Study of Regional Nutrient Balances in Four Municipalities in Manitoba

Presented to:

Manitoba Livestock Manure Management Initiative Inc.

By:

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EXECUTIVE SUMMARY

A nutrient balance model was developed for the Municipalities of Hanover, La Broquerie, Roland and Sifton in Manitoba. The model tracks and estimates all nutrient (nitrogen and phosphorous) inputs, outputs, and losses to the environment for the agricultural industry. The objectives of this study were to: evaluate the reliability of such a model at both the municipal and farm levels; determine gaps in the knowledge base necessary to implement a nutrient balance model as a planning or regulatory tool; and to provide a preliminary assessment of the nutrient balance in four municipalities that represent a matrix of high and low density crop and livestock production.

Four farms in each of the four municipalities were also used to evaluate the budget model. The purpose of these farm budgets was to further test and evaluate the many estimates of nutrient losses that naturally occur in the nitrogen and phosphorous cycles.

An extensive literature review was conducted to review previous work on nutrient budgets. The nutrient flows in an agricultural ecosystem, including inputs, outputs, transfers and losses from the plant, animal and soil pools were investigated. The literature review focused primarily on the central-northern Great Plains area of North America to ensure that the data would be applicable to soil and climate characteristics of Manitoba.

Considerable data for the municipal model was obtained from the 2001 Census of Agriculture, Manitoba Crop Insurance Corporation records, and a proprietary spatial Grain Flow Model developed by Warkentine and Associates, a local consultant with specialized expertise in the analysis of grain flows in Western Canada. Primary data for the farm-scale budgets was provided by the cooperating farmers. Extensive interviews were also conducted with fertilizer dealers to verify current fertilizer practices by crop producers in Manitoba.

The study found that in areas such as Hanover and La Broquerie, which have a significant intensive livestock industry, the importation of large quantities of nutrients in feed is contributing to a build-up of nutrients in the soil on a regional basis. Manure, however, is not the only source of nutrients that must be considered. The farm case studies confirmed previous studies indicating an excessive buildup of nutrients in soils from the over-application of chemical fertilizers is common.

Notwithstanding the apparent increase in nutrients in these municipalities due to manure, the environmental risks to water resources may not have increased proportionally. The literature review found that the loss of nutrients from fields receiving inorganic fertilizers can be greater than fields receiving manure. Both sources and transport factors have to be considered in assessing transport risk.

Better farm management practices are needed to prevent a build-up of available soil nutrients, regardless of the source of crop nutrients and the size of the farm unit. Regulations to address this issue should be consistent with this principle. Annual soil testing, for example, is practiced by approximately ten percent of producers on approximately one-quarter of their fields in any one year.

The losses of nitrogen and phosphorous to the environment comprise a significant component of the nutrient cycle. Nitrogen losses were equivalent to 35 to 79 percent of outputs, and phosphorous losses were between two and 16 percent of outputs. Some loss of nutrients is a natural part of the nutrient cycle. Further research is necessary to quantify the various losses

under “normal” agricultural practices and to understand the impact of these losses on the ecosystem. Critical levels of soil nitrogen and phosphorous for various soils and topographies must be more clearly defined based on environmental risks.

In order to protect the agricultural (livestock and crops) industry and the environment, Manitoba has to conduct research to develop a comprehensive “P Index” that can be used for thresholds and management strategies on a site-specific basis considering both source and transport factors. The RM of La Broquerie would provide an excellent model to conduct site-specific research for better estimating losses of N and P, and strategies for decreasing these losses. More research is needed to better estimate losses as the combination of these losses account for a large percentage of the total outputs. Nitrogen loss research should focus on leaching and denitrification. Phosphorous research should consider losses to surface waters.

Traditional “conservation” farming practices such as grassed waterways, vegetative filter strips, and riparian areas need to be encouraged to a greater extent, as these practices minimize nutrient losses from agricultural lands.

In areas with a high density of intensive livestock operations, there appears to be an excessive use of chemical fertilizers. These nutrient imbalances can be significantly improved, however, with a reduction in fertilizer use.

Nutrient management will need to address more than just fertilizer use to address nutrient imbalances. More precise livestock feed formulations would help decrease inputs for livestock feed. The use of microbial phytase can reduce phosphorous outputs in manure by 30 to 50 percent. In addition, the use of amino acids has been applied in the Netherlands to reduce manure nitrogen content.

On a farm scale, this study revealed that detailed record keeping is required in addition to better estimates of losses to accurately model nutrient flows. Precise estimates of yields, fertilizer use, and manure application rates would increase the understanding of nutrient flow on crop and livestock farms, and provide for strategies to minimize imbalances between inputs and outputs.

Regulating only nitrogen encourages N volatilization losses from manure. As these losses increase, manure application rates must also increase to meet crop N requirements. This normally results in an over-application of P, however, which accumulates in the soil. Technologies that reduce N volatilization, such as storage covers and manure injection, can significantly reduce the buildup of P in soils.

Animal manure is utilized on approximately five percent of Manitoba’s agricultural land. The study verified the beneficial impact of manure in increasing soil organic matter which improves soil structure, water infiltration and water storage capacity. Increases in soil organic matter or reductions in the rate of loss of soil organic matter were observed in Hanover and La Broquerie, in comparison to Roland and Sifton. Strategies or programs to encourage the distribution and/or application of manure on a greater land base would benefit most soils in Manitoba.

1.0 INTRODUCTION

Nutrient budgets are conducted to improve nutrient use efficiency, estimate regional long-term nutrient (fertilizer) requirements, and to provide estimates of losses from the plant, animal, and/or soil system to the atmosphere and/or hydrosphere. Regions that have intensive livestock operations and that import large quantities of nutrients in the form of feed have the potential to accumulate nutrients in the soil. Losses of nitrogen and phosphorus to surface and groundwater can pose environmental risks. Nitrate-nitrogen is a regulated drinking water contaminant of concern because of blue baby syndrome. Ammonia-nitrogen and phosphorus in surface water present risks of toxicity to fish and accelerated eutrophication (algal blooms).

A reliable model, developed by Frissel (1978), was used to describe the flow of nitrogen and phosphorus on a regional basis. As municipalities are the level of government that govern land use, the model was tested on four municipalities in Manitoba. The four municipalities selected for this project were Hanover, La Broquerie, Roland and Sifton. These municipalities were selected as providing as approximate matrix of intensive livestock and crop production, as depicted below.

Table 1.1 Selected Municipalities and Agricultural Activity.

	Crop Intensity	
Livestock Intensity	HIGH	LOW
HIGH	Hanover	La Broquerie
LOW	Roland	Sifton

Nutrient budgets of four farms from each of these municipalities were also conducted. These farms were representative of the commodity for each region. The purpose of the farm-scale budgets was to test and evaluate the nutrient balance model at this level. The reliability and accuracy of inputs and outputs is different between the municipal and farm levels as the data is from different sources. It was felt that the farm-scale budget would provide a method to verify the model, including factors such as losses.

Losses, such as denitrification and ammonia volatilization, vary with farming practice, environmental conditions, etc. and were estimated from literature values. For the nitrogen cycle, these losses can contribute a significant portion of the total losses. The quality of these literature values utilized in the nutrient model was therefore evaluated.

In order to put the nutrient loading to the environment into perspective, non-agricultural loads were also estimated. These loads are the N and P contained in the discharge from municipal and industrial storages that treat domestic sewage and wastewater from food processing and other industrial activities.

The objectives of this project were to:

- evaluate the reliability of a nutrient balance model at both the municipal and farm levels;
- determine gaps in the knowledge base necessary to implement a nutrient balance model as a planning or regulatory tool; and
- provide a preliminary assessment of the nutrient balance in the four municipalities identified above.

2.0 LITERATURE REVIEW

2.1 Definition of Pools

A nutrient budget developed by Frissel (1978) was used in this study to prepare nutrient budgets on a farm- and municipal scale. This budget was used for several case studies around the world. Nutrient inputs and outputs have been summarized in Table 2.1. Figure 2.1 displays the flow chart of these nutrient transfers for an agricultural ecosystem and the relationship among the three major pools of the ecosystem: plant pool, livestock pool, and soil pool.

2.1.1 Plant Pool

The plant pool includes all parts of the plant. It can be either the crop or that consumed by livestock. In most intensively grazed or cropped systems nutrients spend only a small portion of the overall cycle time in the plant component making it often difficult to define the size of the pool. It is useful to split the plant pool into nutrients in tops (grain and residue) and in roots, as the various plant components usually enter different pools.

2.1.2 Livestock Pool

The livestock pool consists of the nutrients held in animals that consume plant products and manure in storage. Retention of nutrients by the grazing animal is only a very small part of the amount consumed and most ingested nutrients are returned to the soil as excreta. Excreta become part of the soil pool the moment they reach the soil surface, but if they are collected from housed animals and stored they remain part of the livestock pool. Nutrients contained in living animals may increase as the latter mature and are only passed across the system boundary when livestock products are sold.

2.1.3 Total Soil Pool

The soil pool consists of nutrients in organic and mineral components, in the soil solution and on exchange sites; nutrients in the last two categories constitute the available pool. Plants are known to obtain their nutrients from the available soil pool. Thus it is possible to consider one total soil pool or three constituent pools. It is important to consider the organic residue pool as a separate entity because of the very variable and often long residence time of nutrients in this form before becoming mineralized and transferred to the available pool.

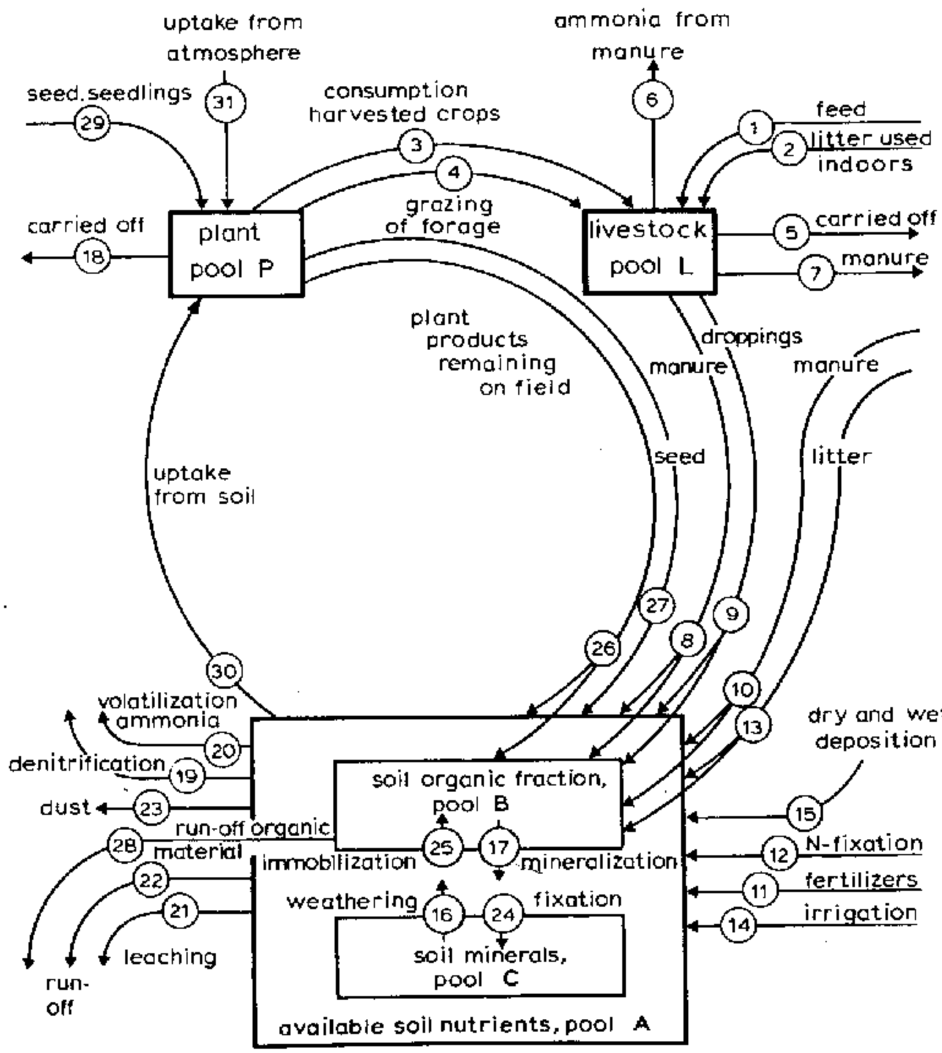

Figure 2.1 Flow chart of the nutrient transfers for an agricultural ecosystem (Frissel, 1978) (refer to Table 2.1).

Table 2.1 Summary of Nutrient Flows

Component	Direction of Flow		Type of Change	Fluxes
Plant Component	**Supplies**	1	Input by seeds or seedlings (29)[1]	→ P[6]
		2	Transfer by net uptake from soil (30)	A[2] → P
		3	Input by uptake from atmosphere (31)	→ P
	Removals	4	Transfer by consumption of harvested crops (3)	P → L[3]
		5	Transfer by grazing of forage (4)	P → L
		6	Output by primary products (18)	P →
		7	Transfer by plant production remaining on field (26)	P → A, P → B[4]
Supplies - Removals		8	Transfer by seed sowing (27)	P → A
Animal Component	**Supplies**	9	Input by feed for livestock (1)	→ L
		10	Input by litter used indoors (2)	→ L
		11	Transfer by consumption of harvested crops (3)	P → L
		12	Transfer by grazing of forage (4)	P → L
	Removals	13	Output by animal products (5)	L →
		14	Output by losses from manure to air before application (6)	L →
		15	Output by manure (7)	L →
		16	Transfer by application of manure and/or waste (8)	L → A, L → B
Supplies - Removals		17	Transfer by droppings on grazed area (9)	L → A, L → B
Soil Component	**Supplies**	18	Transfer by application of manure and/or waste (8)	L → A, L → B
		19	Transfer by droppings on grazed areas (9)	L → A, L → B
		20	Input by application of manure (10)	→ A, → B
		21	Input by fertilizers (11)	→ A
		22	Input by N-fixation (12)	→ A
		23	Input by application of litter, sludge and waste (13)	→ A, → B
		24	Input by irrigation and flooding (14)	→ A
		25	Input by dry and wet deposition (15)	→ A
		26	Transfer by plant products remaining on field (26)	P → A, P → B
		27	Transfer by seed for sowing (27)	P → A
	Removals	28	Output by denitrification (19)	A →
		29	Output by volatilization of ammonia (20)	A →
		30	Output by leaching (21)	A →
		31	Output by run-off of available nutrients (22)	A →
		32	Output by dust (23)	A →
		33	Output by organic matter, removed by run-off (28)	B →
Supplies - Removals		34	Transfer by net uptake from soil by plant (30)	A → P
Available Soil Nutrients	**Supplies**	35	Transfer by application of manure and/or waste (8a)	L → A
		36	Transfer by droppings on grazed areas (9a)	L → A
		37	Input by application of manure (10a)	→ A
		38	Input by fertilizers (11)	→ A
		39	Input by N-fixation (12)	→ A
		40	Input by application of litter, sludge and waste (13a)	→ A
		41	Input by irrigation and flooding (14)	→ A
		42	Input by dry and wet deposition (15)	→ A
		43	Transfer by weathering of soil mineral fraction (16)	C[5] → A
		44	Transfer by mineralizing of soil organic fraction (17)	B → A
		45	Transfer by plant production remaining on field (26a)	P → A
		46	Transfer by seed for sowing (27)	P → A
	Removals	47	Output by denitrification (19)	A →
		48	Output by volatilization of ammonia (20)	A →
		49	Output by leaching (21)	A →
		50	Output by run-off of available nutrients (22)	A →
		51	Output by dust (23)	A →
		52	Transfer by fixation in soil mineral fraction (24)	A → C
		53	Transfer by immobilization in soil organic fraction (25)	A → B
Supplies - Removals		54	Transfer by net uptake by the plant (30)	A → P
Soil Organic Matter	**Supplies**	55	Transfer by application of manure and/or waste (8b)	L → B
		56	Transfer by droppings on grazed areas (9b)	L → B
	Removals	57	Input by application of manure (10b)	→ B
		58	Input by application of litter, sludge and waste (13b)	→ B
		59	Transfer by immobilization in soil organic fraction (25)	A → B
		60	Transfer by plant products remaining on field (26b)	P → B
		61	Transfer by mineralization of soil organic fraction (17)	B → A
Supplies - Removals		62	Output by organic matter, removed by run-off (28)	B →
Soil Minerals	**Supplies**	63	Transfer by fixation in soil mineral fraction (24)	A → C
	Removals	64	Transfer by weathering of soil fraction (16)	C → A

[1]refer to Figure 2.1, [2]available soil nutrient pool, [3]livestock pool, [4]soil organic fraction pool, [5]soil mineral pool, [6]plant pool

2.2 Nutrient Flows for an Agricultural Ecosystem

Table 2.1 can be simplified by removing all repeated inputs, outputs, and transfers. Table 2.2 is a downscaled version of Table 2.1.

Table 2.2 Nutrient Inputs, Outputs, and Transfers

Inputs
By application of litter, sludge, and waste
By application of fertilizers
By application of manure
By litter used indoors
By irrigation and flooding
By feed for livestock
By seeds or seedlings
By dry and wet deposition
By N-fixation
To plant by uptake from atmosphere
Outputs
By primary products
By animal products
By losses from manure to air before application
By manure
By volatilization of ammonia
By denitrification
By leaching
By run-off of available nutrients
By organic matter, removed by run-off
By dust
Transfers
To plant by net uptake from soil
To soil by plant production remaining on the field
By consumption of harvested crops
By grazing forages
To by seed sowing
By application of manure and/or waste to soil
By droppings on grazed areas
By immobilization in soil organic fraction
By mineralizing of soil organic fraction
By fixation in soil mineral fraction
By weathering of soil mineral fraction

2.2.1 Elements

The study focused on the elements nitrogen and phosphorus. The most important characteristics of elements which determine their cycling patterns are solubility in water, volatility, and electrochemical potential or degree of chemical reactivity (Frissel, 1978). Of the two elements, nitrogen, in both its volatile gaseous compounds and highly water-soluble solid compounds, is an extremely dynamic element and has many complicated pathways and transfers. Many studies have been focused on nitrogen cycles in agricultural ecosystems resulting in a large pool of data.

Phosphorus compounds have low solubility in water so only a small portion of the total phosphorus in soils and plants is present in the available soil pool and/or in the plant component (Hayman, 1975). Phosphorus cycles are less prone to nutrient losses than nitrogen cycles. Many studies have focused on the phosphorus cycle because of increased incidences involving eutrophication of water bodies.

2.2.2 Nutrient Inputs

2.2.2.1 Application of Manure, Sludge Litter, and Waste.

Nutrient inputs by the application of manure, sludge, litter, and waste were determined during interviews conducted with the various farmers. Nutrient inputs include any nutrient that is brought into the boundaries of the farm. Manure inputs would be any manure received from outside the farm to be spread onto fields. The rates at which manure and/or fertilizers are applied as well as the history of application are important factors in the determination of nutrient inputs. The nutrient content of the purchased manure can be determined by chemical analysis or estimated using values obtained in the Farm Practice Guidelines for Livestock Producers in Manitoba (Tables 2.3 to 2.6). Typical values for Manitoba can be found in Table 2.7. Values used in Alberta have also been included (Table 2.8).

Nutrients in manure exist in two forms: organic and inorganic. Since only inorganic forms of N and P are available to plants, only a portion of the total nutrients can be utilized in the year of application. The organic form must first be mineralized to an inorganic form, which occurs naturally in the soil. The rate of mineralization is dependent on several factors (see Nutrient Transfers). Mineralization can be advantageous for the crop because not all the manure nutrients are immediately available. When manure is applied at acceptable rates, the slow release of nutrients minimizes possible crop damage and prevents excess nutrient from being lost before the plant uptake occurs.

Availability of manure nutrients to the crop depends on the organic/inorganic composition of manure. Approximately 50 percent of the total phosphorus in manure is in the organic from, with only a small portion available to plants in the year of application. The remaining 50 percent is inorganic P that is assumed available to plants in the first year.

With nitrogen, three different measurements are given in a manure analysis (Manitoba Agriculture, 2001):

1. Total Kjeldahl Nitrogen (TKN) is the total amount of organic and ammonia N in the sample.
2. Ammonia nitrogen (NH_3) is the amount of inorganic N that is readily converted to plant available forms.
3. Organic nitrogen is determined by the difference between total N and ammonia N.

In general, it is expected that mineralization will result in 25-30 percent of the organic nitrogen in manure becoming available to plants in the first year, with much of the remainder becoming available during the next three years at a decreasing rate.

Table 2.3 Typical Swine Manure Nutrient Content[1]

Animal	Weight (kg)	Nutrient Content (kg/day)		
		N	P_2O_5	K_20
Weanling	16	0.007	0.005	0.005
Grower	41	0.019	0.014	0.015
Finisher	79	0.035	0.027	0.028
	102	0.046	0.034	0.036
	113	0.052	0.039	0.040
Gestating Sow	125	0.028	0.022	0.022
	148	0.033	0.026	0.026
	181	0.041	0.032	0.032
Sow & Litter	136	0.083	0.063	0.066
	181	0.111	0.084	0.086
Boar	159	0.035	0.027	0.028

[1]Farm Practices Guidelines for Hog Producers in Manitoba.

Table 2.4 Typical Poultry Manure Nutrient Content[1].

Parameter	Total Nitrogen	Ammonia	Organic Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)	Dry Matter %
Solid manure (lb/ton)	34.4	2.3	32.1	30.4	28.1	60.0
Liquid manure (lb/1000 gal)	53.0	48.0	5.0	11.7	17.2	4.0

[1]Farm Practices Guidelines for Poultry Producers in Manitoba.

Table 2.5 Typical Dairy Manure Nutrient Content[1].

Class of animal	Waste Production (L)	Nutrient Production (kg/day)		
		N	P_2O_5	K_2O
Heifers, 0-3 months	5	0.032	0.015	0.024
Heifers, 4-13 months	14	0.081	0.038	0.063
Heifers, 14-24 months	21	0.173	0.082	0.135
Dairy cows	45	0.270	0.128	0.210

[1]Farm Practices Guidelines for Dairy Producers in Manitoba.

Table 2.6 Typical Beef Cattle Manure Nutrient Content[1].

Class of animal	Weight (kg)	Nutrient Production (kg/day)		
		N	P_2O_5	K_2O
Feeder	250	0.085	0.052	0.063
	350	0.119	0.073	0.089
	450	0.153	0.094	0.114
	550	0.187	0.115	0.139
Cow		0.160	0.124	0.142

[1]Farm Practices Guidelines for Beef Producers in Manitoba.

Table 2.7 Average Nutrient Analysis of Manures (Manitoba Agriculture and Food, 1999).

