operation
- ▶ manure sample analysis that may have changed since the initial results used for the original plan
- ▶ subsequent soil analysis that may show nutrient balance increasing over time
- ▶ commercial fertilizer rates or manure rates that may have to be modified based on results from side-by-side comparisons
- ▶ new technology that may affect application rate or timing (e.g., application equipment, livestock ration options, storage process such as anaerobic digesters or composting)
- ▶ purchase or rental of additional land base, or the addition or suspension of manure agreements.

Adjustments are made constantly in farming based on new ideas, new products or technology, coffee-shop talk, regulations, an advertising blitz, or just the need to try something different.

In nutrient management planning, adjustments are made from a systems perspective – using observations, record-keeping and monitoring information to reinterpret actions and decisions.

COMMON AREAS FOR ADJUSTMENT

CHANGING TIMING AND TECHNIQUE

Changing the time of application may require other changes.

Consider the case of a layer operation with liquid manure and a heavy clay land base that has been in a no-till system for over 10 years. The egg producer tries to late-summer apply the manure in order to avoid compaction problems and to make best use of the nitrogen in manure. After the first year, the application equipment is adjusted so that the injection units will leave the soil more level and the injection paths covered.

The adjustment is made because the equipment was not designed for the heavy clay conditions or the dry soil conditions. Although consideration could be given to changing the timing of application or the tillage (from no-till to conventional), some management decisions are cast in stone and manure management must work around them – sometimes with compromises.

Changing the timing of application to a side-dress operation may require equipment changes.

NEW TECHNOLOGY

Equipment

Farmers are skillful at modifying equipment to make it work for specific conditions, and manufacturers are looking for these new ideas for development of new technology – whether for no-till, zone till or for manure application equipment. Don't hesitate to ask and work with manufacturers and dealers to ensure the equipment purchased meets the needs and conditions of the farm.

Composting reduces manure volume, odour and pathogens.

Manure treatment

When problems are identified, chances are that research can offer solutions to problems. For example, large operations with not enough land base have the option of alternative treatment systems such as composting or anaerobic digestion. Composting is a process that when completed (i.e., when compost is cured), reduces the volume, odour and pathogens compared to its raw form. Anaerobic digestion is a process that converts some of the carbon to energy and also reduces odours and pathogens. Both processes can be expensive and labour-intensive. Investigating the results of local demonstration projects and current research (done under similar climate, management and political conditions) is a good method of determining whether or not this is an economic option for your farm.

Monitoring and record-keeping

Computer-based and remote-sensing techniques have been developed to improve calibration, resource and input monitoring, as well as record-keeping.

Prudence and accountability are at the core of monitoring - with or without modern technology.

Let's say a farm with a major stream meandering through several cornfields is prone to flooding. A custom applicator with a global positioning system (GPS) is chosen to apply manure to those fields. The applicator has a flow meter that tracks application rate as well as a positioning system that tracks exactly where manure has been applied.

A map can be produced to verify setback distances. The data can be used by the local fertilizer dealer to compensate areas that did not receive manure with commercial fertilizer.

Sampling frequency

How often should you sample manure?

- ▶ each time the storage is emptied until you're satisfied that there is consistency in analysis results
- ▶ each time that you change your livestock type, rations, bedding or manure storage or other management that affects manure characteristics.

Note the implications for your nutrient management plan and its implementation. This could mean different manure application rates, adjustments to fertilizer use, and, if significant, adjustments to timing and separation distances.

How often should you sample soil for analysis?

- ▶ every three years, or
- ▶ at the same point in rotation, or
- ▶ after major changes in nutrient application.

Manure runoff from open yards and storage pads can occur after most rainfall events.

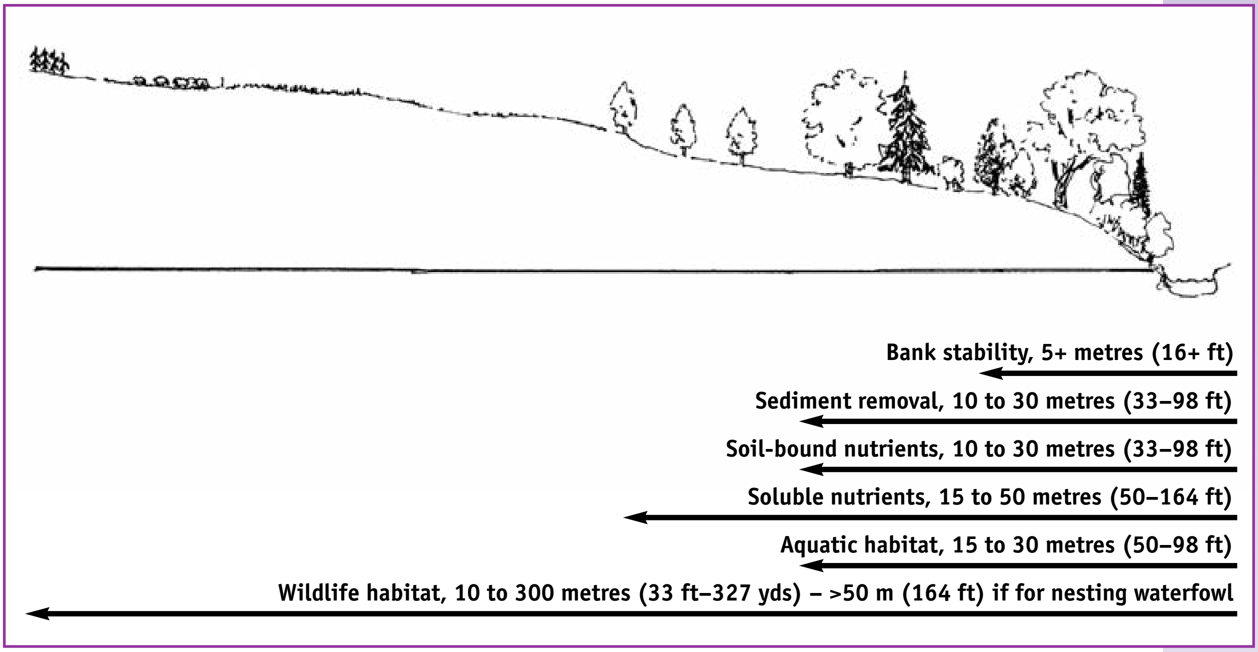
CASE STUDY FARM – VEGETATED BUFFER

After intense rainfalls, if the soil in the field erodes and the streambank slumps, the need for a vegetated buffer is evident. One adjustment to the plan would be to install a 15-ft vegetated buffer with the goal of bank stabilization. A drop structure could be considered to repair the gully.

A switch to conservation tillage and maintaining 30% surface residue should also help to reduce soil erosion. Future monitoring of erosion and sedimentation to determine the effectiveness of 15-ft vegetated buffer will help determine if the buffer should be increased to 30 feet or if a grassed waterway to handle concentrated flow would be more effective.

Use the diagram below to choose the function and suitable width of a planned buffer strip.

A properly sized and established grassed buffer strip will help reduce the amount of manure runoff from croplands that reaches a watercourse.



STARTER FERTILIZER ECONOMICS

Another adjustment considered in 2003 and 2004 was the use of starter fertilizer. With a P soil test between 40 and 60 ppm, it seemed necessary to determine whether or not the starter fertilizer was required.

In a replicated side-by-side comparison, there was no yield difference where starter was used and where it wasn't – both strips yielded 145 bu/ac.

The starter material going through the fertilizer boxes on the planter was 150 lbs/ac 8-32-16 at a cost of approximately $18.00/ac. By not using starter fertilizer, the application rate could go from a current maximum of 4,500 gal/ac to 6,250 gal/ac.

If soil tests were in the medium range, and a producer wasn't comfortable with eliminating the starter fertilizer, then the option of liquid seed-placed starter at a low rate (4 gal/ac) could be tested in a side-by-side comparison for several years.

Impact of side-by-side in making adjustment

The owner of the case study farm is looking at including wheat in the crop rotation. His decision will be based on whether manure could be utilized on the wheat crop. The farmer, in co-operation with his neighbour, did a side-by-side to help make the decision.

After interpreting the information, they decided to try this comparison for one more year to examine the results from a drier year. Based on one comparison, the decision to include wheat in the rotation looked promising.