Type of manure	Number of samples	Total N (available)[1]	Ammonium N	Organic N	P_20_5 (available)	Dry matter content (%)
LIQUID			kg/1000 litres			
Hog	36	2.3 (1.8)	1.6	0.7	1.5 (0.75)	
Dairy	7	2.6 (1.8)	1.4	1.2	1.3 (0.65)	2
SOLID				kg/tonne		
Hog	3	7 (3)	1	6	7.5 (0.38)	35
Poultry	2	17 (6)	1.2	16	15 (7.5)	37
beef	33	4.5 (1.5)	0.15	4.5	2 (1)	30

[1]Amount of available for following crop use; for N = ammonium-N + 30% organic-N, for P_2O_5 = 50% of total P_2O_5

Table 2.8 Nutrient Content of Manures (kg/tonne) used in Alberta[1].

Type of Livestock		Total N % Range	Total N (typical)	Available N[2]	Crop N[3]	Total P
Beef	Feeders Finishers Feeder Calves Cow/Calf Cow/Bulls	0.65-1.25	10	2.6	3.2	2.4
	Paved Feedlot	0.45-0.80	7.0	2.7	2.5	2.5
Dairy	Free Stall	0.35-0.60	4.0	1.8	1.7	0.9
	Tie Stall Loose Housing Replacements Calves	0.45-0.65	5.0	2.1	1.9	0.9
Swine	Liquid	0.20-0.55	3.5	1.6	1.6	1.1
	Solid	0.60-0.90	8.0	3.2	3.1	1.5
Poultry	Layers (solid) belt cage	2.50-3.50	30.1	20.1	18.9	15.4
	Layers (solid) deep pit	2.00-3.00	24.1	16.0	15.1	12.3
	Layers (liquid)	0.50-1.00	6.0	4.0	3.8	2.5
	Broilers Pullets	3.50-4.00	34.1	19.5	18.4	9.5
	Breeders	1.60-2.10	30.1	17.2	16.3	9.5

[1]Agricultural Operation Practices Act, Province of Alberta.
[2]This is the portion of the total nitrogen that is in the mineral (usually ammonium) plant available form at the time of application.
[3]This is an estimate of the available nitrogen plus the portion of the organic nitrogen that is mineralized over the growing season less estimated losses.

2.2.2.2 Commercial Fertilizers

Inputs from commercial fertilizer were determined from interviews with fertilizer dealers, Manitoba Crop Insurance Corporation data, and data from Statistics Canada. On a per acre basis, Manitoba farmers use more fertilizer than in any of the other Prairie Provinces (Johnston and Roberts, 2001). Nitrogen, phosphorus, and potassium are essential to produce good yielding crops. Increasing trends in crop production has closely paralleled consumption of these nutrients during the past few decades (Figures 2.2 and 2.3).

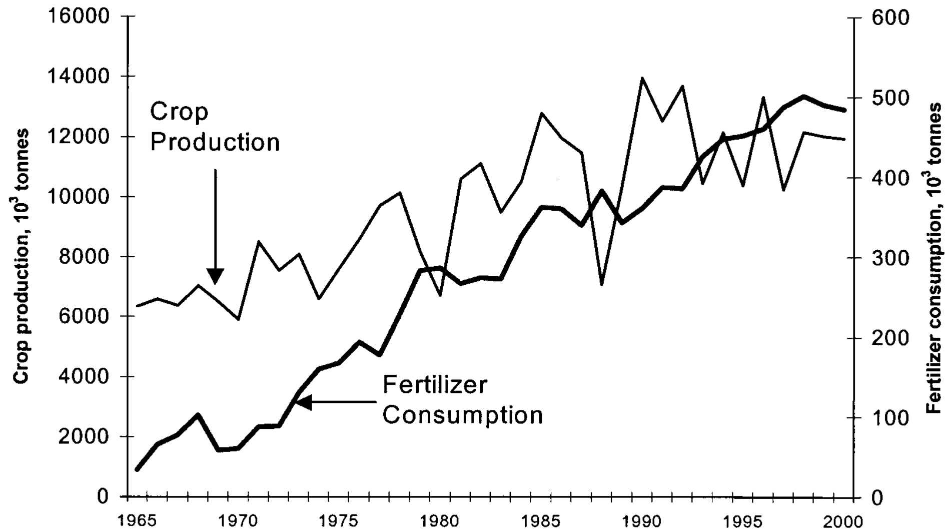

Figure 2.2 Production of major crops and total N, P_2O_5, and K_2O sold in Manitoba between 1965 and 2000 (Statistics Canada Crop production series and Korl and Rattray, 2001).

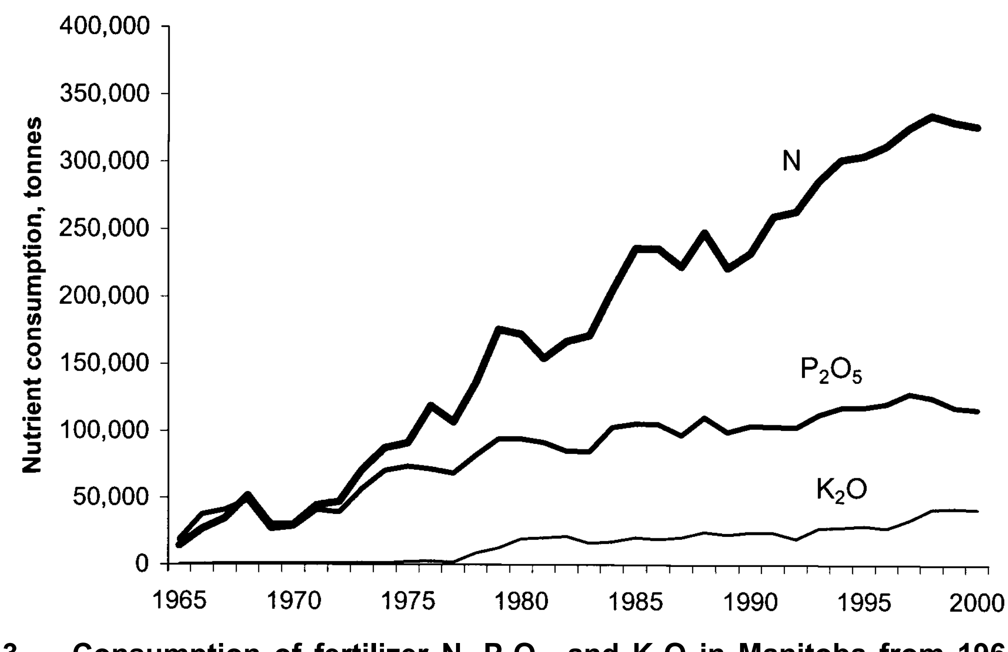

Figure 2.3 Consumption of fertilizer N, P_2O_5, and K_2O in Manitoba from 1965-2000 (Korol and Rattray, 2001).

2.2.2.3 Irrigation and Flooding

Inputs by irrigation and flooding are not an important factor in areas where flooding does not occur and irrigation is not used. In flood prone areas or where irrigation is used, chemical analysis of the water would provide an assessment of the N and P content and loadings. Unless nutrient enriched waters are used, the effect of irrigation on the overall nutrient inputs are minimal and can usually be ignored. A nutrient balance study conducted in Nebraska evaluated nitrates in irrigation water and concluded that their influence on the total nitrogen inputs were negligible (Koelsch and Lesoing, 1999). For the purpose of this study, N and P inputs through irrigation and flooding were ignored.

2.2.2.4 Feed for Livestock

Inputs by feed for livestock are feedstuffs brought into the farm. The amount of feed purchased on a yearly basis will depend on the type and size of livestock operation. The nutrient content of the feed was determined from the feed company, by tabulated chemical analysis, or from the literature. The nutrient content of feed was also determined using values for the nutrient content removed in harvested portion of crops, as tabulated by the Canadian Fertilizer Institute (see Table 2.35). Feed grown on the farm for consumption within the same farm is considered a transfer, and is discussed later in this review.

2.2.2.5 Seeds or Seedlings

The amount and type of seed purchased on a yearly basis will determine the nutrient inputs by seeds or seedlings. The nutrient content of seeds was also determined using the nutrient content removed in the harvested portion of crops as tabulated by the Canadian Fertilizer Institute (see Table 30).

2.2.2.6 Dry and Wet Deposition

Inputs by dry and wet deposition include inputs from lightning, precipitation, and dust. The N deposited on agricultural lands, consisting of NH_4^+, NO_2^-, NO_3^-, and organically bound N, is a common constituent of atmospheric precipitation. Nitrite occurs in trace amounts and is usually ignored or included with nitrate determination. Organically bound N is probably associated with terrestrial dust and does not represent a new addition to landmasses of the world. The amount of N added to the soil each year in atmospheric precipitation is normally too small to be of significance in crop production (Stevenson, 1982). Values of dry and wet deposition determined from nutrient balance studies from the United States can be seen in Table 9. A study conducted by Environment Canada estimated nitrogen inputs by atmospheric deposition for the entire country at 2.5 kg N /ha/year. Environment Canada's Experimental Lakes research station near the Manitoba/Ontario border has been monitoring atmospheric deposition of nitrogen for several years and provided a value of 5 kg N/ha/year (wet and dry deposition) for 2000 (Environment Canada, pers. comm.).

Table 2.9 Nutrient Inputs through Wet and Dry Deposition Used for Various Farm Budgets in the United States (kg/ha/year) (Frissel, 1978).

Type of farm	Location	N	P
Intensive arable, soybean for grain	N.E. Arkansas	10	0.3
Intensive arable, wheat	Central Kansas	6	0.1
Intensive arable, Irish potatoes	Maine	6	0.1
Intensive livestock, grazed bluegrass	Western North Carolina	10	0.3

2.2.2.7 Nitrogen Fixation

Inputs of nitrogen fixation to soils are dependent of the microbial composition of the soil. Organisms that fix molecular N are placed into two groups: (1) the nonsymbiotic fixers, or those that fix molecular N_2 apart from a specific host; and (2) the symbiotic fixers, or those that fix N_2 in association with higher plants (Stevenson, 1982).

2.2.2.7.1 Non-Symbiotic N Fixation

A variety of free-living photosynthetic microorganisms are capable of using molecular N_2 as a source of N. In the United States, it is estimated that no more than 7 kg of N/ha/year are added to soils by the combined activities of nonsymbiotic N_2-fixing microorganisms (Stevenson, 1982). On this basis, the amount of N fixed by nonsymbiotic N_2 fixers under intensive cultivation would appear to be too low to have much practical impact (Stevenson, 1982). Paul *et al*. (1971) found nitrogen fixation in cultivated soils consistently very low, with less than 1 kg N fixed/ha/year.

Rice and Paul (1967) found fixation equivalent to 42 to 52 kg N/ha/year in soils at field capacity and 13 to 150 kg N/ha/year in water logged soils, when the soil was amended with one percent straw or less. Soils amended with 5 to 20 percent straw that were incubated under water logged conditions showed fixation rates of 500 to 1000 kg N/ha/year. They concluded that atmospheric aerobic conditions provided a favourable environment for aerobic organisms, which stimulated decomposition of the straw to provide energy material for anaerobic N fixing organisms flourishing in water, logged soils.

Delwiche and Wijler (1957) failed to detect nitrogen fixation in various non-enriched soils or soils amended with straw, grass, or grass roots. However, they did detect significant N fixation when the soil was enriched with glucose or sucrose (45 kg/ha, 15 cm). In a study conducted by Fehr (1969) using soils from Manitoba, no significant N fixation was found for soils under both aerobic and anaerobic condition without added energy.

2.2.2.7.2 Symbiotic N Fixation

The symbiosis of root nodule bacteria with leguminous plants is still the main source of fixed N for the majority of the world's soils (Havelka *et al*., 1982). Rates of N_2 fixation by nodulated soybeans, cowpeas, clover, alfalfa, and lupines range from 57 to 600 kg/ha per year (Stevenson, 1982). Table 2.10 lists values of nitrogen fixation for clovers and alfalfa grown at grown at sites in Alberta and northeastern British Columbia.

Table 2.10 N_2-fixation by alfalfa, alsike clover and red clover forage (Rice, 1976).

			Kg N fixed/ha		
Soil	Established	Harvested	Alfalfa	Alsike Clover	Red Clover
Hazelmere, CL	1972	1973	1	87	61
Grey Luvisol	1972	1974	1	105	54
	1973	1974	3	137	77
Landry, CL	1972	1973	1	32	15
Black Solod	1972	1974	1	44	24
	1973	1974	1	50	26

Atmospheric plant uptake is relevant to leguminous crops and only involves nitrogen uptake, which directly enters plant matter. The area of leguminous plants grown will have an effect of the amount of nitrogen that is fixed into the soil and directly used by the plants. Table 2.11 lists various legumes with percentages of plant N derived from the atmosphere and N_2 fixed. A nutrient balance study conducted in Pennsylvania used a value of 225 kg/hectare/year for the biological N fixation for alfalfa. Racz (pers. comm.)

using data from Kelner *et al*. (1997) estimated biological N fixation for alfalfa at approximately 220 kg/ha/year for alfalfa yielding 3 tonne/hectare.

Table 2.11 Maximum N_2 fixation in Western Canadian legumes as determined by ^{15}N isotope dilution (Rennie, 1985).

Legume	Cultivar	% Ndfa*	N_2 fixed**	Reference
Glycine max	Chippewa	23-58	10-92	Rennie *et al*. 1978
(soybean)	X005	67	115	Rennie *et al*. 1982
	Various USA	50	100	Ham & Caldwell 1978
Phaseolus vulgaris	Various	38-68	40-125	Rennie & Kemp 1983a
(field bean)	Various USA	30-50	89-90	Westermane *et al*. 1981
	Cascade	56	95	Witty 1983
Lens culinaris	Eston	79-86	188-192	Rennie & Dubetz 1986
(lentil)	Laird	72-86	129-162	Rennie & Dubetz 1986
				Bremer *et al*. 1988
Pisum sativum	Trapper	75-80	169-189	Rennie & Dubetz 1985
(field pea)	Century	77-82	166-178	Rennie & Dubetz 1985
				Bremer *et al*. 1988
Vicia faba	Various	73-92	138-237	Rennie & Dubetz 1986
(faba bean)	Minden UK	64	174	Witty 1983
Medicago sativum (alfalfa)	Various USA	43	138-224	Heichel *et al*. 1983

* % Ndfa = % plant N derived from the atmosphere
** Kg N/ha

2.2.3 Nutrient Outputs

2.2.3.1 Animal and Primary Products and Manure Outputs

The major output of N, P and K from farms occurs when crops are harvested and transported from the farm boundary. In the Prairie Provinces, cereal grains are the most common primary products, as defined in Table 2.1.

The sale of livestock and livestock products are another output of nutrients from the farm. The nitrogen content for milk, slaughter cattle, sheep and hogs, poultry meat and eggs was calculated in a study conducted in 1976 (Table 2.12). Tables 2.13 and 2.14 provide nutrient concentrations for a variety of animal products.

Table 2.12 Nitrogen content of livestock, milk, poultry meat, and eggs in Western Canada (Laverty *et al*. 1976).

	Manitoba	Saskatchewan	Alberta
Total Milk			
Produced Weight Tons	409	376	749
N Content Tons	2.29	2.11	4.19
Slaughter cattle and calves marketed			
Production No.	253.5	407.0	1,044.3
Production Weight Tons	139.4	223.8	574.2
N Content Tons	3.34	5.37	13.78
Slaughter sheep and lambs marketed			
Production No.	17.9	28.7	105.7
Production Weight Tons	0.9	1.4	5.3
N Content Tons	0.02	0.04	0.14
Slaughter Hogs Marketed			
Production No.	1,216	1,070	1,717
Production Weight Tons	133.8	117.7	188.9
N Content Tons	3.21	2.82	4.53
Chicken Fowl and Turkey (eviscerated)			
Produced Weight Tons	31.8	21.3	46.5
N Content Tons	2.80	1.87	4.09
Eggs			
Produced Weight Tons	42.3	18.0	33.2
N Content Tons	3.51	1.49	2.76

Table 2.13 Nitrogen and phosphorus content of milk, eggs, and wool[1].

Animal Products	N factor	P factor
Milk	0.0050[2]	0.001
Eggs	0.0167	0.002
Wool	0.0012	0.0001

[1]Manure Management Stewardship Curriculum 2002.
[2]Assumes 3.2% protein in milk.

Table 2.14 Nutrient concentration in meat animals[1].

Species	N Fraction	P Fraction
Beef cattle (< 1000 lbs)	0.027	0.0073
Beef cattle (> 1000 lbs)	0.024	0.0065
Dairy cattle (replacement herd)	0.029	0.0083
Dairy cattle (milking herd)	0.025	0.0072
Swine (< 100 lbs)	0.025	0.0056
Swine (100 to 300 lbs)	0.024	0.0047
Swine (> 300 lbs)	0.023	0.0047
Poultry	0.028	0.0058
Goat	0.024	0.0060
Sheep	0.025	0.0060

[1]Manure Management Stewardship Curriculum 2002.

2.2.3.2 Losses of Nutrients from Manure to Atmosphere Before Application

Values of nutrient losses from manure to air before application were obtained from the Farm Practices Guidelines for Livestock Producers in Manitoba. The majority of this loss will be due to the volatilization of ammonia, which is dependent on the type of storage used by the livestock operation and the method of field application. Ammonia losses that occur during application will be estimated by volatilization of ammonia, which is discussed later in this review.

Table 2.15 Nitrogen Loss Summary (Percent loss) (Manitoba Agriculture, 1998).

LIQUID SYSTEMS	
Storage[1]	**N loss (%)**
Enclosed	10 – 20
Open	10 – 30
Earthen	30 – 50
Application[2]	
Broadcast	20 – 30
Broadcast & Incorporate within 24 hours	1 – 5
Injection	0 – 2
Irrigation	25 - 35
SOLID SYSTEMS	
Storage[1]	**N loss (%)**
Daily scrape	15 – 35
Manure pack	20 – 40
Open lot	40 – 60
Application[2]	
Broadcast	15 – 30
Broadcast & Incorporate within 24 hours	1 - 5

[1]losses can vary widely depending on climatic and management factors. The values in this table are based on typical practices.
[2]nitrogen losses after fall application will be approximately 20 percent greater than spring or summer applications.

Table 2.16 Nitrogen Storage and Application Factor (Manitoba Agriculture, 1998).

Storage Method	Application Method			
	Injection	Broadcast and Incorporate within 24 hours	Broadcast	Sprinkler
Liquid Manure Systems				
Enclosed	0.83	0.81	0.64	0.60
Open (except earthen)	0.78	0.76	0.60	0.56
Earthen	0.59	0.57	0.45	0.42
Solid Manure Systems				
Daily Scrape		0.71	0.60	
Manure Pack		0.67	0.56	
Open Lot		0.48	0.40	

2.2.3.3 Volatilization of Ammonia

Under suitable conditions, NH_3 can be lost from soils to the atmosphere by volatilization. These losses are significant during the storage and application of animal manure (Table 2.15).

The volatilization of ammonia depends on the following factors (Stevenson, 1982):

1. Losses are greater in calcareous than acidic soils, especially when NH_4^+-containing fertilizers are used. Only slight losses occur in soils of pH 6 to 7, but losses increase markedly as the pH of the soil increases.
2. Losses increase with temperature and they can be appreciable when neutral or alkaline soils containing NH_4^+ near the surface lose water.
3. Losses are greatest in soils of low cation exchange capacity (CEC), such as sands. Clay and humus adsorb NH_4^+ and prevent its volatilization.
4. Losses can be high when nitrogenous organic wastes, such as farmyard manure, are permitted to decompose on the soil surface, even a soil that is acidic, because of the localized increase in pH resulting from NH_4^+ formation.

Table 2.17 gives a summary of results from field studies of NH_3 losses following surface applications of fertilizers. The amounts of NH_3 volatilized are small when N fertilizers are incorporated into the soil, and NH_3 losses are normally low ($\leq$15 percent of applied N) when ammoniacal fertilizers are surface applied to acidic or neutral soils (Nelson, 1982). McGill (1971) treated Almasippi very fine sand (pH 7.7) and a Manitou clay (pH 6.2) with ammonium fertilizers and obtained losses of applied N as NH_3 only when the fertilizer were surface applied and only on the Almasippi sand. The largest loss of N as NH_3 amounted to 7.2 percent of the nitrogen applied. Toews (1971) found the amount of NH_3 volatilized from ammonium fertilizers to increase with amount applied, but the percentage lost of the amount applied decreased with amount applied. Toews studies were conducted in the laboratory at 25°C. Losses over 120 hours varied from 38 to 46 percent of the amount applied. Reduction of the incubation temperature to 15°C resulted in losses of 6.7 percent or less of that applied. At 15°C the greatest loss of N as NH_3 was 6.7 percent of that applied and occurred on a very fine sand surface treated with 150 ppm N as urea. Losses of N as NH_3 generally decreased with decreases in soil pH and increasing soil cation exchange capacity.

Table 2.17 A summary of ammonia losses as measured in the field (Nelson, 1982).

Fertilizer Added					
Type	Amount, Kg N/ha	Soil Texture	pH	% of added N evolved as NH_3	Reference
Urea	50	Loamy sand	7.7	22	Nommik 1966
NH_4NO_3	50			17	
Urea	200	Forest litter	4.3	25	Nommik 1973
$(NH_4)_2SO_4$	280	Clay	7.6	50	Hargrove et al. 1977
$(NH_4)_2SO_4$	280	Clay	7.6	35	Kissel et al. 1977
Urea	500	Forest litter	4.1	3.5	Overrein 1968
Urea	100	Forest litter	-	7	Volk 1970
Urea	100	Grass sod	-	20	
		Fine sandy loam	5.6	40	Volk 1959
		Fine sandy loam	5.8	9	
$(NH_4)_2SO_4$	150	Silt loam	6.3	4	Kresge & Saschel 1960
Urea	150	Silt loam	6.3	19	
$(NH_4)_2SO_4$	100	Clay loam	7.1	3	Ventura & Yoshida 1977
Urea	100			8	
$(NH_4)_2SO_4$	90	Clay	7.0	7	Mikkelsen et al. 1978
Urea	90			6	

Volatilization losses that occur during the application of manure are dependent on the method of application (Table 2.15). Manure application by injection results in the lowest ammonia losses whereas highest losses occur when manure is broadcast without incorporation.

2.2.3.4 Denitrification

Denitrification is the microbial reduction of nitrate (NO^-_3) or nitrite (NO^-_2) to gaseous nitrogen (N_2). Factors controlling denitrification are the presence of organisms capable of denitrification, quality and quantity of substrate, and a supply of electron acceptors (O2, NO^-_3, NO^-_2, N_2O).