MANURE ON WHEAT SIDE-BY-SIDE COMPARISON
Treatments

- **A** Full manure with AerWay®
- **B** Full manure surface-applied
- **C** 2/3 rate manure with AerWay 1/3 fertilizer N
- **D** Fertilizer N only
- **E** Manure @ 133% N rate (120 N)
- **F** Manure 67% N (60 lbs. N)

Target Nitrogen Rate: 90 lbs/ac

PLOT LAYOUT – NORTHEAST CORNER

	A 1	**B** 2	**C** 3	**D** 4	**E** 5	**F** 6	**A** 7	**D** 8	**B** 9	**E** 10	**C** 11	**F** 12	**E** 13
YIELD (BU/AC)	73.3	76.2	68.1	72.8	87.4	71.6	73.6	79.9	83.6	84.7	75.0	68.2	72.5
MOISTURE %	14.4	14.8	14.6	14.9	14.3	15.0	15.1	15.4	15.1	14.8	15.2	15.3	15.2
ACTUAL N APPLIED	124	124	103	90	146	73	107	90	107	142	101	71	142

Plot summary:

90 lbs Manure N with AerWay (3,000 gal/ac):	73.4 bu/ac	14.75 % moisture
90 lbs Manure N surface-applied (3,000 gal/ac):	79.9 bu/ac	14.95% moisture
60 lbs Manure N (AerWay, 2,000 gal/ac); 30 lbs commercial N:	71.6 bu/ac	19.90% moisture
90 lbs Commercial fertilizer N:	76.4 bu/ac	15.15% moisture
120 lbs Manure N with AerWay (4,000 gal/ac):	81.5 bu/ac	14.76% moisture
60 lbs Manure N with AerWay (2,000 gal/ac):	69.9 bu/ac	15.15% moisture

Additional Information

- 60-ft wide plots
  - 975 to 1625 ft plot length, longer plots on south side of field
  - combine header 17.5 ft with middle 35 ft of each plot combined
  - wheat planted Oct 15th –19th – Pioneer® 25R26
- manure (and commercial N) applied May 15 (30-ft application width) (overcast, 11 °C., moist to wet soil conditions)
- wheat harvested August 9
- fusarium levels > 1.5% (roughly estimated between 2.5 and 3.5%) samples submitted for protein and fusarium testing weeds pressure (moderately weedy)

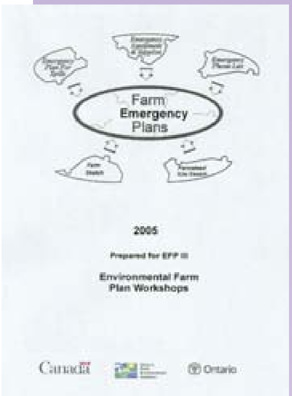
Step 10. PLAN FOR THE UNEXPECTED

You need to be prepared for the unexpected. The best way to do that is to think ahead and plan "what you would do if…?"

A contingency plan is a written document that sets out actions to be taken in the event that a nutrient management plan or strategy cannot be followed. For example, a manure storage may become filled with rainwater before the contained manure can be applied. Another example is a spill or unanticipated release of nutrients. Preparing a contingency plan in advance speeds up your ability to take corrective action on short notice.

Identify potential scenarios. The contingency plan answers questions, such as:

1. What procedure will I follow if a spill occurs?
2. What steps will I take to contain, eliminate and clean up a spill – at the storage, at the transfer site, in the field?
3. What will I do if my operation has more nutrients than planned, e.g., livestock must be held for longer than planned, thus increasing the volume of manure?
4. If wet weather delays application of nutrients and storage is nearing capacity, where will I transport the nutrients?
5. If excess rainfall fills the nutrient storage to capacity, where would I transfer or spread the nutrients/manure?
6. If soil conditions are not compatible with planned spreading operations, what are my alternatives and how will I compensate?



The EFP Emergency Plan should be completed as part of your NMP contingency plan.

Next, identify the resources required in case the plan must be put in place. Some of these could include:

- finding a local custom applicator with a vacuum tanker
- locating tile outlets for monitoring
- making a list of the telephone numbers required and remembering the list's location.

Communicate the contingency plan to all those involved in the operation. It's important that all farm help, family members, custom applicators, etc. are aware of the details of the contingency plan and the location of the emergency list(s). And of course they must also be able to execute the required actions.

Document what was done when an emergency occurred. Detailed reports of what was done, when, who was called, and what was discussed will help in case of complaint or spills follow-up.

When a situation has required that a contingency plan be put into effect, the plan should be evaluated to determine if improvements are needed and changes made accordingly.

A contingency plan will provide step-by-step actions to address nutrient-related emergencies such as a manure spill.

WHY HAVE A CONTINGENCY PLAN?

- to protect the environment, your family, your livestock and your business (may help minimize potential liability)
- to demonstrate that you are prepared for emergencies
- so that you can react when there's an emergency – and not panic!

It's an offence under the provincial Environmental Protection Act and the federal Fisheries Act to pollute a stream and kill fish.

WEATHER OR EQUIPMENT CONDITIONS IMPEDING PLANNED STORAGE OR APPLICATION

Timing change

When the timing of manure application must be changed:

- adjust commercial nutrients applied to reflect the change in timing (e.g., when changing from fall to spring application, adjust commercial N to reflect higher N availability from the manure)
- adjust subsequent applications of nutrients to accommodate the change in timing of the nutrient application
- record the change in your nutrient management plan.

LONG-TERM FORECAST

	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY
	Cloudy periods	Mainly sunny	Mainly sunny	Mainly sunny	Cloudy periods	Scattered showers
HIGH	29°C	32°C	32°C	30°C	26°C	25°C
LOW	17°C	21°C	20°C	22°C	15°C	16°C
P.O.P.	0%	20%	0%	0%	10%	40%
PRECIP ACCUM	–	–	–	–	–	close to 10 mm
WIND	SW 10 km/h	W 10 km/h	SW 10 km/h	SW 15 km/h	SW 25 km/h	NE 5 km/h

Source: www.farmzone.com (weathernetwork.com)

Crop change

Nutrient amounts and fertilizer formulation should be adjusted (where possible) to account for a change in crop. If the nutrients have already been applied, the amount and formulation should be adjusted for the next crop where possible, to account for the nutrient needs and removal of the current crop. In the big picture, a change in crop grown won't have that much impact on a plan over the whole crop rotation.

When changing crops during the growing season, adjust your fertility program as needed.

CONTINGENCIES FOR MORE MANURE THAN PLANNED

If the application rates for nutrients in a NMP are at the maximum, you must be prepared to set up alternative destinations for the nutrients. Some possibilities include:

- ▶ finding a broker who can take the excess nutrients
- ▶ finding a neighbour (e.g., cash cropper) who may be looking for manure nutrients and will accept the excess nutrients, or
- ▶ locating an intermediate processor – such as a commercial compost operation for excess solid manure.

CONTINGENCIES FOR MORE NUTRIENTS THAN STORAGE CAPACITY

In some cases, generally due to adverse weather conditions, manure storages may be in danger of overtopping.

If a manure tank is overflowing, and the manure cannot be land-applied due to weather or a lack of available land, the preferred option is to transfer the manure to another storage facility.

A broker may also be used to take the excess manure.

If the conditions for land application are suitable, additional land may be used to apply the manure. However, this change should be recorded and incorporated into your nutrient management plan.

CHECKLIST FOR AN EMERGENCY PLAN FOR SPILLS

A properly developed emergency plan has the following components.

- ✔ A list of preventative best management practices and routine equipment inspection
- ✔ A list of contingency measures
- ✔ A step-by-step procedures list for eliminating the source
- ✔ A list – near each phone – of all necessary emergency call numbers
- ✔ A map of the facilities indicating areas of risk and location of clean-up equipment and supplies – you should have a secure location for the map and your emergency plan
- ✔ A list of who is responsible for what
- ✔ Staff and family training plus documentation of any preventative measures taken
- ✔ An account of how the spill will be cleaned up
- ✔ A formatted blank form to be completed after a spill is dealt with

IN THE EVENT OF A SPILL

This is an important issue due to the potential adverse effects. The emergency plan should outline the required equipment, who to notify, contacts and safety precautions. The idea is to minimize the potential for a spill, and if one does occur, to ensure that the operator and the employees know what actions to take.

For more information about how the Ontario Ministry of the Environment defines a "spill," see the textbox on the next page.