2.2.3.4.1 Non-Manured Soils

Rates of denitrification in agricultural soils vary tremendously, ranging from 0 to 70 percent of applied fertilizer N (Rolston *et al.*, 1976, 1979; Craswell, 1978; Kissel & Smith, 1978; Kowalenko, 1978). Many researchers developing N simulation models have assumed that denitrification was negligible or that denitrification loss represented a constant fraction (usually 15 percent) of added fertilizer N (Rolston *et al.*, 1984). In a global review, Smil (1999) suggested that, on average, about 10 to 15 percent of susceptible N might be lost via complete denitrification from agroecosystems (not including N_2O). In another global review, Barton *et al*. (1999) found that, on average, N losses from denitrification in agricultural soils averaged 13 kg N/ha/year (3 kg N/ha/year in unfertilized soils). There are three main factors that affect the rate of denitrification: presence of nitrate, anaerobic environment (saturated with water) and presence of soluble carbon source. The maximum potential for denitrification occurs at complete soil saturation, where all the soil pores are completely filled with water and the diffusion of oxygen is entirely limited by diffusion through soil-water (Rolston *et al*., 1984).

Estimates of denitrification occurring during an entire season were made by Rolston & Broadbent (1977), representing 9 percent loss of an application of 150 Kg N/ha. Aulakh *et al*. (1992) summarized that denitrification losses were usually in the range of 12 to 20 percent of the available N added, however values in excess of 30 percent had also been reported. In an unpublished report, Campbell et al. (1975) studied nitrogen disposition in a wood mountain loam after 35 year cropping to a wheat-fallow rotation. They found that 79 percent of the nitrogen was unaccounted for. Losses may have been due to leaching, volatilization, or denitrification. Denitrification rates have been shown to be higher in soils having a shallow water table because of more rapid organic carbon transport to the saturated zone near the water table (Starr & Gilham, 1993). Denitrification rates were reported to be highest immediately above and below the water table (Trudell *et al*., 1986). Kuenzler and Craig (1986) reported denitrification rates as high as 60 kg/ha per year on some poorly drained Coastal Plain soils.

Meisinger & Randall (1991) *(in Paul & Clark, 1996)*, using data from a number of studies, constructed estimates based on soil organic matter content and drainage characteristics (Table 2.18). In a study by Mills and Zwarich (1981), they concluded that the majority of the nitrogen must have been lost due to denitrification, as little nitrogen was found in groundwater.

Table 2.18 Approximate N Denitrification Estimates for Various Soils[a]

	Soil Drainage Classification				
Soil Organic Matter Content	**Excessively well drained**	**Well drained**	**Moderately well drained**	**Somewhat poorly drained**	**Poorly drained**
<2	2-4	3-9	4-14	6-20	10-30
2-5	3-9	4-16	6-20	10-25	15-45
>5	4-12	6-20	10-25	15-35	25-55

[a]Percentage of inorganic fertilizer plus precipitation N that is denitrified.

2.2.3.4.2 Manured Soils

As the presence of a carbon source will influence the rate of denitrification, manured soils have been shown to have higher rates of denitrification than non-manured soils. Denitrification rates as high as 70 Kg of N/ha per day were measured directly on a plot maintained near saturation which received 34 metric tons/ha of manure for about three weeks (Rolston & Broadbent, 1977). Uncropped plots, with no carbon addition and maintained near saturation had a maximum rate of 2.5 Kg of N/ha per day. Flynn (1992) determined the fate of nitrogen from hog manure on sand and clay textured soils. Values are tabulated in the following table.

Table 2.19 NO_3-N content for Emerson silty clay loam at various times of 1995.

Treatment	June 13	July 11	August 23	September 18
		NO_3-N (Kg/ha to 300 cm)		
Control	146	238	264	143
Rate 1*	306	276	363	228
Rate 2**	229	262	298	112
Irrigated rate 2	-	582	513	45

* rate of 143 Kg N/ha
** rate of 268 Kg N/ha

Table 2.20 NO_3-N content for Poppleton sandy loam at various times of 1995.

Treatment	June 13	July 11	August 23	September 18
		NO_3-N (Kg/ha to 300 cm)		
Control	248	117	254	228
Rate 1*	259	145	264	243
Rate 2**	242	136	274	303
Irrigated rate 2	-	70	282	323

* rate of 143 Kg N/ha
** rate of 268 Kg N/ha

Flynn (1992) found that the plots treated with manure for the Emerson silty clay contained higher amounts of nitrate than plots without manure and that plots treated with high rates of manure contained less nitrate than plots treated with low rate of manure. The lower amounts of nitrate in the plots treated with high rate of manure may have been due to a greater rate of denitrification associated with an increased organic C content. The significant decrease in nitrate for the irrigated plot in September was also probably due to denitrification. For the Poppleton soil, plots treated with higher rates of manure had lower nitrate content for June and July. The increased carbon may again have increased losses via denitrification. Rates of nitrate disappearance for both soils can be found in Table 2.21.

Table 2.21 Nitrate-Nitrogen disappearance rates of the Emerson clay loam and Poppleton sand profiles at 7.5°C and 15°C (Flynn, 1992).

Soil Depth cm	Emerson Clay Loam 7.5°C	15°C	Poppleton Sand 7.5°C	15°C
		$\mu g\ NO_3\text{-}N\ g^{-1} day^{-1}$		
0-15	2.87	6.41	2.56	5.76
15-30	1.49	2.59	0.99	1.51
30-60	1.77	4.08	0.19	0.26
100-120	0.16	0.38	0.09	0.22

Paul *et al*., 1997 found carbon to be the limiting factor controlling the rate of denitrification, as manured plots produced significantly higher rates than fertilized plots. At greater depths denitrification losses were also higher from the manure plots than from the fertilized plots, likely due to downward movement of carbon in the manured plots (Paul *et al*., 1997). They stated that because of higher rates of denitrification in manured soils, nitrate leaching to drainage systems might be lower than from commercially fertilized soils because of higher denitrification losses in the subsoil following manure application. Ploughing in of the manure is often done to minimize ammonia volatilization losses but this action may stimulate denitrification losses. In a study comparing spring versus fall manure application, Paul *et al*. (1997) found a greater denitrification rate when manure was applied in the spring. They stated that higher temperatures encountered in the spring resulted in a greater rate of denitrification than fall manure application. Fall application of manure resulted in a higher concentration of nitrate leaching than denitrification.

In a laboratory study conducted by Mills and Zwarich (1982), it was found that soil samples amended with sewage sludge, from all depths (0-185 cm) were capable of reducing nitrate, but the intensity decreased rapidly with depth (Figure 2.4). The denitrification intensity was integrated over the soil profile, resulting in a maximum denitrification capacity of approximately 150 kg/ha/day. This figure would be reduced considerably if seasonal soil temperatures were used but would still be much larger than the actual denitrification losses observed in the field, as the denitrification intensity is based upon flooded conditions. However, it illustrates the great potential for denitrification that exists in the soil.

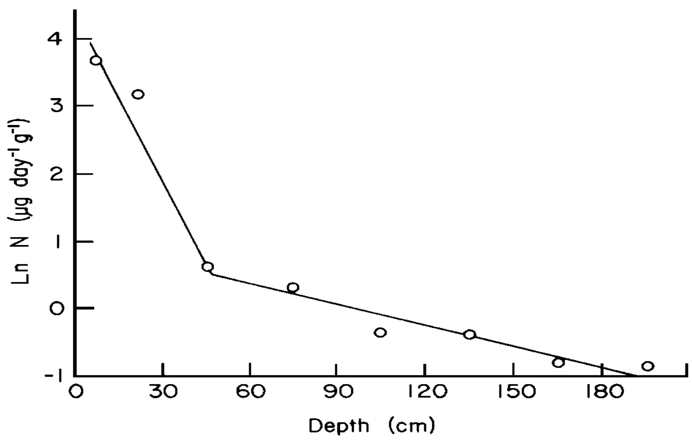

Figure 2.4. Denitrification Intensity as Related to Soil Depth.

2.2.3.5 Leaching

2.2.3.5.1 Phosphorus

Phosphorus is a relatively immobile nutrient in the soil. It is strongly adsorbed on the surface of soil particles and forms stable, insoluble compounds with ordinary soil constituents like calcium and magnesium. In Manitoba, agricultural soils are predominantly calcareous. The calcium and magnesium cations in the soil react with P rendering it immobile. However, P may be one of the more important elements limiting long-term manure application (McCalla, 1974; Miller, 1992) because after P saturates the fixing capacity of the soil, it can become mobile and contaminate ground and surface waters. In most cases, P leaching is insignificant due to fixation by P-deficient subsoil, but in soils with a low fixation capacity (i.e. sands, acid organic or peat soils) that have high volumes of water percolation, measurable quantities of P can migrate through the soil profile (Johnston and Roberts, 2001).

Some studies have found that the movement of P from manure in soil may be more rapid than from inorganic sources, as organic P compounds have been found to have greater penetrability than inorganic P compounds (Hannapel *et al.*, 1964). Campbell and Racz (1975) also found that organic and inorganic P applied as manure extract moved faster than an equivalent concentration of inorganic P. Although manure P moves faster than inorganic P, they did find lower concentrations of organic P in soil samples from under feedlots, caused by a greater mineralization of organic P under manured than non-manured conditions. The mineralization of P will be discussed in more detail in the Transfers section. Campbell and Racz concluded that the movement of P and the contamination of the groundwater at the feedlot were probably minimal as the soil at groundwater depth was capable of fixing large quantities of both inorganic and organic P.

2.2.3.5.2 Nitrogen

a. Non-Manured Soils

Leaching is often the most important pathway of N loss from field soils other than that accounted for in plant uptake (Allison, 1973). Losses occur mainly as nitrate, a highly soluble compound that is closely related to water movement. Major losses of N occur when two prerequisites are met: (1) soil nitrate content is high, and (2) water movement is large. Nitrate movement is seasonal, mainly occurring in spring and fall when soils are saturated and plant growth is slow, and also after heavy rainfalls during the growing season (Hedlin, 1971; Campbell *et al*., 1973, 1984; Chang and Cho, 1974).

The accumulation of nitrate in soil increases the risk of nitrate loss to groundwater. Management strategies such as rate, timing and formulation of fertilizer N application will limit the amount of nitrate in the soil and reduce potential losses. Previous crop also influences the amount of residual nitrate remaining in the soil (Table 2.22). Residual nitrate will be particularly high following drought years where adverse plant growing conditions limit nitrogen uptake by the crop. Water movement through the soil profile is dependent on many factors such as soil texture and structure, precipitation, and anthropogenic factors such as cultivation and cropping practices.

Over-fertilization over time can lead to the accumulation of nitrate-nitrogen in the soil profile. Table 2.23 indicates the impact of this for several different crops. Nitrogen fertilizers added in excess of uptake on a continual basis results in nitrogen accumulation. With time and various rainfall events, the N moves below the rooting zone of annual crops. The fate of this N is largely unknown, but in coarse textured soils leaching to groundwater is highly probable.

The prudent use of fertilizers does not lead to nitrate accumulation. Studies by Racz (Table 2.24) showed that nitrate-nitrogen did not accumulate in soils when nitrogen fertilizer rates were maintained at or even somewhat above amounts needed to obtain near-maximum yields.

Table 2.22 Residual soil NO_3^--N levels in Manitoba as affected by previous crop and growing conditions.

Previous Crop	Soil nitrate-N lb/ac in 0-24 depth	
	Drought years (1988-89)	1990-1998
Wheat	102	50
Barley	76	43
Canola	79	38
Flax	88	39
Corn	107	64
Potatoes	94	71

*Data form AGVISE Laboratories. (Source: www.gov.mb.ca/agriculture/soilwater/soilfert/)

Globally, rates of leaching loss from farmlands may average about 10 to 15 kg N/ha/year (Smil, 1999). On the prairies of western Canada, where most fertilizer is applied, leaching may be minimal because potential evapotranspiration exceeds precipitation by a wide margin (Fairchild *et al*., 2000). It has been estimated that 10 to 15 percent of the available N in soil can be leached in a year (Akinremi, pers. comm.). The application of recommended rates of nitrogen and annual soil testing will help to reduce over-application of N fertilizers. Manitoba Agriculture recommends N fertilizer application rates for a range of crops based on soil nitrate testing and agronomic N response trials. The rate of N fertilizer application is dependent upon the expected yield goal for crop. Unrealistic high yield goals will result in excessively high rates of fertilizer N, increasing the risk of nitrate contamination of groundwater, and reducing the profitability of the enterprise (Burton and Ryan, 2000).

Other nitrogen sources such as previous legume crops or animal manure applications should be considered in estimating fertilizer N requirements. Excessive rates of N application can occur if these other sources of N are ignored and will increase the potential for nitrate loss from the root zone.

Table 2.23 Effect of Different Cropping Practices on Soil Nitrate Content (McGill and Ewanek, unpublished data).

	Soil Nitrate Content (kg/ha) (Average of Fields Sampled)						
Depth (m)	**Annual Crops***	**Potatoes**	**Vegetables**	**Annual Crops – Manure**	**Summer Fallow – Manure**	**Grass**	**ZeroTill**
0-0 – 0.3	47	92	86	137	225	9	64
0.3 – 0.6	55	59	79	92	103	1	46
0.6 – 0.9	74	68	159	101	84	1	53
0.9 – 1.2	64	73	116	81	82	4	44
1.2 – 1.5	39	53	112	57	39	2	36
1.5 – 1.8	30	45	115	45	29	2	30
1.8 – 2.1	16	40	94	31	43	3	27
2.1 – 2.4	10	32	87	18	31	1	16
2.4 – 2.7	16	26	81	22	22	2	18
2.7 – 3.0	13	22	64	17	31	2	11
3.0 – 3.3	8	16	60	16	19	1	9
3.3 – 3.6	10	17	50	24	19	1	7
No. of Fields	11	19	6	16	3	9	7
TOTAL							
Low	28	101	502	69	409	0	139
High	801	1063	1589	1752	994	97	889
Average	329	543	1204	645	727	29	360

Table 2.24 Effect of Various Rates of Nitrogen Fertilizer on Nitrate Nitrogen Content of Fallow and Non-Fallow Land after Cropping to Barley (Kg/ha) (Racz, G.J., unpublished data).

	Fertilizer Treatment at Seeding (kg/ha)						
	9	**34**	**67**	**100**	**134**	**202**	**269**
				Fallow Sites			
Yield	3612	3890	4052	4278	4327	4278	4176
NO_3-N (0-60 cm)	21	27	35	46	65	109	153
NO_3-N (0-120 cm)	18	18	16	18	20	21	31
				Stubble Sites			
Yield	1988	2585	3226	3588	3700	4000	3912
NO_3-N (0-60 cm)	19	17	22	35	34	83	150
NO_3-N (0-120 cm)	13	13	15	19	19	30	43

In a review of N losses in western Canada, Rennie *et al*. (1976) concluded that summer fallow practices have allowed deeper penetration of precipitation than was possible before cultivation, resulting in the movement of nitrate into lower horizons. Mills and Zwarich (1981) found no significant amounts of nitrate in groundwater after the application of digested sludge in three fields. The average application rates to the three fields were 210, 360, and 470 dry tonnes per hectare, respectively. Based upon typical total nitrogen content of 2.6 percent, the nitrogen application rates ranged from 5,500 to 12,000 kg N/ha. The fields were left fallow for one summer after application and then were cropped to cereals, usually wheat. The concentration of nitrogen found in two fields can be found in Tables 2.25 and 2.26. The concentration of nitrate decreased steadily with time at a rate of 260 to 1600 kg N/ha/year depending on the rate of sludge applied. They concluded that much of the nitrate moving through the soil profile was lost via denitrification.

Table 2.25 Summary of nitrate-nitrogen distribution (Mills and Zwarich, 1981).

Date	Crop	Kg/ha in 0-60 cm	Kg/ha below 60 cm	Depth of NO_3 maximum (cm)
3 Aug. 1973	Fallow	2500	36	0-15
19 Sept. 1974	Stubble	1300	105	0-15
16 Sept. 1975	Stubble	1500	350	30-45
12 May 1976	Stubble	1500	260	30-45
9 Nov. 1976	Stubble	1000	790	45-60
22 June 1977	Wheat	160	1000	60-90
10 Nov. 1977	Stubble	220	1060	60-90
8 June 1978	Wheat	170	850	60-90
17 July 1979	Fallow	500	800	60-90

Table 2.26 Summary of nitrate-nitrogen distribution (Mills and Zwarich, 1981).

Date	Crop	Kg/ha in 0-60 cm	Kg/ha below 60 cm	Depth of NO_3 maximum (cm)
19 Sept. 1974	Fallow	6400	-	0-15
23 Apr. 1975	Fallow	5900	90	0-15
16 Sept. 1975	Stubble	3400	220	15-30
12 May 1976	Fallow	2700	310	15-30
24 Aug. 1976	Fallow	2100	150	15-45
22 June 1977	Wheat	2200	820	30-60
10 Nov. 1977	Stubble	700	1820	60-90
20 June 1978	Fallow	350	900	60-90
18 July 1979	Wheat	1200	1500	60-90

In Manitoba, Michalya (1959) found up to 225 kg of nitrate per hectare between the 1.2 and 1.8 m depths of plots in a crop-fallow rotation. The amounts of nitrate-nitrogen in the sub-soil decreased as the frequency of fallow in the crop rotation decreased. Of interest was the finding that little or no nitrate-nitrogen is present in the sub-soil where continuous cropping had been followed. Studies on a cultivated Almasippi fine sand loam and Red River clay showed little or no accumulation of nitrate down to a depth of three to four metres.

Tillage practices affect the potential for nitrate leaching by altering the rate of residue breakdown and by disruption soil macropores. Crop residues left on the soil surface reflect light and insulate soil, reducing soil temperature and loss of water through evaporation (Bond and Willis, 1969). A favourable environment is created for microbial activity in soils that normally tend to be warm and dry (Power *et al*., 1986). Carbon residues also serve as a carbon and nitrogen substrate, which is decomposed through microbial activity. The incorporation of residues in the soil associated with conventional tillage practices increases the rate of breakdown relative to conservation tillage practices where residues accumulate on the soil surface (Burton and Ryan, 2000). Rapid decomposition results in the mineralization of nitrogen, increasing nitrate availability to the plant and the potential for nitrate loss from the profile. Nitrate will accumulate in the soil and may be leached from the profile if crop residue breakdown occurs when there is no actively growing crop. Conservation tillage practices may reduce leaching of nitrate over the fall to spring period following the incorporation of crop residues under conventional tillage, by retaining nitrogen in crop residues. In addition to incorporating crop residues, tillage disrupts the continuous pores and channels which form as a result of plant root growth and earthworm activity (Burton and Ryan, 2000). These channels may be the major pathways of water percolation in fine-textured soils (Edwards *et al*., 1989). Disruption of the continuous channels will slow water movement through the soil and increase the availability of N to the processes occurring at or near the surface (plant uptake, denitrification). Thus tillage may decrease the rate of water movement through fine-textured soils.

Irrigation generally occurs on coarse-textured soils that have good drainage and are prone to leaching losses. This area creates conditions with a high risk of groundwater contamination compared to dryland farming. As irrigation increases yield potential, increased nitrogen levels are required to meet the potential. Excessive inputs of either nitrogen or water, particularly on irrigated coarse-textured soils, substantially increase the potential for nitrogen leaching. Under irrigation, profitable crop production and groundwater protection have been demonstrated when existing guidelines for nitrogen application and water management are followed. Montgomery *et al*. (1990) found that high corn yields could be produced with carefully managed irrigation and nitrogen fertilizer inputs in North Dakota. Lower irrigation inputs with well managed scheduling resulted in significant reductions in nitrate leaching (Table 2.27).

Table 2.27 Nitrogen and irrigation amounts applied to lysimeters and the resulting nitrate-nitrogen losses and final grain yields averaged over three years (Montgomery *et al*., 1990).

Nitrogen Rating	Nitrogen Fertilizer (lbs/ac)	Relative Irrigation Amount	Irrigation Amount (inches)	Nitrate Leaching Losses (lb/ac)	Final Grain Yield (lb/ac)
Low	83	Low	7.6	17.6	200
Low	83	High	10.0	30.2	195
High	127	Low	7.6	19.7	215
High	127	High	10.0	30.1	215

The application of fertilizers containing a high percentage of ammoniacal producing forms on nitrogen (urea, UAN, anhydrous ammonia) delays the formation of nitrate and thus reduces the potential for loss during this period. Similarly, the use of nitrification inhibitors in combination with ammoniacal N sources delays nitrification (conversion of ammonium to nitrate) and reduces the potential for nitrate loss (Burton and Ryan, 2000). Nitrification is also delayed by banding of urea and ammonium-based fertilizers, which reduces the potential for nitrate loss (Burton and Ryan, 2000). Delaying nitrogen fertilizer application results in increased availability to the plant and reduces potential for nitrate leaching (Appleton and Helms, 1925). Split applications of N fertilizer are also a commonly used approach to increase fertilizer use efficiency (Burton and Ryan, 2000). Racz et al. (1994) examined the influence of fertilization rates of the preceding potato crop on fall residual soil nitrogen content. The use split applications of N, controlled release N products or nitrification inhibitors all decreased the amount of nitrate remaining in the soil during the fall period.

Many people assume that additions of fertilizer N will increase nitrate leaching. Research data does not readily support this assumption. In fact, soil samples from rotational experiments in Saskatchewan show that N fertilizer applied at recommended rates may increase water and N use by crop, thereby reducing the amount of nitrate available for leaching in fertilized systems (Campbell *et al*., 1987, 1992c). Other studies in the Prairie Provinces have measured little movement of fertilizer N below the crop rooting zone (Baker, 1987; Heaney *et al*., 1988; Swerhone *et al*., 1989; Mahli *et al*., 1991a). Table 2.28 summarizes N leaching losses used for various nutrient budgets conducted in the United States for various cropping systems

Table 2.28 Nitrogen leaching losses for various agricultural operations in the United States (Frissel, 1978).

Type of farm	Location	N leaching losses (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	15
Intensive arable, soybeans for grain	Northeast Arkansas	10
Intensive arable, wheat	Central Kansas	4
Intensive arable, irish potatoes	Maine	64

b. Manured Soils

Some studies have shown that manured soils result in less nitrate leaching to groundwater than soils fertilized with inorganic fertilizers when applied at recommended rates (Kimble *et al*., 1972; Burton 1994b; Xie and MacKenzie 1986; Jokela, 1992). Some manured soils had less nitrate in their profiles and thus less leaching because of the increased denitrification potential of the soils (Kimble *et al*., 1972; Paul and Beauchamp, 1996). Straw and other organic material in manure has the potential to immobilize inorganic nitrogen and/or enhance denitrification (Burton, 1994b). Meek *et al*. (1974) concluded that frequent irrigations with high manure rates on a fine textured soil resulted in reducing conditions and the movement of soluble organic carbon to the lower profile, resulting in the loss of nitrate from the soil profile as a result of increased denitrification. While many studies have reported increased nitrate near the soil surface, conditions favourable to denitrification lower in the profile may result in the disappearance of this nitrate. In a comparison study between spring versus fall cattle manure application, Paul and Zebarth (1997) reported greater nitrate leaching when manure was applied in the fall. They concluded that fall application of manure resulted in lower rates of denitrification, allowing more nitrate to leach in the soil profile. Spring applied manure had higher rates of denitrification resulting in a lower concentration of nitrate in soils.

2.2.3.6 Run-off of Available Nutrients and Organic Matter

2.2.3.6.1 Phosphorus

Concerns regarding the removal of phosphorus in watershed runoff have increased over the years. Research has indicated phosphorus as the limiting factor for the acceleration of eutrophication of receiving fresh waters. Lake water concentrations of P above 0.02 ppm generally accelerate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 ppm). While P fertilizers are not lost in significant amounts by leaching mechanisms, the movement of P to water-bodies through surface runoff and erosion may present a problem.

The effects of phosphorus on groundwater are not generally a major concern, unless groundwater discharges directly to a surface waterbody (Golder Associates, 1999). The low solubility of phosphorus compounds in water limits phosphorus inputs to groundwater. Phosphorus also has limited mobility in groundwater due to the tendency of phosphorus compounds to sorb to soils. There is a lack of proven human health problems associated with phosphorus compounds, and the effects of P contamination of groundwater are minimal (Golder Associates, 1999).

The loss of P in agricultural runoff occurs in sediment-bound and dissolved forms. Sediment P includes P associated with soil particles and organic material eroded during flow events and constitutes 60 to 90 percent of P transported in surface runoff from most cultivated land (Sharpley *et al.*, 1992). Surface runoff from grass or noncultivated soils carries little sediment and is therefore generally dominated by dissolved P. The dissolved form comes from the release of P from soil and plant material. This release occurs when rainfall or irrigation water interacts with a thin layer of surface soil and plant material before leaving the field as surface runoff (Sharpley, 1985). Most dissolved P is immediately available for biological uptake. Sediment P is not readily available, but it can be a long-term source P for aquatic biota (Sharpley, 1993; Elkholm, 1994).

Many studies conclude that dissolved P loss in surface runoff is dependent on the P content of surface soil. In a review of several studies, Sharpley *et al*. (1996) found that the relationship between surface runoff P and soil P varies with management and is linked to soil P concentration. Heckrath et al. (1995) found that soil test P (Olsen P) greater than 60 ppm in the plow layer of a silt loam caused the dissolved P concentration in tile drainage water to increase dramatically (from 0.15 to 2.75 mg/L). Export coefficients of 0.7 kg P/ha during a low runoff year and 0.26 to 3.37 kg P/ha during a high runoff year were calculated for a small drainage basin located in the Red Deer River tributary in Alberta (Golder Associates, 1999).

In a study of nutrient runoff from fertilized and unfertilized fields in Saskatchewan, nutrient loss was increased by summer fallow rotation, but was barely affected by fertilizer applications (Nicholaichuk and Read, 1978). In Manitoba, a field runoff study at three sites with various rotational treatments determined that nutrient runoff was generally twice as high under summer fallow as wheat, and negligible amounts of nutrients were measured in runoff from alfalfa plots (Table 2.29). Nutrient budgets for various farm operations in the United States estimated P loss through runoff to be between 3 to 5 kg P/hectare per year (Frissel, 1978) (Table 2.30). No estimates were provided in these budgets for P losses by organic matter removed by runoff.

Table 2.29 Average N and P losses in runoff at three sites in Manitoba over a three-year period, as affected by cropping treatment. Plots were placed on 9 percent slopes, and data was collected only during the growing season (Hargrave and Shaykewich, 1991).

	Nutrient loss under different crop treatments			
Nutrient	**Alfalfa**	**Fallow**	**Wheat**	**Corn**
		(kg/ha)		
		Site 1 (sandy loam)		
N	0.43	6.3	3.6	7.9
P	0.33	7.3	7.9	9.4
		Site 2 (clay)		
N	0.91	176.0	91.0	156.0
P	0.3	69.0	33.0	66.0
		Site 3 (sandy clay loam)		
N	0.27	8.1	2.0	12.3
P	0.06	5.8	1.1	3.8

Table 2.30 Phosphorus losses through run-off for various farm operations in the United States (Frissel, 1978).

Type of farm	Location	P run-off losses (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	3
Intensive arable, soybeans for grain	Northeast Arkansas	3
Intensive arable, wheat	Central Kansas	3
Intensive arable, irish potatoes	Maine	5
Intensive livestock, grazed bluegrass	Western N. Carolina	0.2

Balancing farm P input and output in animal operations can be improved by manipulating dietary P intake by animals as feed inputs are often the major cause of P surplus (USDA, 1999). The amount of phosphorus excreted by pigs can be significantly decreased by the inclusion of microbial phytase in the diet, which releases some of the phosphorus bound phytic acid, making it available to the pig (Jongloed *et al*., 1992; Cromwell *et al*., 1993). Thus, the amount of inorganic phosphorus that must be added to meet the available phosphorus requirements is reduced, and phosphorus excretion can be decreased by 30 to 50 percent (Bridges *et al*., 1995; Carter *et al*., 1996). The magnitude of the response to microbial phytase has been shown to be influenced by the source of phosphorus, dietary level of available phosphorus, the amount of phytase added (Lei *et al*., 1994; Kornegay, 1996). Frequent soil testing can indicate the need for P fertilization on soils, those where moderate manure application may be made, and fields where no manure applications need to be made for crop yield response.

In a study in which cattle manure (wet) was applied every year at a rate of 30 Mg/ha/year for 16 years, Whalen and Chang (2001) reported a total of 1.6 Mg P/ha from manure was added to the soil and 1.2 Mg P/ha accumulated in the soil to a 150 cm depth. A study conducted by Qian *et al*. (2002) applied cattle manure (dry) every year for 5 years at three rates, 10 (low), 20 (medium), and 40 (high) Mg/ha, which is equal to 23, 47, and 93 Mg/ha (wet weight). Their results showed that at the low rate, a cumulative input of 155 kg P over 5 years did not lead to measurable increases in total P in the soil. With the medium rate, the cumulative input increased to 311 kg P, and thus an apparent increase in total P of 72 kg P/ha was observed in the surface soil. When cattle manure increased to 40 Mg/ha (dry wt), the cumulative P input reached 622 kg and led to an apparent 99 kg P/ha increase in total P in the 0-15 cm depth. Qian *et al*. (2002) concluded that although the proportion of manure P accumulated in the soil was much smaller that that observed after 16 years of consecutive use of cattle manure (Whalen and Chang, 2001), the trend of accumulating P in soil in their study was not insignificant as the application was over only 5 years. Both of these studies concluded that long-term application of cattle manure can lead to the accumulation of P, including labile P in the soil. Risk from high labile P would mainly be associated with transfer by erosion and runoff.

In the same study, Qian *et al*. (2002) found that soil total P was not significantly increased by the addition of urea or by the addition of swine manure. The reason for limited response of total P concentration to swine manure addition was because of the low amount of P added as swine manure, as shown in Table 31. In general, urea addition caused a slight depletion in labile P possibly due to plant uptake and removal, and a slight increase in recalcitrant P fractions. The effect of swine manure addition was similar to urea, with a possible trend of a decrease in soil P availability, if swine manure with large N:P ratio continued to be used repeatedly. Therefore, the addition of swine manure of the composition used in their study is not a concern for potential P pollution. In fact, the decreasing trend in total P implies that additional P fertilizers may be needed with continued use of swine manure in the following years.

A study by Edwards and Daniel (1994) showed that P runoff losses from fields applied with inorganic fertilizers were higher (2.68 kg/ha) than from fields applied with poultry manure (1.98 kg/ha). Another study found that the application of fertilizer resulted in the largest amount of P transfer under crops of corn and forages (Simard *et al*., 2001). Spring application of manure under corn resulted in the smallest transfer amongst manure treatments whereas fall application was close to values of mineral fertilizer treatments. Under forage, P loads associated with the manure treatments were comparable between fall and spring applications whereas split application resulted in a smaller transfer.

Table 2.31 Rates of total N and P (kg/ha) added as liquid swine manure and solid cattle manure at the low, medium, and high application rates from 1997 to 2001 growing seasons (Qian *et al*., 2002).

Treatment	1997		1998		1999		2000		2001	
	N	P	N	P	N	P	N	P	N	P
Swine manure										
Low	74	7	51	3	97	7	94	3	87	3
Medium	147	14	102	6	195	14	188	6	174	6
High	295	28	204	12	390	28	376	12	348	12
N:P	11		17		14		31		29	
Cattle manure										
Low	121	39	104	30	69	20	113	37	76	29
Medium	242	79	208	60	138	40	226	74	152	58
High	484	158	416	120	276	80	452	148	304	116
N:P	3.1		3.5		3.5		3.1		2.6	

2.2.3.6.2 Nitrogen

The total N in sediment is composed of ammonium, nitrate, nitrite, and organic fractions, with the organic fractions being the most prevalent. Factors that affect total N losses in sediment are seasonal variations, soil texture, fertility, rainfall distribution and intensity, and management practices. Rainfall can influence N losses in two ways:

1) an increase in rainfall results in an increase in nitrogen runoff losses, and

2) increased duration of rainfall produces an increase in runoff resulting in a decrease in concentration of nitrogen in the sediment fraction of runoff (Chichester, 1977).

Total N losses will vary among land uses. Bruwell *et al*. (1975) on a loam textured soil in Minnesota receiving similar N fertilizer rates, found loss of sediment bound N accounted for 96 percent of average total N losses from fallow, continuous corn, and rotation corn treatments. Average annual total N losses due to rainfall through a six year study period were highest from fallow plots (4.2 kg N/ha) followed by continuous corn (21.21 kg N/ha), rotation corn (13.12 kg N/ha), rotation oats (1.91 kg N/ha) and alfalfa plots (0.16 kg N/ha). Estimated annual total N losses in sediment ranged from 0.09 kg N/ha from alfalfa plots to 147 kg N/ha from fallow plots for the entire 10-year study.

Zero tillage can appreciably reduce the N losses in sediment from row crops. N losses from no-till soy bean treatments were 1/10 of losses from conventional till soybeans in Mississippi (McDowell and McGregor, 1980).

In Saskatchewan, where runoff is caused primarily by snowmelt, the annual N loss from summer fallow in solution and sediment was estimated at 10 kg of N/ha (Nicholaichuk and Read, 1978). The average loss of unincorporated fall-applied N fertilizer by surface runoff was about 4 percent; loss of N from unfertilized fallow was 2.8 kg/ha. Runoff losses of soluble N are generally low, except when high rates of N fertilizer are surface applied just before high rainfall events. In many cases, the gain of N in the precipitation is greater than the amounts of soluble N in the runoff (Legg and Meisinger, 1982). A study conducted for a typical nutrient budget for dryland wheat production in central Kansas where precipitation limits yield potential, used a value of 1 kg/hectare per year for N loss by runoff. Export coefficients of 0.1 to 0.6 kg N/ha during a low runoff year and 2 to 14 kg N/ha during a high runoff year were calculated for a small drainage basin located in the Red Deer River tributary in Alberta (Golder Associates, 1999).

Nutrient budgets for various farm operations in the United States estimated N loss through runoff to be between 1 to 12 kg N/hectare per year (Frissel, 1978) (Table 2.32). Losses of N by organic matter removed by run-off were also estimated (Table 2.33).

Table 2.32 Available nitrogen losses through run-off for various farm operations in the United States (Frissel, 1978).

Type of farm	Location	N run-off losses (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	6
Intensive arable, soybeans for grain	Northeast Arkansas	3
Intensive arable, wheat	Central Kansas	1
Intensive arable, irish potatoes	Maine	5
Intensive livestock, grazed bluegrass	Western N. Carolina	12

Table 2.33 Nitrogen losses by organic matter removed through run-off for various farm operations in the United States (Frissel, 1978).

Type of farm	Location	N losses (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	10
Intensive arable, soybeans for grain	Northeast Arkansas	13
Intensive arable, wheat	Central Kansas	4
Intensive arable, irish potatoes	Maine	10
Intensive livestock, grazed bluegrass	Western N. Carolina	2

Losses of all nutrients can be minimized by good management, such as balancing fertilizer applications with crop nutrient requirements, timely incorporation of fertilizers, and adequate plant cover to improve fertilizer efficiency and minimize erosion and runoff losses.

2.2.3.7 Output by Dust

No values could be found for estimating output of nutrients by dust. Therefore, nutrient losses by dust were ignored for this study.

2.2.4 Nutrient Transfers

Nutrient transfers refer to the nutrients that are produced and do not leave the farm boundary. For example, manure produced by a farm and spread on fields within the farm would be considered a transfer of nutrients from the animal pool to the soil pool.

2.2.4.1 Nutrient Uptake and Removal by Field Crops, and Plant Production remaining on the field.

Transfers involving nutrient uptake by plants from the soil can be determined using information provided by the Canadian Fertilizer Institute (CFI). Values from the CFI indicate total nutrient uptake from each crop type for N,P, and K as well as the nutrient removed in the harvested portion of each crop. Values of nutrients remaining in the soil (transferred to soil by plant production) can therefore be easily determined. All nutrients transferred to soil by plant production will be considered a supply through the soil organic matter component. Table 2.35 lists the nutrient uptake and removal for various crops commonly grown in Western Canada.

The Farm Practices Guide for Hog Producers in Manitoba provide soil and crop nitrogen utilization for forages and annual crops. These values are used to determine the required land base for manure spreading by providing factors for spring and fall manure application. These values can be found in the Table 2.34.

Table 2.34 Soil and Crop Nitrogen Utilization[1]

Type of Crop	Nitrogen Utilization (lb/ac)
Forages, Established Stands:	
Alfalfa	225
Grasses	150
Grass – Alfalfa Mixture	175
Annual Crop	
Medium to Heavy soils	80
Light Soils	60

[1]Based upon annual N application.

Table 2.35 Average Nutrient Uptake & Removal by Field Crops (pounds/acre) (Canadian Fertilizer Institute, 1998).

Grains		N	*N (lbs/bu)*	P_2O_5	*P_2O_5 (lbs/bu)*
Spring Wheat	Uptake[1]	85	*2.13*	32	*0.8*
40 bu/A (2890 kg/ha)	Removal[2]	60	*1.50*	24	*0.6*
Winter Wheat	Uptake	68	*1.36*	31	*0.62*
50 bu/A (3360 kg/ha)	Removal	52	*1.04*	26	*0.52*
Barley	Uptake	111	*1.39*	45	*0.56*
80 bu/A (4300 kg/ha)	Removal	78	*0.98*	34	*0.43*
Oats	Uptake	107	*1.07*	41	*0.41*
100 bu/A (3584 kg/ha)	Removal	62	*0.62*	26	*0.26*
Rye	Uptake	92	*1.67*	46	*0.84*
55 bu/A (3450 kg/ha)	Removal	59	*1.07*	25	*0.45*
Corn	Uptake	153	*1.53*	63	*0.63*
100 bu/A (6272 kg/ha)	Removal	94	*0.94*	44	*0.44*
Oilseeds					
Canola	Uptake	112	*3.20*	52	*1.49*
35 bu/A (1960 kg/ha)	Removal	68	*1.94*	37	*1.06*
Flax	Uptake	69	*2.88*	20	*0.83*
24 bu/A (1492 kg/ha)	Removal	51	*2.13*	16	*0.67*
Sunflower	Uptake	75	*1.50*	26	*0.52*
50 bu/A (2240 kg/ha)	Removal	54	*1.08*	16	*0.32*
Pulse Crops[3]					
Peas	Uptake	153	*3.06*	42	*0.84*
50 bu/A (3360 kg/ha)	Removal	117	*2.34*	35	*0.70*
Lentils	Uptake	92	*3.07*	25	*0.83*
30 bu/A (2016 kg/ha)	Removal	61	*2.03*	19	*0.63*
Fababeans	Uptake	286	*5.72*	99	*0.98*
50 bu/A (3808 kg/ha)	Removal	171	*3.42*	61	*1.22*
Soybean	Uptake	260	*5.20*	45	*0.90*
50 bu/A	Removal	194	*3.88*	42	*0.84*
Other Crops		**N**	***N (lbs/tons)***	**P_2O_5**	***P_2O_5 (lbs/tons)***
Sugarbeets	Uptake	211	*9.59*	68	*3.09*
22 tons/A (49.4 tonnes/ha)	Removal	88	*4.00*	41	*1.86*
Potatoes	Uptake	228	*11.4*	67	*3.35*
20 tons/A (44.8 tonnes/ha)	Removal	128	*6.40*	37	*1.85*
Forages – Dry Matter					
Alfalfa 5 tons/A (11.2 tonnes/ha)	Removal	290	*58*	69	*13.8*
Clover 4 tons/A (9 tonnes/ha)	Removal	216	*54*	56	*14*
Grass 3 tons/A (6.7 tonnes/ha)	Removal	103	*34.33*	30	*10*
Barley Silage 4.5 tons/A (10 tonnes/ha)	Removal	155	*34.44*	53	*11.78*
Corn Silage 5 tons/A (11.2 tonnes/ha)	Removal	156	*31.2*	64	*12.8*

[1]Total nutrient taken up by the crop
[2]Nutrient removed in harvested portion of the crop
[3]Legumes such as pulse crops, alfalfa, clover, etc. obtain most of their N from the air if root nodule bacteria are actively fixing N. Legumes should be inoculated prior to seeding.

2.2.4.2 Consumption of Harvested Crops and By Grazing Forages

The transfer of nutrients by consumption of harvested crops is from all feed produced by the farm and consumed within the farm boundaries. The nutrient content of the harvested crops fed to livestock can be determined using information provided by the Canadian Fertilizer Institute (CFI). The nutrient content of forages can also be determined using information provided by CFI.

2.2.4.3 Seed Sowing

Any seed produced by the farm and used within the farm boundaries is a transfer of nutrients. Any seed sowing was determined during interviews with the various producers. The nutrient content of the seed can be determined using information provided by CFI.

2.2.4.4 Application of Manure and/or Waste and by Droppings on Grazed Areas.

Any manure produced by the farm and used within the farm boundaries is a transfer of nutrients. Producers with livestock operations provided information regarding their yearly inventories from which nutrient manure production was estimated. Total manure production was calculated using daily nitrogen and phosphorus production from the Manitoba Guidelines for hog, beef, poultry, and dairy producers. This calculation covered off droppings on grazed area. Losses of nitrogen by volatilization would be higher for grazing animals and was estimated accordingly.

The inorganic nitrogen portion of manure was considered a transfer to the available soil nutrients whereas the organic nitrogen portion was considered a transfer to the soil organic matter. If no laboratory manure analysis data was provided estimates of the inorganic and organic content of manure was accomplished using Manitoba Guidelines for livestock producers, Alberta's Agricultural Operation Practices, and other resources. As approximately 50 percent of the total phosphorus in manure is in the inorganic form, this portion will be considered a transfer to the available soil nutrients. The remaining 50 percent of total phosphorus in the organic form will be a transfer to the soil organic matter.

2.2.4.5 Fixation in Soil Mineral Fraction

2.2.4.5.1 Nitrogen

Nitrogen in the form of NH_4^+ can be fixed in the soil organic fraction. N fixation can influence NH_4^+ transformations by reducing ammonia losses and nitrification rates. In a ^{15}N-balance study, Kowalenko (1978) found that 59 percent of the $^{15}NH_4^+$-N applied to the 0-15 cm layer of an ammonium-fixing clay loam soil was immediately fixed by clay minerals. About 66 percent of the recently fixed $^{15}NH_4^+$ was released within 86 days, but the remainder was held tightly throughout a 17 month period. There is some evidence that the quantities of fixed NH_4^+ do not change greatly over long periods of time when concurrent changes in soil organic N occurs (Jaiyebo and Boulding, 1967; Keeney and Bremmer, 1964).

No value was found to estimate the transfer of nitrogen by fixation into the soil mineral fraction. This transfer is expected to be insignificant on a farm and municipal basis and was therefore ignored for this study.

2.2.4.5.2 Phosphorus

The process of P fixation in soil is a continuous sequence of precipitation and adsorption reactions, which follows two distinct patterns: an initial rapid reaction period followed by a much slower process (Doyle and Cowell, 1993). The nature, amount, and rate at which P precipitation reactions occur are dependent on the nature of the soil. Some major factors, which influence P retention in soils, include oxide content, type and amount of clay, $CaCO_3$ content, soil pH, soil cation exchange capacity, soil temperature, and type and amount of organic matter. There have been numerous investigations of the reactions of soil and fertilizer P with aluminosilicate clay minerals (MacKenzie and Campbell, 1962). Generally, the rate of P fixation by these minerals is directly related to temperature and P concentration, and inversely related to pH (Soper and Racz, 1980).

Racz (pers. comm.) estimated that 60 and 80 percent of the available P in manure would be fixed in coarse textured soil medium to fine textured soils, respectively.

2.2.4.6 Immobilization and Mineralization

2.2.4.6.1 Phosphorus

Campbell and Racz (1975) conducted laboratory experiments to examine the mineralization of P in soil beneath a cattle feedlot. Rates of mineralization were greater for manured than non-manured samples. Mineralization of organic P in laboratory experiments was greater in flooded manured soils than in manured soils maintained at field capacity. They also found that the organic P concentration in the surface soil beneath the feedlot was much lower than the organic P concentration in surface soil of an adjacent nonmanured field. The authors concluded that the anaerobic condition existing in soil beneath the feedlot was likely conducive to a rapid mineralization and depletion of organic P in the soil.

Estimates of phosphorous mineralization and immobilization were developed for nutrient budgets for various agricultural systems in the United States. These estimates can be seen in Table 2.36.

Table 2.36 Phosphorus mineralization estimates for various nutrient budgets in the United States (Frissel, 1978).

Type of farm	Location	P mineralization (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	7
Intensive arable, soybeans for grain	Northeast Arkansas	3
Intensive arable, wheat	Central Kansas	3
Intensive arable, irish potatoes	Maine	6
Intensive livestock, grazed bluegrass	Western N. Carolina	6

In general, the inorganic P content of plant tissue varies from 0.1 to 0.5 percent. Mineralization of P will be favoured if the C:P ratio is lower than 200:1; immobilization of P will be favoured if the C:P ratio is higher than 300:1. This ratio represents the C:P ratio of the entire tissue. If the actual substrate is examined, the critical ratio at which mineralization occurs is closer to 50-70:1.

Racz (pers. comm.) using values from the literature and through consultation with many plant and soil scientists estimated that P mineralization and immobilization would be approximately one eighth the value of N mineralization. It was assumed that this estimation would be consistent for all crop and soil types.