To avoid a spill

Spread the nutrient according to your NMP or contain it in an adequate nutrient storage for later application. In addition:

- calibrate your manure application equipment regularly so that you can follow the rate specified in your plan
- follow setbacks to surface water required by the NMP for the site
- mark all tile outlets and catch basins for nutrient application and inspection purposes
- use two people with a radio link or an automatic shutdown system for a direct-flow system
- avoid spreading before rain events.

In the event of a spill, stop it and contain it.

To stop a spill

1. Immediately stop the cause of the spill if possible.
2. Shut down the appropriate pumps and valves.
3. Ensure the system cannot be restarted.
4. Contact the 24-hour Spills Action Centre at 1-800-268-6060 or your local Ontario Ministry of Environment office.

To contain a spill

- minimize opportunity for manure to enter tile drain or plug the tile in the event that flow appears to be contaminating the tile drains
- if the spill is moving over the ground surface, build an earthen berm with farm or commercial equipment, such as backhoes or dump trucks
- use a vacuum tanker to apply contained manure
- notify downstream users

Numbers at hand

The following contacts should be posted by all phones for immediate access in case of a spill:

- Spills Action Centre (1-800-268-6060)

Other phone numbers that should be readily accessible:

- local Ontario Ministry of the Environment office
- bulldozer or backhoe operator
- custom applicator (preferrably one that has a vacuum tanker)
- municipality
- neighbours
- neighbour with a vacuum tanker

THE SPILL RESPONSE NETWORK (http://www.nuhn.ca/spillsubmit.html)

The Spill Response Network is designed to be part of a nutrient management contingency plan.

The website contains a list of individuals and organizations with vacuum spreaders, including those equipped with a loading arm. These persons are willing to assist another producer in cleaning up in the event of a manure spill. The equipment can quickly and effectively suck spill from fields and ditches, etc. This listing is open to any brand of equipment.

If a producer can show that all reasonable action has been taken to prevent and alleviate environmental contamination, a defence of diligence may be used. The existence of this network shows diligence on the part of the agricultural community as a whole and may help in any liability issues. It may even result in a lower insurance premium.

Payment for service is an initial fee plus an hourly rate for cleanup time.

WHAT IS A SPILL?

The Ontario Ministry of the Environment (MOE) defines spills as releases of pollutants into the natural environment originating from a structure, vehicle, or other container that are abnormal in light of all circumstances.

There is a legal obligation to report a spill immediately to the Ministry of the Environment through the Spills Action Centre (SAC) at 1-800-268-6060 and also to the local municipality, if the spill causes one or more of the following adverse effects:

- impairment to the quality of the natural environment – air, water, or land
- injury or damage to property or animal life
- adverse health effects
- safety risk
- making property, plant, or animal life unfit for use
- loss of enjoyment of normal use of property, OR
- interference with the normal conduct of business.

The person who caused the spill and the person who had control of a material at the time it was spilled (if different from the person who caused the spill) both have the responsibility to report the spill. In addition to reporting the spill, when a farm-related spill occurs it is the responsibility of the owner of the material and the person who had control of the material at the time it was spilled to clean up and dispose of the material in a timely manner.

APPENDIX

SPOTLIGHT ON THE NUTRIENT MANAGEMENT ACT, 2002

Plenty of general and technical information on this legislation is available in print and on the Internet. In this section, we'll simply highlight key features regarding who's responsible for what in the provincial government, requirements if your operation comes under the act, and a reminder of what constitutes "normal" farm practices.

The Nutrient Management Act (NMA), 2002 is intended to provide for the management of materials containing nutrients in ways that will enhance protection of the natural environment and provide a sustainable future for agricultural operations and rural development.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and Ministry of the Environment (MOE) jointly manage a comprehensive program to support the NMA.

Geri Kamentz and Paul Mistele of the OFA executive support BMPs for Nutrient Management Planning.

Geri: "Ontario farmers are recognized as industry leaders throughout the world, leading in innovation efficiency and environmental responsibility. These BMPs are the tools that can help us make that happen."

Paul: "These best management practices will once again underscore the positive relationship that Ontario farmers have with the environment."