2.2.4.6.2 Nitrogen

Nitrogen mineralization and immobilization are mutually dependent and operate simultaneously in the soil. The amount of available mineral N (usually as ammonium and nitrate) found in soil will largely depend on the difference between rates of immobilization and mineralization (Killham, 1994). The mineralization-immobilization turnover is a continual process whereby an increase or decrease in the inorganic N content of the soil is simply an indication of net mineralization or net immobilization.

Straw management practices can influence the mineralization-immobilization process. The carbon and nitrogen ratio of organic material applied to the soil can play an important role in determining which process will dominate (Figure 2.5). Research has shown that the application of plant residues with high C/N ratio (eg. wheat straw) to the soil will induce rapid immobilization of inorganic N (Stojanovic and Broadbent, 1956). Work conducted by Tomar and Soper (1987) showed that when immature barley and fababeans, with C/N contents of 21:1 and 22:1 respectively, were applied to the soil, net mineralization of N occurred. Further research has elucidated that the N content for the mineralization-immobilization equilibrium is about 1.5 percent (Grenier and Soper, 1987). That is, for organic material containing N contents greater than 1.5 percent, net mineralization is expected to occur and for organic residues containing less than 1.5 percent, net immobilization is expected.

Tillage practices can affect the mineralization-immobilization turnover. In an undisturbed system, most N released during oxidation of organic matter is immobilized in the cells of microorganisms, taken up by plants, or conserved as surface litter (Doran and Smith, 1987). Tillage alters this steady state by increasing soil aeration, removing the insulating effect on evaporation and temperature, and distributing the organic substrate throughout the plow later (Van Veen and Paul, 1981). This increases the accessibility of the organic substrate to decomposition by soil microorganisms, and thus increases mineralization (Elliot, 1986).

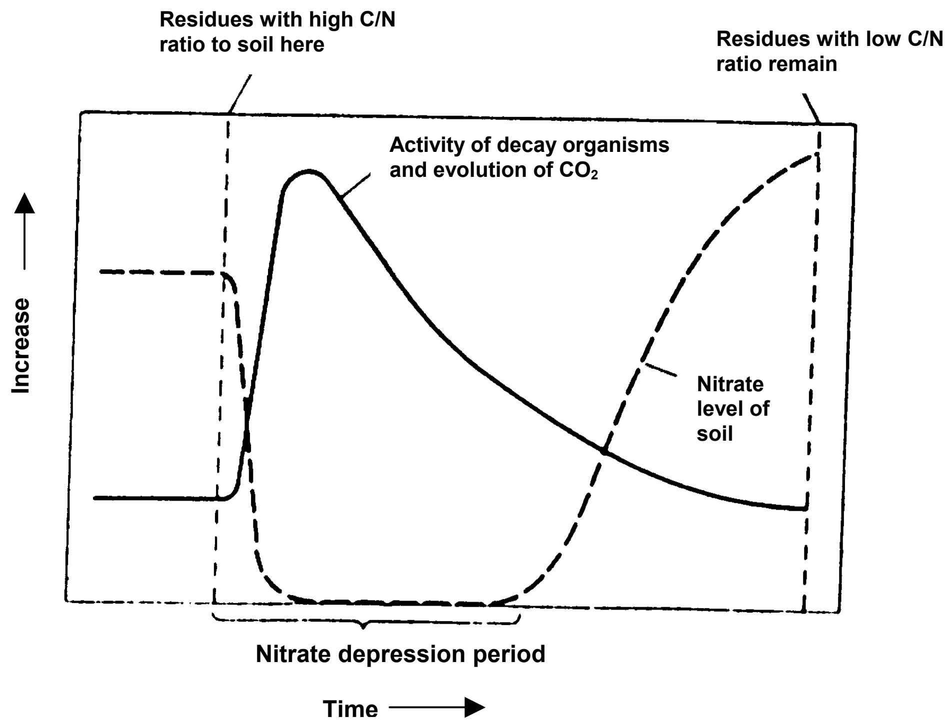

Figure 2.5 Mineralization-Immobilization Turnover

Researchers have found that immobilization of ammonium N is greater than immobilization of nitrate N. Although immobilization is responsible for removing considerable amounts of inorganic N from the available form (20-60 percent), little can be done to decrease the amount of immobilization. Immobilization can perhaps be decreased by band placement of N as opposed to broadcast application, which makes the N more available to crops. Table 2.37 summarises nitrate nitrogen content of a soil profile.

Table 2.37 Nitrate-Nitrogen Content of Soil Profile to a Depth of 121 cm (kg/ha) (Principles & Practices of Commercial Farming, 1977).

Stage	1st crop after summer fallow	2nd crop after summer fallow	3rd crop after summer fallow	Summer fallow year
At seeding time	112	58	40	40
Mineralized during growing season	45	45	45	50
Crop uses	-120	-84	-66	-
Harvest time	37	19	19	90
Mineralized during fall and spring	21	21	21	22

In a Manitoba study, Campbell *et al*. (1988) found that net N mineralization for summer fallowed soils varied from 64-86 kg N/ha and 36-52 kg N/ha for cropped dryland. Broesma *et al*. (1988) found net N mineralization (kg/ha) from a Grey Luvisol for the following diverse cropping systems in the Peace River region of Alberta: continuous barley, 92 kg N/ha; barley-forage, 32 kg N/ha; continuous bromegrass, 105 kg N/ha; forage-barley, 122 kg N/ha; and continuous legume, 207 kg N/ha.

Racz (pers. comm.) estimated mineralization and immobilization values for alfalfa and grasses and for cultivated land one and four years after alfalfa or grass from a review of the literature (Kelner *et al*., 1997) and personal communication with Vessey and Entz. Estimates of mineralization and immobilization were based on yields of alfalfa and grasses and are summarized in the following table.

Table 2.38 Estimations of mineralization and immobilization rates for alfalfa and grass systems (Racz, pers. comm.)

	Alfalfa*	Grasses*
Mineralization during growing period	120	75
Mineralization years 1 to 4 after alfalfa breaking	165	100
Mineralization years 5 to 8 after alfalfa breaking	100	85
Immobilization	165	90

*assuming a yield of 3 tonne/hectare

Estimates of nitrogen mineralization and immobilization were developed for nutrient budgets for various agricultural systems in the United States. These estimates can be seen in Table 2.39.

Table 2.39 Mineralization and Immobilization estimates for various nutrient budgets in the United States (Frissel, 1978).

Type of farm	Location	N immobilization (kg/ha/year)	N mineralization (kg/ha/year)
Intensive arable, corn for grain	Northern Indiana	10	50
Intensive arable, soybeans for grain	Northeast Arkansas	-	15
Intensive arable, wheat	Central Kansas	4	28
Intensive arable, irish potatoes	Maine	10	65
Intensive livestock, grazed bluegrass	Western N. Carolina	13	48

When manure is applied to soils, the availability of the organic N fraction of manure in the first year after application could range from 0-64 percent, depending on the source, N content, stage of decomposition and various factors involved in the management of manure. Shepers and Mosier (1991) listed decay constants for various manures (Table 40). Flowers and Arnold (1983) and Bernal and Kirchmann (1992) found that the addition of pig slurries to soil in the laboratory resulted in a temporary immobilization of N followed by a slow linear mineralization. Kirchmann and Lundvall (1993) concluded that fatty acids in slurry act as an easily decomposable carbon source for microorganisms which in turn caused immobilization of N. Bernal and Roig (1993b) reported that the mineralization of the organic nitrogen in pig slurry is very slow and that much of the N is not available to the crop in the first year after application, although it contributes to the soil N pool. Lindeman and Cardenas (1984) and Paul and Beauchamp (1996) concluded that the net mineralization rates of sludge or manure amended soils did not increase the NH_4^+ and NO_3^- content of soils because N mineralization was offset by N losses via denitrification in manure soils.

Table 2.40 Nitrogen content and annual decay constants for various animal manures (Shepers and Mosier, 1991).

Manure Source	N in manure %	Decay Constants Year after application 1	2	3	4
			yr^{-1}		
Poultry					
Hens,fresh	4.5	0.9	0.10	0.05	0.05
Broilers and turkeys,fresh	3.8	0.75	0.05	0.05	0.05
Broilers and turkeys, aged covered	<3.0	0.60	0.05	0.05	0.04
Swine	2.8	0.90	0.04	0.02	0.02
Dairy					
Fresh	3.5	0.50	0.15	0.05	0.05
Liquid manure tank	<3.0	0.42	0.12	0.06	0.04
Anaerobic lagoon	2.0	0.30	0.08	0.07	0.05
Beef feeders					
Fresh	3.5	0.75	0.15	0.10	0.05
Stockpiled or dry	2.5	0.40	0.25	0.06	0.03

2.2.4.7 Weathering of Soil Mineral Fraction

No information could be found to determine the transfer of nitrogen, phosphorus, and potassium to the nutrient pool by weathering of soil mineral fraction. This contribution on a yearly basis would be extremely minimal and was ignored for this study.

2.3 Nutrient Budgets

This section will summarise various nutrient budgets conducted in Manitoba and various locations throughout North America. The basis for each nutrient budget was an attempt to determine the environmental impact of various agricultural operations on surface and groundwater. This section will also provide information on the estimates used to calculate the various nutrient flow components for each nutrient budget.

2.3.1 Assiniboine Delta Aquifer (Burton and Ryan, 2000)

An assessment of the environmental fate of nitrate in the Assiniboine Delta Aquifer was conducted to determine the effect of agriculture on nitrate loading. The Assiniboine Delta is an unconfined sand aquifer and is considered environmentally sensitive due to the predominance of well-drained coarse-textured surface deposits that lie above the aquifer. An estimate of the potential for nitrate loading to groundwater, based on speculative assumptions resulted in an estimated average nitrate concentration of recharge water of 44 mg N/L. This represents 4,130 tonnes of nitrate leached per year at a rate of 9.5 kg nitrate/ha when averaged over the area of the aquifer under agricultural production. No single land use resulted in a dominant contribution to nitrate loss. The purpose of the study was to emphasize the need to improve our estimates of the relative contribution of various land used to nitrate loading to groundwater.

The following assumptions for nitrate loading were made by Burton and Ryan to calculate the average nitrate concentration of recharge water.

Grain crop production

- For grain crops, it was assumed that annual nitrate loss is equivalent of 10 percent of the maximum recommended rate of nitrogen fertilizer.

- The maximum recommended fertilization rates of nitrogen fertilizer application for this region is 100 kg N/ha (Manitoba Agriculture).
- Therefore, for a recommended range of 100 kg N/ha, the estimated annual nitrate loss would be 10 kg N/ha.

Potato production

- For potatoes, it was assumed that annual nitrate loss is equivalent to 30 percent of the maximum recommended rate of nitrogen fertilizer.
- The maximum recommended fertilization rate was 146 kg N/ha (Manitoba Agriculture).
- Therefore, the estimated amount of nitrate loss would be 44 kg N/ha.

Legume crop production

- Nitrate leaching losses from growing alfalfa stands were assumed to be zero.
- Alfalfa plowdown was assumed to have nitrate leaching losses of 50 kg N/ha and one-quarter of the total area in alfalfa would be plowed down each year.
- Therefore, the area in alfalfa was assumed to have an annual nitrate loss rate of 12.5 kg N/ha.

Intensive livestock operations

- Nitrate leaching from intensive livestock operations, where manure is primarily collected and distributed a few times during the year was assumed 25 percent of the total N in the manure would be leached to groundwater.
- For the more extensive operations where the animals spend at least a portion of the time grazing in pastures, total loss to groundwater was assumed to be 10 percent of total estimated manure production.

Summerfallow

- It is assumed that the area that Statistics Canada reports as fallow is indeed summerfallow.
- A conservative estimate of 25 kg N/ha was used as the annual estimate of nitrate loading to groundwater for land under summerfallow.

Recharge Rate

- An average annual recharge rate of 2.2 cm/year was used.

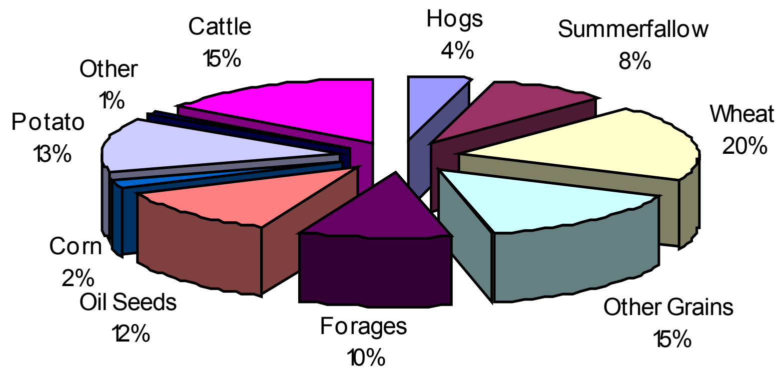

Figure 2.6 Relative contribution of various land uses to nitrate loading of the Assiniboine Delta Aquifer. Estimated are based on land uses as reported in the 1996 Statistics Canada Agricultural Census and typical rate of nitrogen use and nitrate leaching as reported in literature sources.

Burton and Ryan (2000) stated that the estimates used in their exercise were relatively conservative. High rates of nitrogen fertilization of vegetable crops, high protein wheat or the use of high rates of animal manure could significantly increase this estimate. Improved N budgets for the major crops grown in the region coupled with actual measures of leaching loss is needed to assess the validity of this estimate.

They concluded that based on their estimate the risk of nitrate contamination of the Assiniboine Delta as a consequence of agricultural activities is high, due to the characteristics of the aquifer and its geological setting, and to the suitability of the land for agricultural development and use. Expansion of intensive crop production, irrigation, and livestock would further increase this risk. They also concluded that field-scale groundwater studies are needed to provide a clear assessment of the risk of nitrate leaching. Most studies have been conducted in the root zone and the extrapolation of these studies into the groundwater zone to predict groundwater impacts is problematic at best.

2.3.2 High Soil Phosphorus – Is it a problem in Manitoba? (Johnston and Roberts, 2001).

A phosphorus budget was prepared to assess the P status of Manitoba soils. The Potash & Phosphate Institute surveyed commercial laboratories for soil samples collected in Manitoba from the fall of 2000 to spring of 2001. They reported that 73 percent of the approximately 15,000 fields sampled tested medium or less in plant available P. An earlier survey conducted in 1996-7 reported that 80 percent of Manitoba soils were testing medium or lower. Soils testing medium or lower will usually respond to P fertilization resulting in crop yield increases.

Figure 2.7 shows a simple P balance from 1965 through 2000. This balance was updated from an earlier budget calculated from estimates of the P_2O_5 removed in grain and hay in major crops based on typical nutrient concentrations. Phosphate removed in harvested crops has been fairly well matched to P added in fertilizer up to the early 1990's. In recent years, P application with fertilizer has exceeded crop removal.

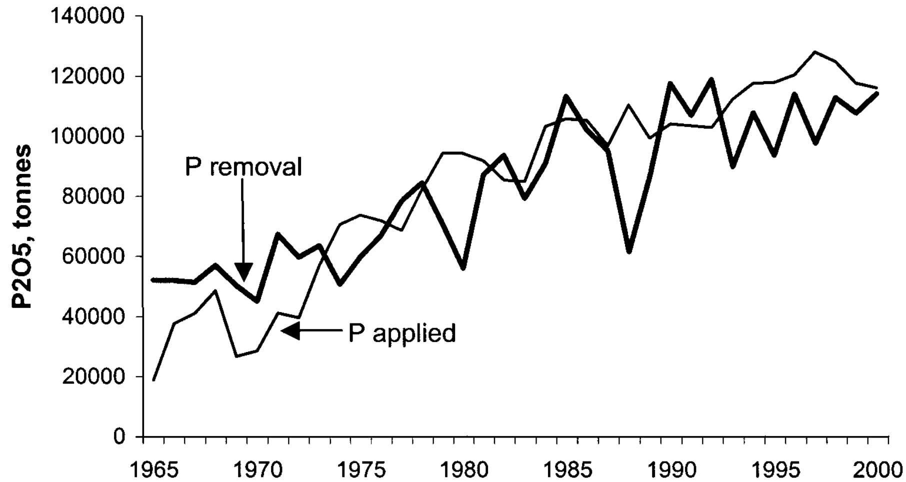

Figure 2.7 Crop removal and replacement of fertilizer P_2O_5 in Manitoba from 1965 to 2000. Assumes that P_2O_5 is removed in harvested grain and hay, and straw is returned to the soil (Adapted form Doyle and Cowell, 1993).

A more thorough P budget was created that included P removal by crops and P additions from both fertilizer and manure using the twelve Agricultural Regions of Manitoba. Specifics on the process of determining these values for the production year 2000 are as follows:

- Crop and livestock data was obtained from the 2000 issue of the Manitoba Agriculture Yearbook (Manitoba Agriculture, 2001).
- Production data for the grain corn, all wheat, barley, oats, rye, canola, flax, potatoes, alfalfa, and tame hay were used as they represent in excess of 95 percent of total crop production in the province. The distribution of alfalfa, grain corn, and potato were determined using the 1996 Census of Agriculture (Statistics Canada, 1997) and consultation with Manitoba Agriculture.
- The values for nutrient removal per unit of yield were obtained for the Potash and Phosphate Institute website. (http://www.ppi-ppic.org/ppiweb/canadaw.nsf)
- Fertilizer P consumption for 2000 was obtained from the Agriculture and Agri-Food Canada statistics branch. Given that only provincial totals for fertilizer nutrients are available, they assumed the use of P was proportional to the purchase of total fertlizer and lime in each Agricultural Region, as detailed in the 1996 Census of Agriculture (Statistics Canada, 1997).
- Manure nutrients were determined using livestock numbers from the Manitoba Agriculture Yearbook, and recoverable manure nutrient calculated using the method described by the USDA-NRCS (Kellogg *et al*., 2000).
- It is important to clarify that these are estimates, and by no means should be considered a definitive balance, given the nature of the available data and the assumptions made.

Fertilizer P_2O_5 met or exceeded crop removal in eight of the twelve regions, with the remaining four showing a negative balance (Table 2.41). When manure is included in the budget, Manitoba's twelve agricultural regions had an average P_2O_5 surplus of only 5.6 lbs per acre. The surplus/deficit was almost balanced in seven regions and exceeded 5 lb P_2O_5/acre in five regions. These regions with a high surplus have large livestock populations and/or potato production.

Table 2.41 Estimated P_2O_5 in crop removal, fertilizer application, and recoverable manure nutrients on a per acre basis for the 12 Agricultural Regions of Manitoba in 2000.

Agricultural Region	Crop Removal	Fertilizer Applied	Recoverable Manure	Balance
	lb P_2O_5/acre			
1	18.1	15.7	1.2	-1.2
2	18.4	20.3	2.0	3.9
3	17.3	20.1	1.4	4.1
4	14.5	14.9	1.1	1.5
5	24.7	20.3	1.0	-3.4
6	17.6	17.0	1.3	0.8
7	18.5	27.7	3.2	12.3
8	21.6	26.2	3.2	7.8
9	15.1	26.9	11.5	23.3
10	13.1	14.5	6.2	7.7
11	16.8	23.1	4.4	10.7
12	17.0	13.0	4.0	0
Average	17.7	20.0	3.4	5.6

They concluded that surplus P from manure is a serious problem in a few small areas of Manitoba. Farmers, crop advisors, input and service suppliers, researchers, government agencies and industry will need to work together to solve potential problems related to nutrient management. It is important that localized, or site-specific approaches be employed to prevent unnecessary constraints on productivity. The majority of Manitoba's agricultural soils are low in P and require fertilization. Where possible, and where economically feasible, the nutrients in manure should be utilized. However, care must be taken to ensure manure nutrients are utilized in ways that will maximize crop production and minimize impact of the environment.

2.3.3 Nutrient Management Planning of Four Virginia Livestock Farms (VanDyke et al., 1999)

In the Chesapeake Bay, nutrient enrichment is one of three major waste quality problems. In the 1987 Chesapeake Bay Agreement, Virginia, Pennsylvania, Maryland, and the District of Columbia committed to a 40 percent reduction in the controllable loads of nitrogen and phosphorus entering the Chesapeake Bay. Controllable loads include both point and nonpoint sources of pollution, with nonpoint sources encompassing pollutants from urban runoff, septic tanks, lawns, and agriculture. Because agriculture accounts for an estimated 39 percent of the nitrogen and 49 percent of the phosphorus entering the Bay, water quality protection programs in the Bay watershed have focused on agriculture.

Nutrient management planning was developed in the area with the goal to minimise adverse effects, primarily upon water quality, and avoid unnecessary nutrient applications above the point where long-run net farm financial returns are optimised.

Four livestock operations were analysed: two dairy (110 and 160 dairy cows), one swine (4,950 hogs), and one poultry (680,000 broilers). The following tables summarises changes that were implemented for each operation under the nutrient management plan, the mineral nitrogen and phosphorus available per hectare before and after the plan, the average annual per hectare nitrogen and phosphorus losses before and after the plan, and the economic impact of nutrient management. No estimates of nutrient losses from denitrification, leaching, or runoff were done for this study.

Table 2.42 Changes in Management Practices with Implementation of Nutrient Management Plans.

Farm	Changes in nutrient management practices with plan
100 dairy	Credit manure for nutrient Reduce nitrogen fertilizer Split nitrogen applications Nitrate quick test
160 dairy	Install manure pit Apply manure to more land Credit manure for nutrients Reduce commercial fertilizer applications
Swine	Construct manure storage Apply manure to all cropland Inject manure applied to corn Credit manure for nutrients Reduce commercial fertilizer applications
Poultry	Construct two litter sheds and mortality composter Reduce litter applications Compost poultry mortalities Sell excess litter

Table 2.43 Mineral nitrogen and phosphorus (kg) available per hectare before and after nutrient management plan[1].

	100 dairy	160 dairy[2]	Swine	poultry
Total mineral N before plan[3]	188	256	120	222
Total mineral N after plan[4]	152	200	67	152
Reduction in total mineral N[5]	36 (19%)	56 (22%)	53 (44%)	69 (31%)
Total P_2O_5 before plan	45	90	58	320
Total P_2O_5 after plan	45	64	32	183
Reduction in total P_2O_5	0 (0%)	29 (32%)	26 (45%)	137 (43%)

[1] Weighted averages based on amount of each crop rotation and soil on farm.
[2] Does not include nitrogen provided by the addition of legumes to crop rotations after the implementation of the plan
[3] Available mineral nitrogen includes current year commercial nitrogen applications plus the mineralized portion of the current year and past year manure applications. Some available mineral nitrogen may be lost to volatilization, leaching, and runoff.
[4] Totals may be affected by rounding.

Table 2.44 Average annual per hectare nitrogen and phosphorus losses before and after nutrient management plan.

	100 dairy	160 dairy	Swine	poultry
Total mineral N before plan[1]	53	69	46	24
Total mineral N after plan[2]	39	46	25	19
Total loss reduction[3]	14 (27%)	23 (33%)	24 (45%)	6 (23%)
Range of N loss reduction by field	10 to 15	3 to 105	-3 to 58	1 to 12
Total P before plan[3]	8	18	3	9
Total P after plan[3]	8	14	1	6
Total P loss reduction[2]	0 (0%)	4 (23%)	2 (66%)	2 (32%)
Range in P loss reduction by field	0	-2 to 27	-1 to 10	0 to 7

[1] Average per hectare losses are weighted averages based on the acreage of each soil and crop rotation on farm.
[2] Totals may be affected by rounding.
[3] P losses are nearly all attached to eroded sediment.

Table 2.45 Economic impact of nutrient management[1]

Farm	Additional cost ($)	Reduced income ($)	Additional income ($)	Reduced costs ($)	Net income change[2] ($)
100 dairy	2,270	0	0	2,665	395
160 dairy	7,643	0	0	12,236	4,593
Swine	15,041	2,195	0	20,251	3,015
Poultry	3,020	562	2,240	3,639	2,297

[1] Costs including annualized cost of investments and operator labour.
[2] Net income change equals additional income plus reduced costs minus additional costs minus reduced income.

They concluded that the adoption of management practices outlined in nutrient management plans of four Virginia livestock farms resulted in significant reductions in nutrient losses and increased farm income. Due to the small number of farms analyzed for this study, it should not be concluded that nutrient management planning increases income on all farms, or that income increases are sufficient to cause voluntary adoption of nutrient management planning. To achieve the greatest nitrogen and phosphorus loss reductions at the least cost, nutrient management planning efforts should be targeted at confined livestock facilities, which lack adequate manure storage. The construction of storage allows flexibility to apply manure when and where it will be most beneficial to crops, thus reducing fertilizer applications, costs, and nutrient losses.

2.3.4 Nutrient Mass Balance for the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia, 1990 (McMahon and Woodside, 1997).

A 1990 nitrogen and phosphorus mass balance calculated for eight National Stream Quality Accounting Network (NASQAN) basins in the Albemarle-Pamlico drainage basin indicated the importance of agricultural nonpoint sources of nitrogen and phosphorus and watershed nitrogen retention and processing capabilities. Basin total nitrogen and phosphorus input estimates were calculated for atmospheric deposition (which averaged 27 percent of total nitrogen inputs and 22 percent of total phosphorus inputs); crop fertilizer (27 and 25 percent, respectively); animal waste (22 and 50 percent, respectively); point sources (3 percent each of total nitrogen and total phosphorus inputs); and biological nitrogen fixation (21 percent of total nitrogen inputs).

Highest in-stream nitrogen and phosphorus loads were measured in predominantly agricultural drainage areas. Intermediate loads were observed in mixed agricultural/urban drainage areas; the lowest loads were measured in mixed agricultural/forested drainage areas. The following provides a summary of the methodology used to estimate nutrient inputs and outputs.

Nutrient Inputs: Atmospheric Deposition

Atmospheric loads of nitrogen were calculated by using water year 1990 data from four National Atmospheric Deposition Program/National Trends Network (NACP/NTN) sites located in or adjoining the Albemarle-Pamlico study area. Table 2.46 provides a summary of deposition rates used to calculate atmospheric nutrient deposits. The total nitrogen contribution from atmospheric deposition was calculated as the sum of nitrate nitrogen and ammonium nitrogen wet deposition, nitrate dry deposition, nitrate droplet deposition, and nitrate urban dry deposition. Deposition in each of these categories was calculated by multiplying the associated deposition rate by the corresponding area of the drainage basin and a conversion factor changing the nitrogen units from ionic to elemental nitrogen. Deposition estimates are conservative since data were not available for dry ammonia and organic nitrogen deposition. The total phosphorus component of atmospheric nutrient loads was based on a literature-derived value of 0.19 ton of total phosphorus deposited per square mile of drainage basin.

Table 2.46 Summary of deposition rates used to calculate atmospheric nutrient deposition.

Item	Deposition Source	Rate (lb/acre/year)	Rate (kg/hectare/year)
1	Nitrate N, wet deposition	8.8	9.9
2	Ammonia N, wet deposition	2.5	2.8
3	Nitrate N, dry deposition	0.82[a]	0.82
4	Nitrate N, droplet deposition	9.6 ([1]+[3])[b]	10.8
5	Nitrate N, urban dry deposition	15.6	17.5
6	Nitrate N, urban wet deposition	5.5	6.2
7	Ammonia N, dry deposition	Not done	-
8	Organic N deposition	Not done	-
9	Total phosphorus deposition	0.6	0.7

[a] Dry nitrate nitrogen is calculated by multiplying wet nitrate nitrogen deposition by an estimate of the rates of dry to wet deposition for North Carolina. In North Carolina this ratio, in units of kilotonnes, is 0.82.
[b] For areas with elevations greater than 2,000 feet.

Nutrient Inputs: Crop Related

Estimates of the 1990 total nitrogen and total phosphorus inputs to the eight basins from major agricultural crops were made by using (1) crop acreage for major crops within the basin; (2) recommended fertilizer application rates for various major crops; and (3) estimates of biologically mediated nitrogen fixation associated with soybeans and peanuts. Crop acreages were based on 1990 crop statistics for harvested acreage reported by county in North Carolina and Virginia. Estimates of fertilizer use were made by multiplying recommended application rates by harvested acres per crop, and then summing all crop types. Estimates of biologically fixed nitrogen inputs were made by multiplying harvested acres of soybeans and peanuts by nitrogen fixation constants of 105 and 112 pounds per acre, respectively.

Recommended fertilizer application rates were used for this study because of the uncertainty associated with apportioning county-level fertilizer sales data to fertilizer use in a particular county. Using recommended application rates also results in lower fertilizer-use estimates than those obtained by basing estimates on county fertilizer sales data. When 1990 county fertilizer sales data are allocated to the eight basins, nitrogen and phosphorus fertilizer-use estimates result that may be as much as 220 to 990 percent higher, respectively, than estimates based on recommended application rates. Puckett (1995) reported on studies indicating that farmers may apply 24 to 38 percent more fertilizer than suggested because of uncertainties regarding weather and soil-nutrient status.

Crop related nutrient input estimates did not include nutrients introduced by nitrogen-fixing forage crops because of data unavailability. Urban fertilizer sources were not considered because of the lack of information for these basins.

Nutrient Inputs: Animal Waste

County livestock inventories for chickens, cattle, hogs, and turkeys were obtained from the U.S Department of Agriculture's 1987 Census of Agriculture, the most recent year relative to 1990 for which data are available for all study-area counties. Livestock inventories were multiplied by estimates of annual per-animal waste nutrient content from Barker (1991), and waste nutrient loads were summed for all livestock types in a drainage basin to estimate total livestock-related nutrient generation. The assumption was made that all animal feed is imported into the basin.

Nutrient Inputs: Point Sources

Because of limits in available data, different methods were used to estimate the 1990 total nitrogen and total phosphorus loads generated by point-source discharges in Virginia and North Carolina. Permitted discharges in both states were primarily municipal wastewater-treatment plants. The Virginia Water Control Board supplied daily discharge data for 106 permitted point-source dischargers in the Virginia portion of the Albemarle-Pamlico drainage basin, along with Standard Industrial Codes described the type of activity, such as municipal wastewater-treatment plant associated with each permit. These facilities discharge approximately 170 million gallons per day of waste effluent. The number of discharges measurements reported by each discharger ranged from 2 to 48 during 1990. Annual nutrient load estimates were obtained by (1) calculating the median value of the daily discharge values, (2) multiplying the median value by a total nitrogen and total phosphorus concentration value based on the SIC to estimate daily nutrient loads, and then (3) multiplying the product obtained in step 2 by 365 (days).

The North Carolina Department of Environment, Health, and Natural Resources, Division of Environment Management, supplied 1990 monthly average discharge and nutrient concentration data for 172 point-source dischargers in the North Carolina drainage basins that reported discharges in 1990. These facilities' combined discharge was approximately 280 million gallons per day. For these discharges, monthly load estimates were calculated by multiplying the average daily discharge for a given month by the average total nitrogen and total phosphorus concentration values for the same month. Monthly load estimates for each discharger having a twelve month data set were summed over the entire year. For dischargers, having less than twelve months of 1990 data, annual nutrient loads were calculated in the same manner as those for Virginia dischargers. The median of all reported daily discharge data for a discharger was multiplied by the median total nitrogen and total phosphorus concentrations for the same discharger in order to estimate daily loads, and these loads were summed to produce an annual estimate.

Nutrient Outputs: In-Stream Loads

In-stream loads for 1990 were estimated for the annual mass of total nitrogen and total phosphorus transported past each station. Estimates also were made for nutrients removed from each basin by crop harvest. Finally, a nutrient residual estimate was made by subtracting nutrients removed from the basin from the total 1990 estimated nutrient inputs.

The total mass of a constituent transported by a stream is correlated with the quantity of streamflow. When calculating loads, it is desirable to have water-quality samples representing all parts of the flow regime of a stream, especially the less frequently occurring high-flow periods when a high proportion of annual sediment and nutrient load are transported by the stream. Annual loads of total nitrogen and total phosphorus were calculated for water years 1980-92. A log-linear regression model was used to produce minimum-variance unbiased estimates of seven parameters that were used, in turn, to estimate loads. The dependent variable, constituent load, is based on concentrations of total nitrogen and total phosphorus and, thus, reflects contributions of sediment-related nutrients.

Nutrient Outputs: Crop Harvest and Residual

Estimates of nitrogen and phosphorus removal were made by allocating 1990 county-level crop harvest data for the eight basins using the same technique described for allocating crop acreage data. Data for average nutrient content of harvested crop materials were used in conjunction with harvest estimates to calculate harvest nutrient removal.

A residual term is calculated as the difference between total nutrient inputs and the sum of in-stream load and crop harvest categories. This category represents nutrients that otherwise cannot be accounted for in the mass balance because of a lack of knowledge about terrestrial and aquatic nutrient cycling associated with processes such as denitrification, retention in forest ecosystems, uptake by stream biota, soil and streambed storage, and losses to groundwater. This category also arises due to uncertainty in estimates of the input and output categories used in this study.

The following tables provide a summary of total nitrogen and total phosphorus inputs and outputs as a percent of total station inputs and in kilograms per hectare.

Table 2.47 Summary of total nitrogen and total phosphorus inputs and outputs (kg/ha), as a percent of total station nutrient inputs, for National Stream Quality Accounting Network in the Albemarle-Pamlico Drainage Study Area, 1990.

Category	Site 1 VA[1]		Site 2 VA		Site 3 VA		Site 4 VA		Site 1 NC[1]		Site 2 NC		Site 3 NC		Site 4 NC	
	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P
Inputs																
Atmospheric Deposition	17.9	21.0	25.5	26.1	39.8	30.5	38.1	25.5	44.0	30.9	20.6	16.9	20.9	14.9	10.9	7.9
Commercial Fertilizer	31.9	46.6	22.9	28.7	13.8	11.0	16.2	8.6	17.8	9.1	31.6	27.9	34.9	32.6	43.8	37.8
Nitrogen Fixation	40.3	-	35.2	-	15.8	-	6.2	-	5.1	-	24.9	-	20.6	-	22.1	-
Animal Waste	9.7	32.0	16.1	43.6	29.9	57.4	34.8	61.9	25.4	48.3	21.5	52.9	19.1	48.1	22.1	53.4
Point Sources	0.2	0.4	0.3	1.6	0.7	1.1	4.7	4.0	7.7	11.7	1.4	2.3	4.5	4.4	1.1	0.9
Outputs																
Crop Harvest	63.8	82.3	47.8	51.0	23.5	18.8	14.6	13.2	14.8	14.3	35.9	35.8	32.5	34.4	41.0	40.1
In-Stream Load	10.1	4.6	8.8	7.4	14.0	8.8	14.4	4.8	30.4	25.4	14.4	12.1	15.7	9.9	10.2	9.0
Residual	26.1	13.1	43.4	41.6	62.5	72.4	71.0	82.0	54.8	60.3	49.7	52.1	51.8	55.7	48.8	50.9

[1] Virginia, [2] North Carolina

Table 2.48 Summary of total nitrogen and total phosphorus inputs and outputs, in kilograms per hectare of basin drainage area, for National Stream Quality Accounting Network in the Albemarle-Pamlico Drainage Study Area, 1990.

Category	Site 1 VA[1]		Site 2 VA		Site 3 VA		Site 4 VA		Site 1 NC[1]		Site 2 NC		Site 3 NC		Site 4 NC	
	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P
Inputs																
Atmospheric Deposition	6.43	0.65	6.38	0.65	6.32	0.65	6.82	0.65	6.95	0.65	6.84	0.65	7.58	0.65	6.88	0.65
Commercial Fertilizer	11.44	1.45	5.73	0.72	2.19	0.24	2.90	0.22	2.82	0.19	10.51	1.08	12.6 9	1.43	27.64	3.14
Nitrogen Fixation	14.48	0	8.79	0	2.50	0	1.11	0	0.81	0	8.30	0	7.48	0	13.96	0
Animal Waste	3.47	1.00	4.02	1.09	4.74	1.23	6.23	1.58	4.02	1.02	7.18	20.4	6.95	2.11	13.96	4.43
Point Sources	0.08	0.01	0.08	0.04	0.12	0.02	0.85	0.10	1.22	0.25	0.47	0.09	1.63	0.19	0.72	0.07
Outputs																
Crop Harvest	22.91	2.56	11.95	1.27	3.72	0.40	2.62	0.34	2.35	0.30	11.96	1.38	11.79	1.50	25.89	3.33
In-Stream Load	3.64	0.14	2.20	0.19	2.22	0.19	2.58	0.13	4.80	0.54	4.80	0.47	5.69	0.42	6.42	0.74
Residual	9.36	0.41	10.84	1.04	9.92	1.55	12.71	2.09	8.67	1.27	16.54	2.02	18.84	2.45	30.85	4.22

Atmospheric nitrogen inputs, measured as a percent of all inputs, on average, were the largest input category, while atmospheric phosphorus inputs, on average, are less important that commercial fertilizer and animal waste. Atmospheric inputs of nitrogen and phosphorus, as a percent of total nutrient inputs, are comparable to nutrient inputs from crop fertilizer. As atmospheric nutrient sources are even more dispersed in space and time than agricultural sources, the relative importance of atmospheric inputs creates an especially difficult challenge for developing nonpoint-source nutrient management plan.

On a kilogram per hectare basis, combined crop-related nitrogen fertilizer and nitrogen fixation were the largest source of nitrogen in six of the eight basins (Table 2.46). Animal related nitrogen inputs average 22 percent for the eight drainage areas while phosphorus inputs averaged 50 percent. The data indicate that phosphorus derived from animal waste was the largest source of phosphorus inputs, as is also evident for phosphorus inputs on a kilogram per hectare basis. The significance of this finding was heightened by the rapid growth of the livestock industry that has occurred in the Albemarle-Pamlico drainage basin since 1987. Achieving optimum crop yields without applying excessive nutrients is a goal of farmers for both economic and environmental reasons. The excess of available agricultural nutrient in the eight basins, relative to nutrients removed by crop harvest, confirms the general importance of efforts to promote nutrient management.

Point source contribution of total nitrogen and total phosphorus averaged 2.6 and 3.3 percent, respectively. Point source nutrient inputs consistently composed a very small proportion of total nutrient inputs in the eight basins. These small percentages may be misleading, however, in indicating the relative importance of point sources of nutrients for water quality. Although point sources may constitute a small proportion of overall nutrient inputs, because they are discharged into water bodies, they may have a disproportionate impact on nutrient loads.

The residual category had significantly large results and indicates the potential of a large mass of accumulated nitrogen and phosphorus in the estuary drainage system, but it is impossible to know with any certainty the extent to which this accumulation actually exists. The residual category is an indication of the uncertainty and error associated with estimating the other mass balance compartments.

2.3.5 Nutrient Balance on Nebraska Livestock Confinement Systems (Koelsch and Lesoing, 1999).

An accounting of nutrient inputs (purchased feed, purchased fertilizer, purchased animals, biologically fixed nitrogen, and nitrogen in irrigation water) and managed nutrient outputs (animals, crops, and manure moved off farm) was completed for 16 cattle feedlots and 17 swine confinement operations. A personal visit was made to each cooperator, during which the desired information was collected and a preliminary nutrient balance was completed. A literature review provided the basis for the selected values for nutrient concentrations of animals (Table 2.49).

Both a nitrogen and phosphorus balance is presented. A phosphorus balance provides a preferred indication of the degree of risk to water quality. An imbalance in nitrogen does not distinguish between the relatively benign volatilization losses of ammonia to the atmosphere and the relatively harmful losses of nitrate to water. Volatilization losses from open lots, anaerobic lagoons, or surface application of manure can be large. In contrast, phosphorus losses impact only water quality through increased soil phosphorus levels and greater concentration of phosphorus moving with surface runoff water. A relative balance between phosphorus inputs and managed outputs would suggest that the risk to water quality remains relatively constant and thus a potentially “sustainable” system exits. A phosphorus imbalance would suggest an increasing risk to water quality alone, whereas a nitrogen imbalance would suggest an increasing risk to both air and water resources.

Table 2.49 Nutrient concentrations and assumption used for estimating nutrient balance.

Nutrients inputs/outputs	Concentration[1] N	Concentration[1] P
Swine body weight	2.32 to 2.52% of BW	0.47 to 0.56% of BW
Beef body weight	2.40 to 2.80% of BW	0.65 to 0.73% of BW
Crops, feeds, and forages	Individual analysis or NRC Feed Library	
Commercial fertilizers	Individual analysis	
Manure sold	Individual analysis	
Irrigation water	Individual analysis	
Legume-fixed nitrogen[2]		
1st year hay crop (>90% legume)	30% of harvested N	
2nd year or older hay crop (>90% legume)	60% of harvested N	
1st year hay crop (grass & legume mix: 25-90% legume)	18% of harvested N	
2nd year hay crop (grass & legume mix: 25-90% legume)	36% of harvested N	
Soybeans	40% of harvested N	
Dry edible beans	40% of harvested N	

[1] BW = body weight (value provided by producer); EBW = empty body weight.
[2] Only if manure has not been applied within past year.

The following table provides a summary of the nutrient balances for 33 livestock farms.

Table 2.50 Average characteristics and nutrient balance for 33 Nebraska livestock farms.

Item	<250 animal units	250-2,500 animal units	>2,500 animal units
Farm characteristics			
Number of livestock units	12	13	8
Animal units (454 kg)	154	668	7,597
Cropland, ha/animal unit	1.5	0.6	0.1
Nitrogen balance, Mg/year			
Inputs	34	92	836
Managed outputs	-23	-38	-368
Inventory change[1]	-3	-8	-2
N imbalance, Mg/year	8	46	466
Inputs/Outputs[2]	1.8:1	2.4:1	2.3:1
Phosphorus balance, Mg/year			
Inputs	4.6	12.0	163
Managed outputs	-3.7	-7.9	-102
Inventory change[1]	-0.3	-1.3	-1
P imbalance, Mg/year	0.6	2.9	60
Inputs/Outputs[2]	1.6:1	1.6:1	1.6:1

[1] Negative inventory change indicates an increase in inventory.
[2] Phosphorus imbalance ratio shown is an average that equally weight values from each livestock operation with a growing. It cannot be calculated from the previous input and output values contained in the table

Figures 2.8 and 2.9 provide a graphical summary of the sources of nutrient inputs and outputs of nitrogen and phosphorus and their overall contribution.

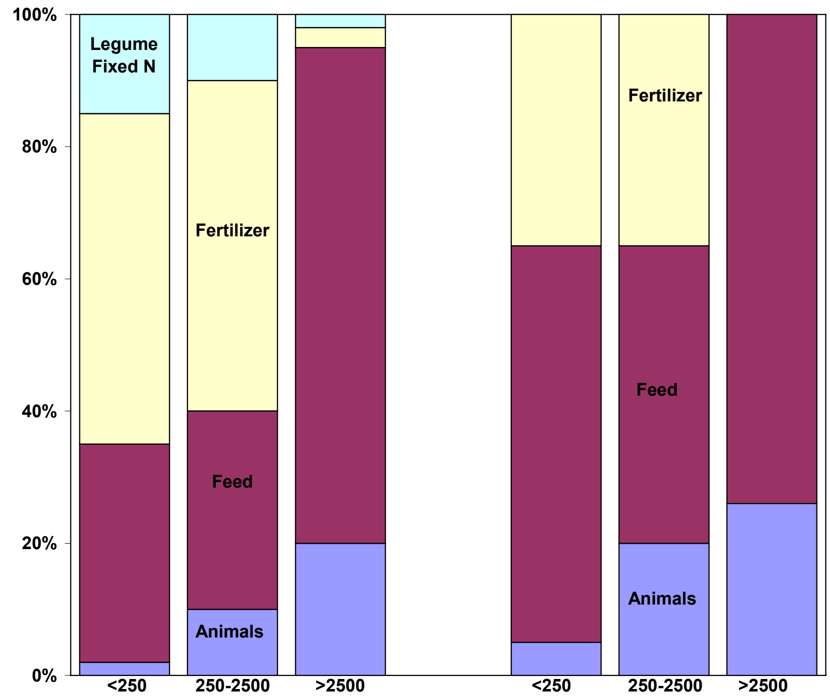

Figure 2.8 **Relative sources of nitrogen and phosphorus inputs with different-sized Nebraska livestock operations.**

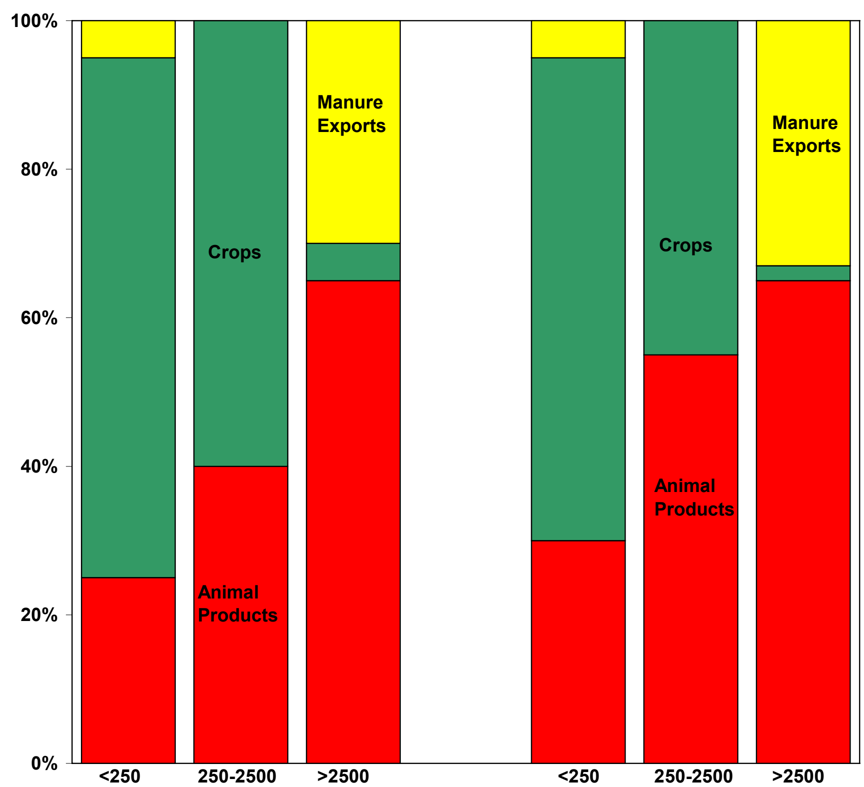

Figure 2.9 **Relative sources of nitrogen and phosphorus outputs with different-sized Nebraska livestock operations.**

An interesting result was that the supplementation of swine diets with mineral phosphorus was an important contributor to the phosphorus inputs for smaller livestock operations. Of the 16 participating swine farms, nine provided feed data from which mineral phosphorus purchases could be separated and quantified. On these nine farms, mineral phosphorus represented just over 60 percent of the total phosphorus inputs as feed and approximately one third of the total farm inputs of phosphorus. They suggested that the use of phytase in diets for swine would increase nutritional availability of phytic acid phosphorus and reduce the purchases of mineral phosphorus sources. This would substantially reduce the excess phosphorus removed from manure observed in their nutrient balance study.