OMAFRA and MOE Joint Responsibility

- Policy and program development
- Research and science
- Field assistance
- Outreach and information

OMAFRA Responsibility

- Approvals
- Information management
- Training, education and certification

MOE Responsibility

- Compliance, including inspections and complaint response
- Investigations and enforcement

DEFINITIONS

Nutrient management planning is the key responsibility for those who need to be compliant, and involves the completion of a nutrient management strategy and/or plan.

A nutrient management strategy (NMS) document accounts for all the manure generated, stored and transferred by a farm unit.

A nutrient management plan (NMP) accounts for the application of manure and agricultural source materials to land on a field-by-field basis.

TRAINING AND CERTIFICATION

Anyone preparing a nutrient management strategy or plan for a farm operation captured under the NMA needs to be certified by OMAFRA. You can do your own plan if you get certified by taking ministry-sponsored training courses.

A consultant that has a Nutrient Management Planning Certificate from OMAFRA can develop a NMS document and/or NMP for your operation.

ROLE OF ENFORCEMENT (ABATEMENT AND EDUCATION)

The MOE is responsible for compliance under the Environmental Protection Act, the Ontario Water Resources Act, the Pesticides Act and the Nutrient Management Act. All of this legislation, plus any associated regulations, protocols, and approvals, apply to agricultural operations.

MOE's compliance program is staffed with Agricultural Environmental Officers (AEOs) – provincial officers with specialized agricultural training. An AEO may visit your farm for a number of reasons, including:

- to perform an inspection to assess compliance with legislative requirements
- to respond to a complaint received by the ministry either from the public or through a referral from another agency (regardless of whether an NMS/P is in place), or
- to respond to a report of an environmental incident or spill.

The MOE's on-farm compliance approach engages farmers actively to resolve issues. As the requirements are often complex, AEOs work directly with farmers to achieve compliance with the law.

YOUR FARM SIZE AND THE ACTIVITY ON YOUR FARM DETERMINE HOW YOU ARE AFFECTED BY THE NUTRIENT MANAGEMENT ACT AND AMENDED O.REG. 267/03

FARM SIZE	REFER TO NUMBERS ON NEXT CHART
$\leq$ 5 Nutrient Units (NUs)	1
Between 5 and 300 NUs	Triggers (see below)
Existing $\geq$ 300 NUs OR Expanding to $\geq$ 300 NUs (without building permit)	2
$\geq$ 300 NUs with construction of livestock barn or manure storage	3a

TRIGGERS FOR OPERATORS BETWEEN 5 AND 300 NUs	REFER TO NUMBERS ON NEXT CHART
None of the 4 triggers below apply	1
Building permit with barn/storage OR Building an earthen storage PLUS, if:	3
Application of agricultural source materials within 100 m of a municipal well	3a
Application of non-agricultural sourced materials within 100 m of municipal well	3b
Application of non-agricultural sourced material (NASM)	3c

1	✔ Must follow three requirements for all agricultural operations: i. no application of non-agricultural sourced materials within 20 m of top of bank of surface water ii. no application of sewage biosolids between Dec 1 to Mar 31, or when ground is frozen or snow-covered iii. high-trajectory guns capable of spraying liquid more than 10 m are banned for land application of material with > 1% dry matter content. ✔ OMAFRA also recommends that you… • use OMAFRA-supported BMPs • manage to reduce opportunity for adverse effect • keep good records.
2	✔ Must have a NMS prepared by a certified person and registered with OMAFRA. ✔ Must have a NMP on file at the farm unit. ✔ Must keep good records. ✔ Must follow the three requirements for all farms (as listed in 1).
3	✔ Must have a NMS prepared by a certified person and registered with OMAFRA's Nutrient Management Branch (NMB) Approvals Unit. No NMP is required, but it is strongly recommended that one be written and followed, kept on farm and updated annually. ✔ Must keep good records. ✔ Must follow three requirements for all farms (as listed in 1).
3a	✔ Must have a NMS and NMP prepared by a certified person and kept on farm. ✔ The NMS must be approved by OMAFRA's NMB Approvals Unit. ✔ The NMP must be followed and updated annually. ✔ Must keep good records. ✔ Must follow three requirements for all farms (as listed in 1).
3b	✔ Must have a NMS and NMP prepared by a certified person and kept on farm. ✔ Both the NMS and NMP must be approved by OMAFRA's NMB Approvals Unit. ✔ The NMP must be followed and updated annually. ✔ Must keep good records. ✔ Must follow three requirements for all farms (as listed in 1).
3c	✔ Must have a valid Certificate of Approval, keep good records and follow three requirements for all farms (as listed in 1). ✔ As of January 1, 2007, must have a NMS and NMP prepared by a certified person, and both must be approved by OMAFRA's NMB Approvals Unit.