Conclusions drawn from their review of the nutrient balance on 33 Nebraska farms that include cattle and swine confinement include the following:

1. Most farms exhibit substantially greater nitrogen inputs than managed outputs. The majority of farms also exhibited an accumulation of phosphorus.
2. Livestock feed purchases amount to a significant source of nutrient inputs to livestock operations. Purchased feeds were the primary source of nitrogen input for farms with more than 2,500 animal units and the primary source of phosphorus for all sizes of operations.
3. Substantial variation exists between individual farms. The size of the livestock component and the degree of integration of livestock and cropping systems (crop hectares per animal unit) provided only a limited explanation of the observed variation.
4. Alternative management strategies are needed for addressing a nutrient balance. These strategies must vary for individual livestock operations dependent on the primary sources of nutrient inputs and availability of cropland. Marketing of manure nutrients was observed to produce a “sustainable” nutrient balance for several larger livestock operations with limited cropland.

The preferred strategy for achieving a balanced nutrient system will vary with individual situations. For systems with sufficient land base for utilizing manure nutrient should focus on maximizing their use as a fertilizer and on reducing commercial fertilizer inputs to achieve a nutrient balance. Alternative feeding programs can focus on phosphorus reduction in manure to provide a nutrient source better matched to crop nitrogen and to phosphorus needs. When insufficient land base is available for utilizing manure nutrients, dietary and marketing of manure nutrients to off-farm customers will be fundamental to achieving nutrient balance. For manure to be accepted by off-farm customers, it must be viewed as a valued resource with a focus of efficient nutrient use in cropping programs and limiting of nuisance issues.

2.3.6 The Role of On-Farm Nutrient Balance Assessments in an Integrated Approach to Nutrient Management (Lanyon and Beegle, 1989).

A 56-hectare dairy farm was selected in central Pennsylvania to conduct a nutrient management process. The farm included 14.4 ha of corn grain, 2.6 ha of corn silage, 27.0 ha of alfalfa, 5.5 ha of double-cropped alfalfa and corn silage and 6.5 ha of pasture. The livestock were 54 Holstein dairy cows and 45 heifers, 3 mature hogs and their offspring, and 9 steers. The farmer’s records were used for the field activities, including crop yields, fertilizer, and manure applications, and for purchase and sales information of crops, livestock inputs, livestock products (milk), and livestock. Nutrient balance summaries were calculated form the inputs and outputs to each field, to each livestock unit, and to the entire farm using the farmer's estimates of crop and manure quantities; manure composition of 4.45 kg nitrogen per metric ton of manure, 0.88 kg phosphorus per metric ton, and 3.3 kg potassium per metric ton at 12.9 kg solids per tonne of manure; feed analyses from suppliers; and standard composition values for other materials.

The following table summarizes the results of the nutrient inputs, outputs, and balances.

Table 2.51 An annual plant nutrient inputs, outputs, and balances on a Pennsylvania dairy farm.

Unit	Area (ha)	Crop	Nutrient	Inputs: Fertilizer	Inputs: Manure	Inputs: Biological N fixation[1]	Outputs crop	Balance (In-Out)
						$kg\ ha^{-1}\ year^{-1}$		
A. Individual Fields								
			N[2]	202	367 (73)	-	140	429 (135)
	14.4	Corn	P	10	65	-	27	48
			K	279	244	-	133	410
			N	0	0	225	225	0
	27.0	Alfalfa	P	19	0	-	22	-3
			K	75	0	-	181	-106
B. All Fields								
			N[1]	84	118	145	225	122
	49.4		P	7	21	-	28	0
			K	33	72	-	164	-59
			Nutrient	**Inputs: Purchases**	**Inputs: Fields**	**Outputs: Products**	**Outputs: Manure**	**Balance (In-Out)**
						$kg\ year^{-1}$		
C. Livestock								
	6.5		N	5,931	9,459	2,305	5,252	7,833
Dairy	(includes pasture)		P	563	1,162	409	932	384
			K	1,680	6,966	516	3,224	4,906
			Nutrient	**Inputs: Fertilizer**	**Inputs: Animal Requirements[3]**	**Biological N fixation**	**Output Products**	**Balance (In-Out)**
						$kg\ year^{-1}$		
			N	4,151	6,333	7,163	2,554	15,093
D. Farm	56		P	356	612	-	452	516
			K	1,617	1,745	-	517	2,845

[1] Assumes all N in alfalfa is from biological N fixation.
[2] Available N in parentheses.
[3] Includes feeds and bedding.

The nutrient balance for all fields were positive for N, balanced for P, and negative for K. The positive N balance suggests that there may have been some residual soil N available for loss to the environment after the cropping season. However, the substantial calculated N fixation inputs to alfalfa must be recognized as contributing less to potential N leaching than if the same amount of N was applied to the corn fields. Further, the slow mineralization and volatilization losses of this N would diminish the potential N loss to groundwater.

Purchased feed and feedstuffs made substantial contributions to the nutrient loading of the case-study farm in the farmer managed flows. The N brought onto the farm in animal feed exceeded that added in fertilizer by 53 percent, but the largest apparent contribution to the farm was from calculated biological N fixation by alfalfa. The reported farm loading from N fixation represented only an estimate of the gross accumulation from atmospheric interactions. In reality there would be other atmospheric interactions by which N would be lost from the farm. These losses have not been accounted for in this nutrient balance. Frink (1969) suggest that N fixation and rainfall additions may be approximately offset by N volatilization and denitrification losses on northeastern United States dairy farms.

Any discrepancies in the nutrient balances of this case-study farm may be real, artifacts of inadequate records or inaccurate nutrient concentrations of farms materials, reflect incomplete accounting of significant flows, or some combination of these shortcomings. Improved record keeping to better estimate crop yields and monitor manure applications would be an effective first step in enhancing nutrient management and increasing the understanding of nutrient flow on crop and livestock farms.

2.3.7 South Tobacco Creek Project

Launched in 1991, the South Tobacco Creek (STC) project is a cooperative investigation of the impacts of agriculture on land and water ecosystems within the Red River basin of Southern Manitoba. The STC is unique, as it's the only intensively long-term studied watershed in Manitoba. The Deerwood Soil and Water Management Association (DSWMA) was initially created to address local soil conservation needs. Working with many partners, including the provincial and federal governments, the DSWMA has currently been the focus of several small watershed research projects designed to find out what cost effective conservation measures could be undertaken along the Escarpment.

The STC Watershed is located in South-Central Manitoba (Figure 2.10). The majority of the STC Project watershed is located on the upper reaches of the Pembina Escarpment and to a lesser extent on the immediate area below the eastern toe of the Escarpment extending as far east as Miami, Manitoba.

The STC watershed is known to deliver significant quantities of sediments downstream during spring runoff and major rainfall events. With approximately 75 percent of the watershed in agricultural land-use, a substantial portion of the land base receives nutrient applications. There are numerous livestock operations within the watershed. Several of these are situated close to streams. Significant field application of nutrients also occurs via manure spreading. The potential therefore exists for the release of excess nutrients to the aquatic environment.

The best means of learning more about the movement of nutrients and sediments in watercourses is to study changes at a measurable watershed level. Very little accurate data exists in Manitoba, or elsewhere for that matter, regarding the linkage between present levels, time of application and movement for specific agricultural nutrients within an agricultural watershed. Research results from the STC project will contribute to an increase understanding of these issues.

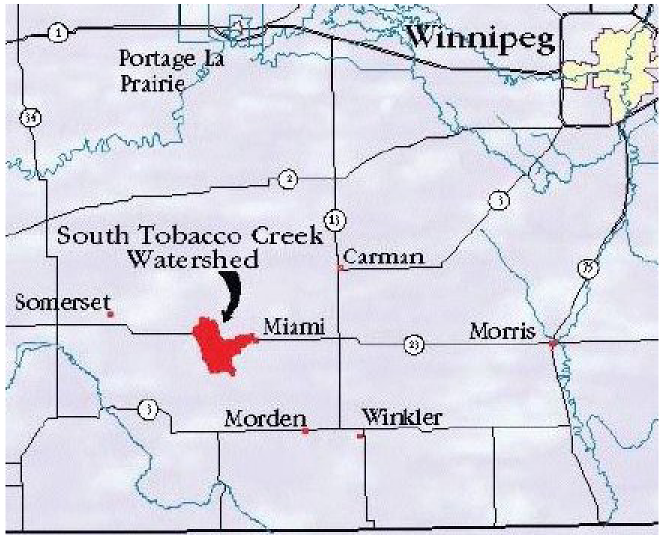

Figure 2.10 Map of STC watershed area.

The following two STC research projects are of interest to the Regional Nutrient Balance Study: (1) the Sediments and Nutrients Research initiative and (2) the Manured Watershed Runoff Study. Both projects are summarized in Sections 2.3.7.1 and 2.3.7.2 for the Sediments and Nutrients Research and Manured Watershed Study, respectively. Annual export coefficients of N and P from both projects are compared to the estimated coefficients used in the Regional Nutrient Balance study.

2.3.7.1 The Sediments and Nutrients Research

The Sediments and Nutrients Research initiative has focused on exploring the linkages between agricultural nutrients and the enhancement of eutrophication. The Nutrient and Sediment Research project's objectives are:

1. To examine potential links between the agricultural use of synthetic fertilizers and eutrophication;
2. To comprehend the movements and origins of all nutrients (synthetic and natural sources);
3. To foster discussion of the design of the study and to help make recommendations toward filling the main gaps in the collective knowledge of the physical, chemical, and biological processes at play within the STC watershed.

Sediments and Nutrients monitoring occurs near the upper reaches of the STC watershed at the Twin Watersheds and is ultimately compared to research results further downstream within the STC.

Samples from four sites (Miami, Hwy 240, Twin Watersheds and Pristine) were collected when flow was present, such as during spring (snowmelt) runoff and during rain events large enough to produce runoff (Figure 2.11). The STC often dries up during extended dry summer or fall periods.

From 1992 to 1996, the two fields at the Twin Watersheds were both managed under conventional tillage. Data collected during this period served to provide calibration for research; that is, it allowed researchers to determine differences in runoff characteristics between the two watersheds when under similar land use. In 1997, the East watershed was placed under zero-tillage for the purpose of comparing the differences between conventional and zero-tillage.

Nitrogen and phosphorus can be present in either a dissolved form or in particulate form. The percentage of each form is largely a result of natural watershed characteristics, climatic influences, and land use activities.

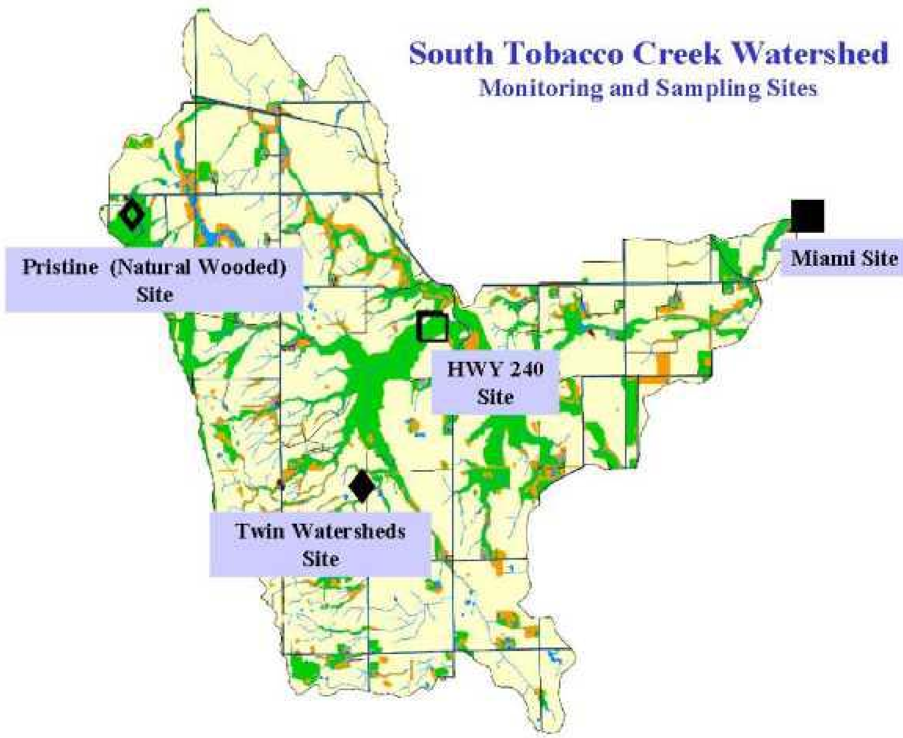

Figure 2.11 STC monitoring sites.

2.3.7.1.1 Results and Discussion

The export coefficients (kg/ha/year) for nitrogen and phosphorus at the two STC main channel sites (Hwy 240 and Miami) were of the same order of magnitude, only slightly higher than the Twin watersheds (Table 2.52).

Table 2.52 Comparison of average (1993-1997) annual export coefficient from STC (spring and summer combined) and Regional Nutrient Balance study.

STC Sediments and Nutrients Initiative				
			Twin Watersheds	
Element	**Hwy 240 site**	**Miami site**	**East Watershed**	**West Watershed**
Nitrogen	3.0	3.3	3.0	3.5
Phosphorus	0.6	0.7	0.35	0.35

Regional Nutrient Balance Study				
Element	**Cropland**	**Summerfallow**	**Seeded pasture**	**Natural pasture**
Nitrogen	2.2	3.5	2.2	2.2
Phosphorus	1	1	0.6	0.6

(Export coefficient = kg/ha/year)

The STC watershed at the Miami site generated a range of 1.3 to 6.7 kg/ha/year of nitrogen. This is slightly higher than the initial review of 1992-1993 results (0.39-1.1 kg/ha/year), but is within the range generally related to rural cropland. Similarly, the phosphorus loading ranged higher than the initial review of 1992-1993 results (0.06-0.34 kg/ha/year), but were still on the low end of the range generally seen for rural cropland and other non-point sources of phosphorus.

The export coefficients estimated for the Regional Nutrient Balance study were based on various cropping practices. The values were estimated using data summarized in the Literature Review. Export coefficient values from the Regional Nutrient Balance study were divided into run-off of available nutrients and run-off by organic matter. The sum of these losses agreed with those observed in the STC study (Table 2.52). As the STC study was conducted near the Manitoba Escarpment, the influence of topography would increase the export coefficient values when compared to the values used in the Regional Nutrient Balance study. The topography in the four Regional Nutrient Balance municipalities was essentially level.

2.3.7.2 South Tobacco Creek Manured Watershed Runoff Study, 1998-2001

The South Tobacco Creek Manured Watershed Runoff Study was undertaken to obtain a better understanding of hog manure management and some basic information on hog manure applications to land and potential affects to the environment on a field scale. This study was mainly created to address the limited amount of this type of data for Manitoba. The study was recently published in March 2002.

The main objective of the STC Manured Watershed Project and of importance to the Regional Nutrient Balance study was the determination of water quality characteristics of runoff from fields applied with hog manure (organic fertilizer) and inorganic fertilizer under fertilization practices commonly used by producers (conventional and zero-till) and to compare the water quality runoff characteristics between the two fertilizer sources. Water quality characteristics under the study included the amount of bacteria, nutrient, organic carbon, and suspended solid residues in runoff that occurred during spring and post-spring rainfall events.

A secondary objective was to obtain runoff data from a relatively undisturbed natural wooded area and a forage field so that water quality characteristics from these areas could be compared with the other fields

The following four watersheds were sampled for both soil and water: (1) Twin Watershed, (2) Manure Watershed (MW), (3) Forage Field (FF), and (4) Natural Wooded Area (NWA) (Figure 2.12).

The Twin Watershed study site was separated into two sub-watershed units referred to as the Conventional-till (CT) field and Zero-till (ZT) field (Figure 2.13).

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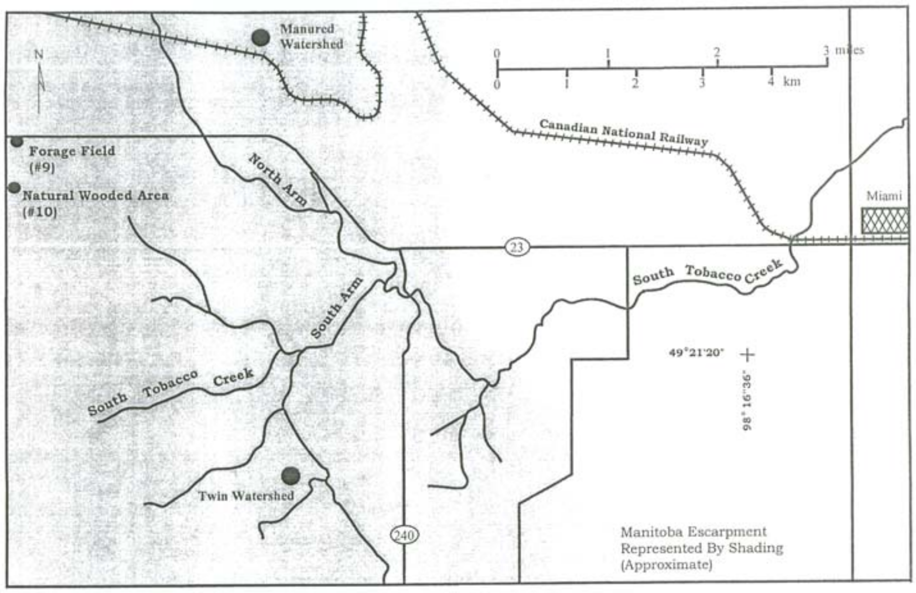

Figure 2.12 Location of the Natural Wooded Area, Forage Field, Manured Watershed and Twin Watershed study areas within the STC Watershed, 1998 – 2001.

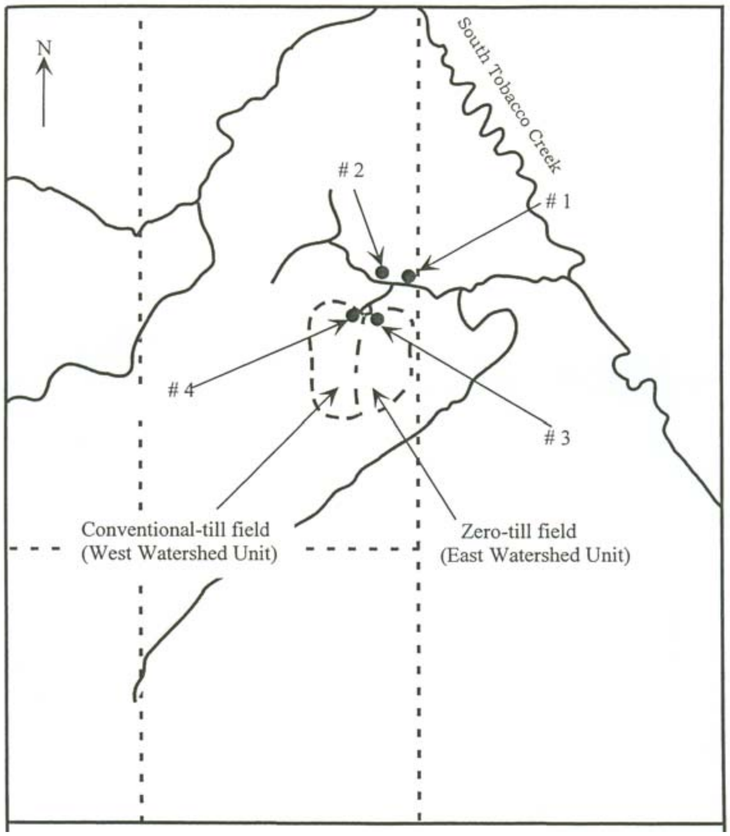

Figure 2.13 Sampling sites associated with the Twin Watershed CT and ZT field units within the STC Watershed, 1998 – 2001.

2.3.7.2.1 Results and Discussion of Manured Watershed Runoff Study

Comparisons of the nitrate-N and phosphorus runoff levels between the MW and the Conventional-till and Zero-till do not appear to be appropriate. The initial soil residual nitrate-N values from 0-60 cm for the MW was approximately 320 kg/ha compared to initial nitrate-N values of approximately 25 kg/ha for both conventional and zero-till fields. Initial levels of P for the MW was approximately 120 kg/ha compared to 25 and 45 kg P/ha for the Conventional and Zero-till fields, respectively. The authors attributed the high initial nitrate-N values to the previous alfalfa crop, which would have released a significant amount of N in addition to the added manure. This excess of manure obviously caused increased N and P levels in the soil. The losses were therefore measured under different nutrient loading conditions.

This study concluded that the MW field was too small to obtain adequate spring runoff events on a consistent basis under natural conditions. Continuation of this type of project to determine loading estimates on a field scale would need a larger field size similar to the Twin Watershed fields. Alternatively, some method such as snow fencing that would capture more snow and enhance the opportunity for runoff may be an option. The MW field was much smaller than the other fields and it would be preferable to have fields as close in size and other characteristics as possible.

The large losses (Table 2.53) in 1998 indicate what can happen under conditions of excess soil and applied nutrients when substantial runoff occurs, but the comparison is not very valid. Similar N rates should be applied to both field conditions, as it is more likely to find nitrate-N and P leaching to greater depths when application rates exceed plant uptake. Initial values of residual N and P should also be similar between fields for better nutrient migration comparisons.