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

For More Information

PUBLICATIONS BY THE ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

The Ontario Ministry of Agriculture, Food and Rural Affairs has extensive information on nutrient management planning, manure and soil testing, soil fertility, farmstead planning, manure storage and management, manure agreements, and more. Specific information on the Nutrient Management Act, 2002, its regulation and protocols is also available.

For information or to obtain copies of ministry publications, please call 1-888-466-2372 from within Ontario or OMAFRA's TTY line at 519-826-7402 for the hearing impaired; e-mail your requests to products@omafra.gov.on.ca or visit the OMAFRA website at **www.omafra.gov.on.ca.** Orders can be faxed to 519-826-3633 or mailed to Government Information Centre, OMAFRA, 1 Stone Road West, Guelph, ON N1G 4Y2.

Publications:
www.omafra.gov.on.ca/english/products/product.html

Nutrient Management Act:
www.omafra.gov.on.ca/english/agops/index.html

ONTARIO GOVERNMENT CONTACTS

Ontario Ministry of Agriculture, Food and Rural Affairs
Agricultural Information Contact Centre
1-877-424-1300
www.omafra.gov.on.ca

Ontario Ministry of the Environment
Public Information Centre
1-800-565-4923
www.ene.gov.on.ca

DISCLAIMER

This publication reflects the opinions of the contributing writers and/or editors, and is based on information available as of the publication date. It may not reflect the programs and policies of the supporting agencies. References to particular products should not be regarded as endorsements.

Printed 2006

Canada

Ontario

OFA Ontario Federation of Agriculture

Acknowledgements

FUNDING

The Best Management Practices program is a partnership of Agriculture and Agri-Food Canada, the Ontario Federation of Agriculture and the Ontario Ministry of Agriculture, Food and Rural Affairs.

Additional funding for this publication has been provided by the Ontario Ministry of Agriculture, Food and Rural Affairs (Nutrient Management Program) and Agriculture and Agri-Food Canada (Canada-Ontario Environmental Farm Plan).

Special thanks go to all those who extended their expertise, resources and time to make this publication possible.

CONTRIBUTORS

Contributing Authors and Task Team Members:

Grand River Conservation Authority: Anne Loeffler

Ministry of the Environment: Harald Schraeder

Ontario Federation of Agriculture: Paul Mistele

Ontario Ministry of Agriculture, Food and Rural Affairs: Jim Arnold, Christine Brown, Harold Cuthbertson, Peter Doris, Hugh Fraser, Don Hilborn, Andrew Jamieson, Sharon Johnston, Jackie McCall, Dale McComb, Kevin McKague, Keith Reid, Arlene Robertson, Donna Speranzini, Bob Stone, Ted Taylor, and Christoph Wand

Ontario Soil and Crop Improvement Association: Andrew Graham, Greg Kitching

Rural Ontario Municipalities Association: Bill Semeniuk

Consultants: Gabrielle Ferguson, Stephen Redmond

Technical Coordinators: Christine Brown, Arlene Robertson, Bob Stone, Ted Taylor

Visual Coordinators: Christine Brown, Ted Taylor

Photographers: Doug Aspinall, Jennfier Birchmore, Christine Brown, Robert Chambers, Jake DeBruyn, Don Hilborn, John Johnson, Kerry Little, Jackie McCall, John Smith, Arlene Robertson, Bob Stone, Ted Taylor, OMAFRA. Also Andrew Graham, Ontario Soil and Crop Improvement Association; Anne Loeffler, Grand River Conservation Authority; Craig Merkley, Upper Thames River Conservation Authority; Kelly Daynard, Ontario Farm Animal Council; Gary Struthers, Ontario Federation of Agriculture

Graphic Artist: David Rouleau, OMAFRA

Watercolour Illustrations and Sketch Artist: Irene Shelton, Winduncroft Studio, Belwood

Editor: Alison Lane

Designer: Marie-Claude Carignan, Neglia Design Inc.