Research conducted by McGill and Ewanek described in the Literature Review, as well as some of the case farms in this study, indicated that the accumulation of nitrate throughout the soil profile occurs for various cropping practices, including soils that have never received manure. In the Manured Watershed study, only the manured field was sampled to a depth of 305 cm and analyzed for N and P migration. The Conventional and Zero-tilled fields should have also been sampled to this depth to provide a direct comparison of nutrient migration.

The authors also stated that for the manured (MW) field "there was evidence that P had moved to a depth of 305 cm" from analyzing only one year of soil test results. As there was no initial soil samples taken at these depths, the assumption that P had leached over a 3-year period is questionable. The results summarized in Figure 2.14 are not indicative of P leaching.

The results of this runoff study did show the importance of soil testing for both N and P before the application of manure. As was discussed in the Regional Nutrient Balance study, levels of soil P can gradually increase when manure application rates are based on nitrogen requirements.

The results of nutrient loss varied considerably within each of watershed study sites over the four-year period (Table 2.53). The average annual N loss for the three sites was 3, 2.5, and 1.8 kg N/ha for the manured, conventional-till, and zero-till sites, respectively. The average annual P loss was 0.43, 0.38, and 0.57 kg P/ha for the manured, conventional-till, and zero-till sites, respectively. Notwithstanding the concern expressed above regarding the reliability of the data in the Manured Watershed study, a comparison of these average values with the loss values used in the Regional Nutrient Balance study (Table 2.54) indicates that the Nutrient Balance values provided a reasonable estimate of both N and P losses in the nutrient budget conducted for all farms and four municipalities. Topography was not an important factor for determining runoff coefficients in the four Regional Nutrient Balance municipalities. The topography was essentially level.

The wide range of values observed from the STC Manured Watershed Runoff Study indicates the difficulties of obtaining field based measurements of nutrient loss as many factors can influence nutrient losses. These field-based studies, however, still provide valuable information for estimating losses of nutrients and differing nutrient and land management regimes.

Table 2.53 Nutrient loss (kg/ha) from the Manured Watershed, Conventional-till and Zero-till fields during spring runoff, 1998 – 2001.

Year	Variable	Runoff Load		
		Manured Watershed	Twin Watershed	
		Manured Watershed field (0.892 ha) kg/ha	Conventional-till field (4.24 ha) kg/ha	Zero-till field (5.64 ha) kg/ha
1998	Total N	8.63	1.77	1.72
	Ammonia-N	1.26	0.29	0.60
	Nitrate-nitrite-N	6.20	0.69	0.48
	Total P	1.25	0.23	0.36
	Dissolved P	1.16	0.15	0.29
1999	Total N	0.03	2.13	0.81
	Ammonia-N	0.01	0.05	0.10
	Nitrate-nitrite-N	0.01	1.67	0.40
	Total P	<0.01	0.08	0.15
	Dissolved P	<0.01	0.06	0.13
2000	Total N	ND	ND	1.86
	Ammonia-N	ND	ND	0.04
	Nitrate-nitrite-N	ND	ND	1.33
	Total P	ND	ND	0.44
	Dissolved P	ND	ND	0.41
2001	Total N	0.09	3.67	3.01
	Ammonia-N	0.01	0.54	0.80
	Nitrate-nitrite-N	0.03	1.87	1.27
	Total P	0.03	0.82	1.33
	Dissolved P	0.02	0.75	1.27

Table 2.54 Comparison of average nutrients losses from MW study and estimated annual export coefficients used in the Regional Nutrient Balance study.

STC Manured Watershed Study			
Element	Manured Watershed	Twin Watersheds	
		Conventional Till	Zero Till
Nitrogen	3.0	2.5	1.8
Phosphorus	0.43	0.38	0.57

Regional Nutrient Balance Study				
Element	Cropland	Summerfallow	Seeded pasture	Natural pasture
Nitrogen	2.2	3.5	2.2	2.2
Phosphorus	1	1	0.6	0.6

(Export coefficient = kg/ha/year)

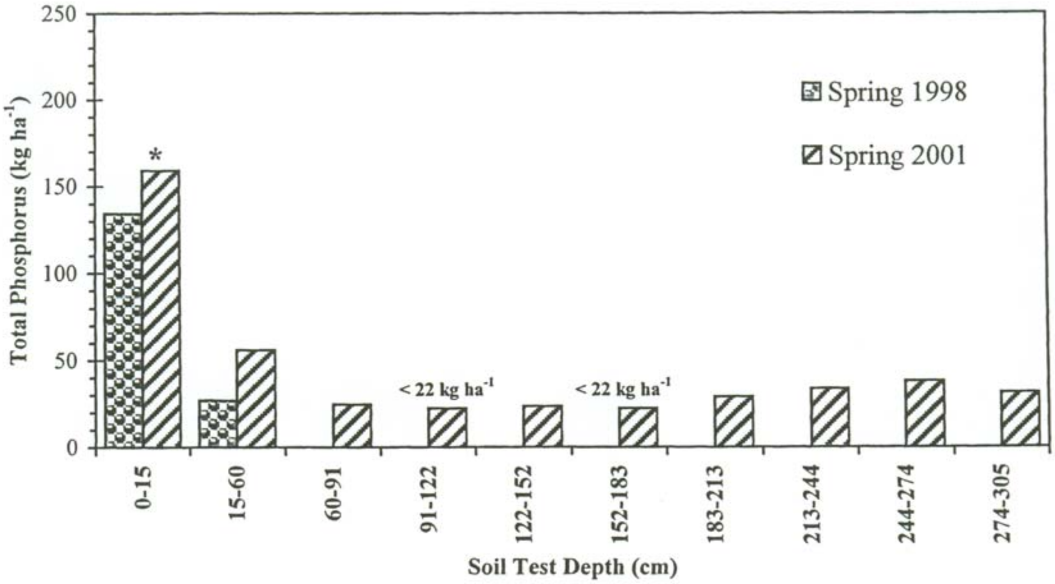

Figure 2.14 Total phosphorus values (kg/ha) for soil test profiles between surface to the 305 cm depth from the Manured Watershed field, May 1998 and May 2001.

* = used fall 2000 soil value and added the applied manure value since there appeared to be a problem with spring test 2001 values at the 0-15 cm depth.

Note: There was no phosphorus data for depths 60-305 cm during 1998. Histograms bars with <22 kg/ha indicate all samples at that depth were less than laboratory detection limits. All other depths had at least one or two of the three samples above detection limit.

3.0 DESCRIPTION OF MUNICIPALITIES

3.1 Sifton

- <u>General</u>

The Rural Municipality of Sifton is located in south-western Manitoba. There are two incorporated communities in the area: the Rural Municipality of Sifton and the Town of Oak Lake. Figure 3.1a shows where in Manitoba the R.M. of Sifton is situated, and Figure 3.1b is a land location map of the Municipality.

The Town of Oak Lake is approximately 25.9 ha (2.59 sq. km). The population of the town is approximately 370. The economic base of the town is mainly service oriented, primarily supporting agricultural operations. No businesses involve significant cycling of nutrients.

The R.M. of Sifton surrounds the Town of Oak Lake. The population of the R.M. of Sifton is approximately 760. Agriculture plays a major role in the economy of the Municipality. Farming activities are mainly comprised of grain, mixed grain and oilseed operations. A small number of other operations in the area specialize in livestock production. There are several large cattle operations in the R.M., and a major P.M.U. operation supplies a local processor. The community also has a seed grower and a seed cleaning plant (Manitoba Community Profiles).

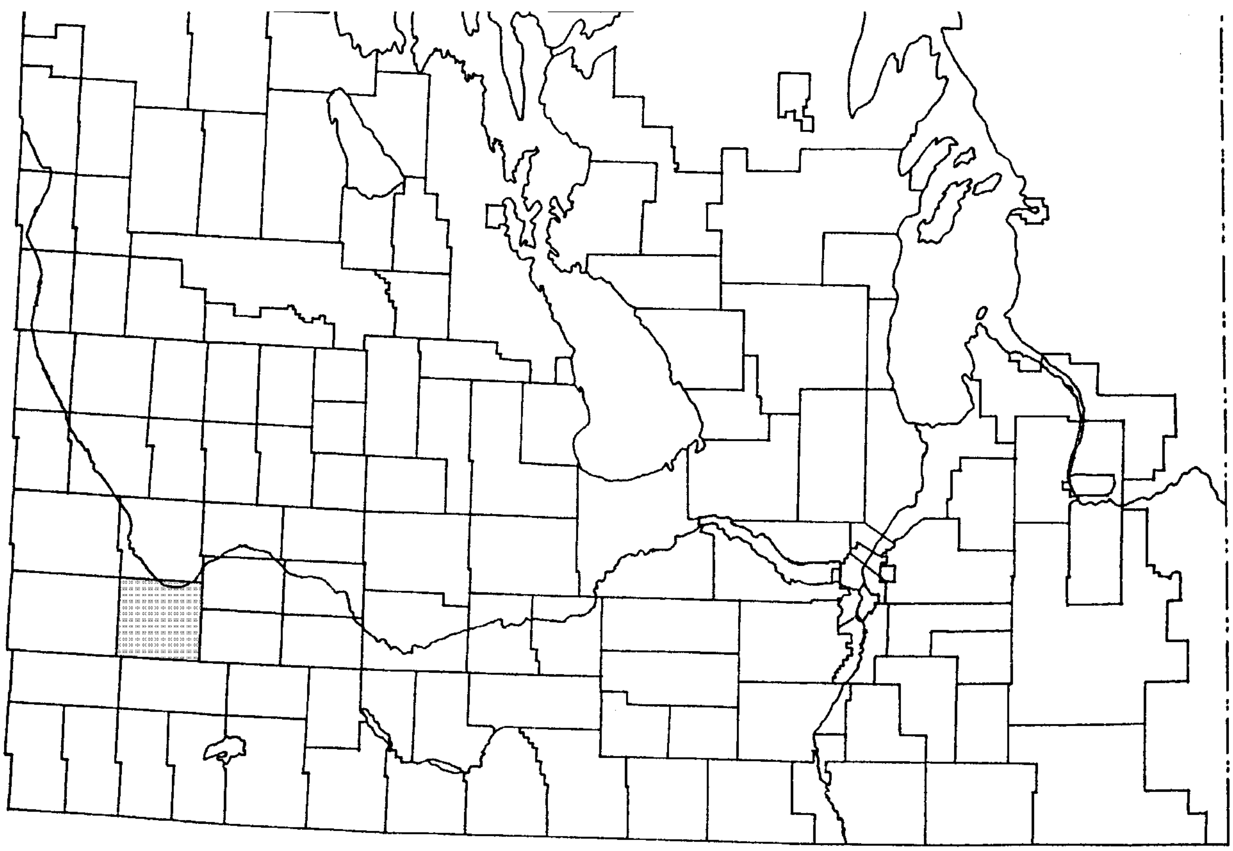

Figure 3.1a Location of the R.M. of Sifton

Rural Municipality of Sifton

No. 94

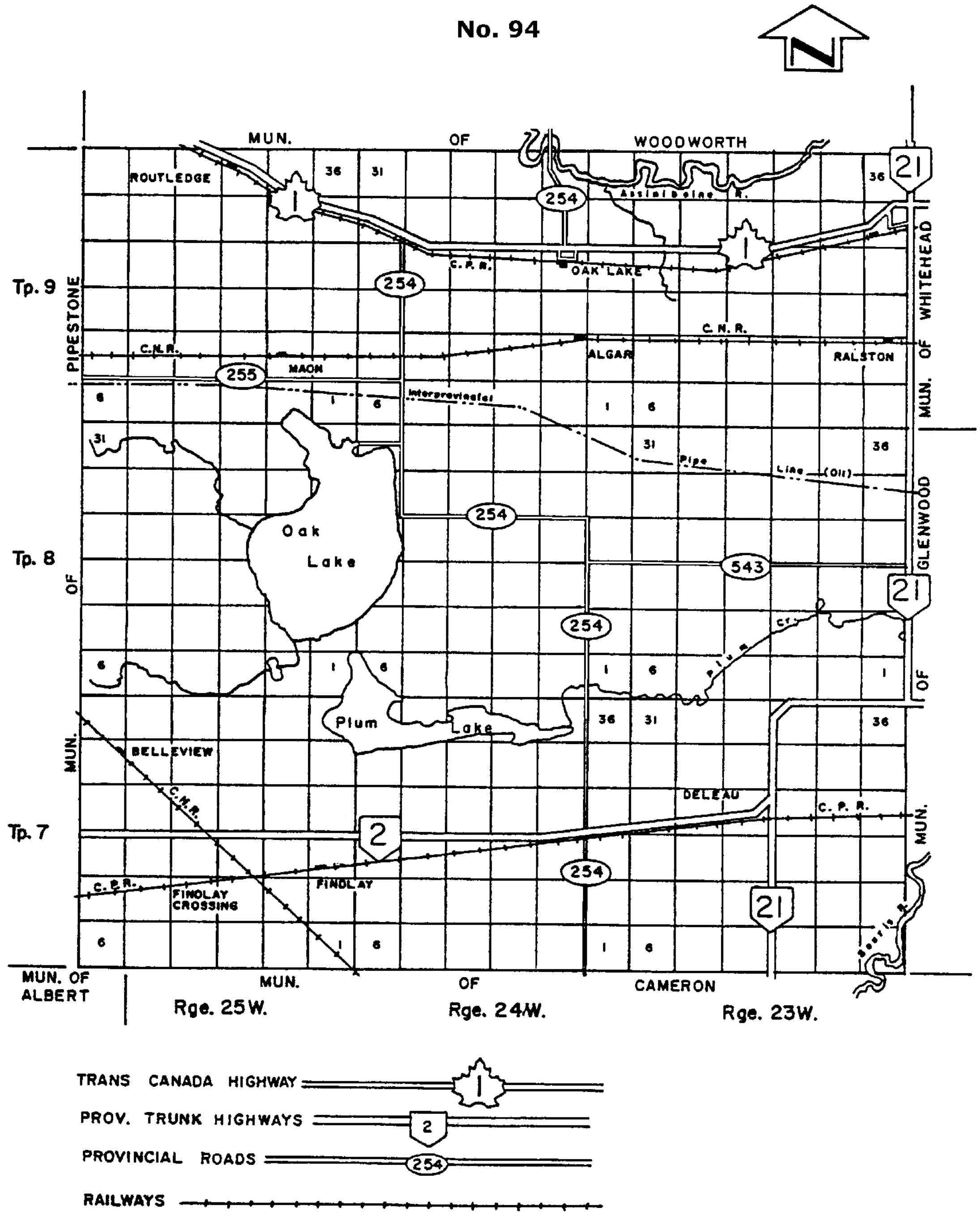

Figure 3.1b Land Locations in the R.M. of Sifton

The Virden Oil Field touches the north-western corner of the R.M. of Sifton at Township 9, Range 25.

No public water system is in place in the R.M. of Sifton or the Town of Oak Lake. Water supply in the area originates from individual wells on-site.

A sewage system services the Town of Oak Lake but is unavailable in the R.M. of Sifton. A wastewater lagoon serving the Town of Oak Lake is located in the south half of 29-9-24W.

Regular garbage pickup service is available in the Town of Oak Lake but is unavailable in the R.M. of Sifton, where waste transfer sites located at SE 23-9-24W, SE 31-8-24W and SW 28-7-23W are used for waste disposal. The wastes generated from the town and the R.M. are eventually disposed of in the solid waste disposal ground located at SE 23-8-24W.

The R.M. of Sifton is a member of the West Souris River Conservation District.

- Topography and Soil Information

A large portion of the municipality occurs in the Antler River – Lake Souris Plan. The total area of the R.M. is approximately 87,000 ha (Information Bulletin 97-13).

The elevation of the R.M. is 437 m.a.s.l. This area is characterized by level to undulating topography with local hummocky (duned) areas and several small water bodies (Oak Lake and the Plum Lakes). Slopes of 0 to 2 percent cover 45 percent of the land (not including water) area, and an additional 45 percent of the land contains slopes of 2 to 5 percent (AAFC Information Bulletin 97-13).

The dominant surficial soil in the RM of Sifton is moderately coarse textured. Ninety-two percent of the land area ranges from loamy fine sand to fine sandy loam. Based on dominant soils and slopes, 52.7 percent of land is classified as prime agricultural land (Class 1—0.0 percent, Class 2—6.1 percent and Class 3—46.6 percent), 41.7 percent as marginal lands (Class 4—1.9 percent and Class 5—39.8 percent) and 5.6 percent as unsuitable for dryland agriculture (Class 6—2.4 percent and Class 7 of 3.2 percent).

As shown in Figure 3.2, the land use in the R.M. is mainly grasslands and forage, covering approximate 60 percent; and annual crop land, covering approximately 19 percent. The remainder consists of trees and wetlands.

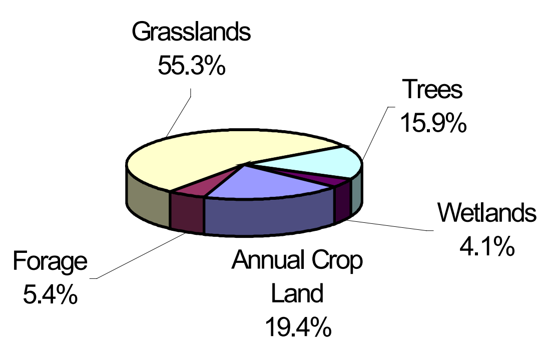

Figure 3.2 Land Use in R.M. of Sifton

- Hydrological and Hydrogeological Information

The average annual precipitation in the R.M. of Sifton is 460 mm (349 mm rainfall and 111 mm snowfall). Most summer precipitation, about 300 mm, is used by the vegetation cover. Most snow meltwater and spring rainfall infiltrates and recharges the aquifer. There is little runoff from the area.

The surface water in the area consists primarily of Oak Lake, Plum Lake, part of Maple Lake and some surface waterways (Figure 3.3). The Assiniboine River also flows through the northern extreme of the municipality. The runoff direction is mainly from west to east. Oak Lake is fed by the Oak Lake Aquifer and Pipestone Creek. The latter usually flows during spring and summer but is often dry by fall.

The Plum Lake area and Maple Lake are drained by Plum Creek and the Maple Drain, respectively.

The main water supply in the R.M. of Sifton is the Oak Lake Aquifer (Figure 3.4), which is an unconfined aquifer; composed mainly of medium to fine grained sand with some gravel areas in the southwest. The Oak Lake Aquifer underlies almost the entire R.M. of Sifton. The water table is within 1.5 to three metres of the ground surface, and slopes toward the lakes and the surface waterways. The aquifer thickness varies considerably between zero and 27 metres, and supplies the water for the Town of Oak Lake and the farmsteads and residences in The R.M. of Sifton.

The aquifer water quality is good, however, stream flow, which provides some of the aquifer's recharge, has been found to occasionally contain trace levels of commonly used agricultural chemicals that are well below the guideline limits for drinking water.

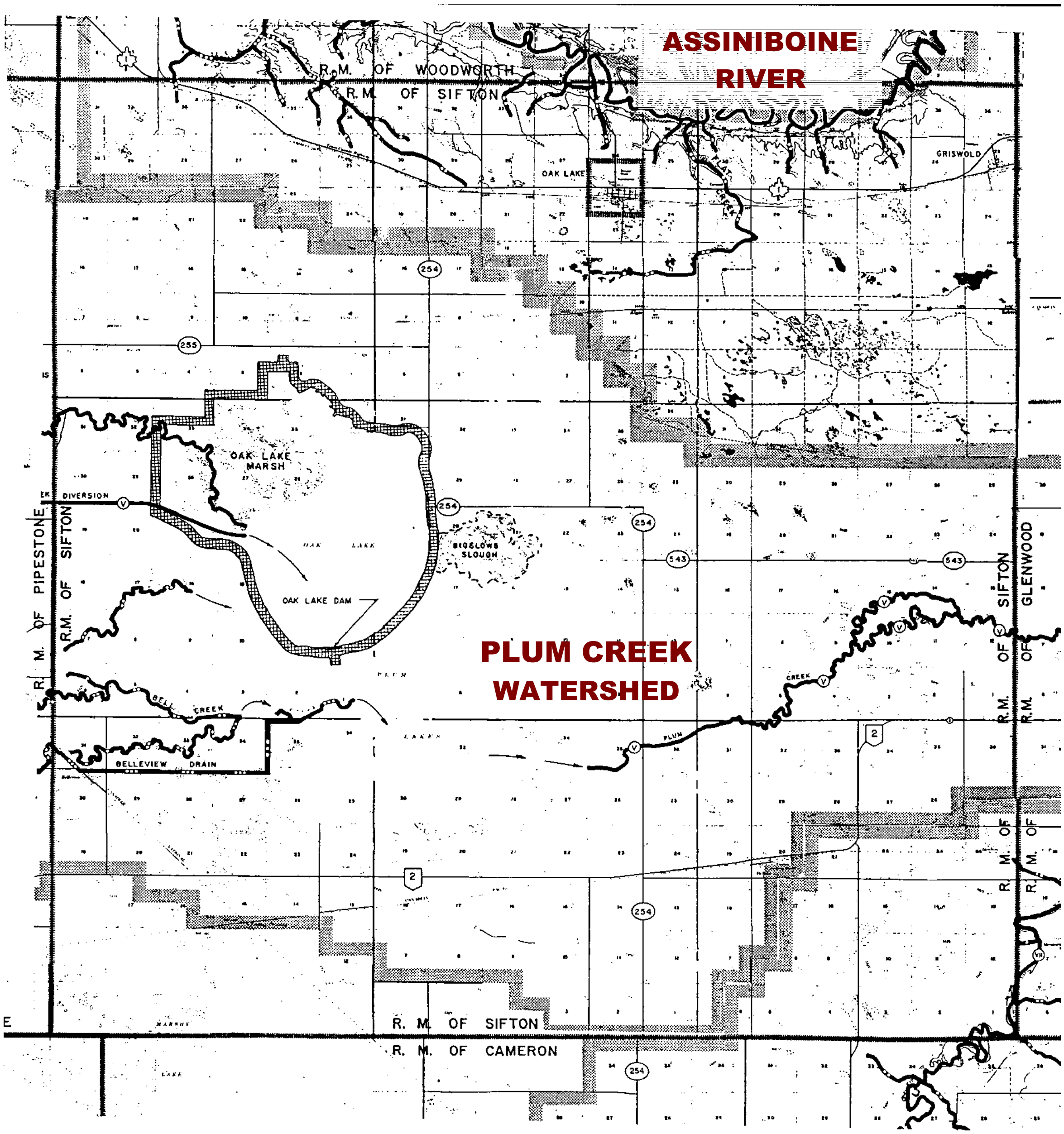

Figure 3.3 Drainage System in the R.M. of Sifton

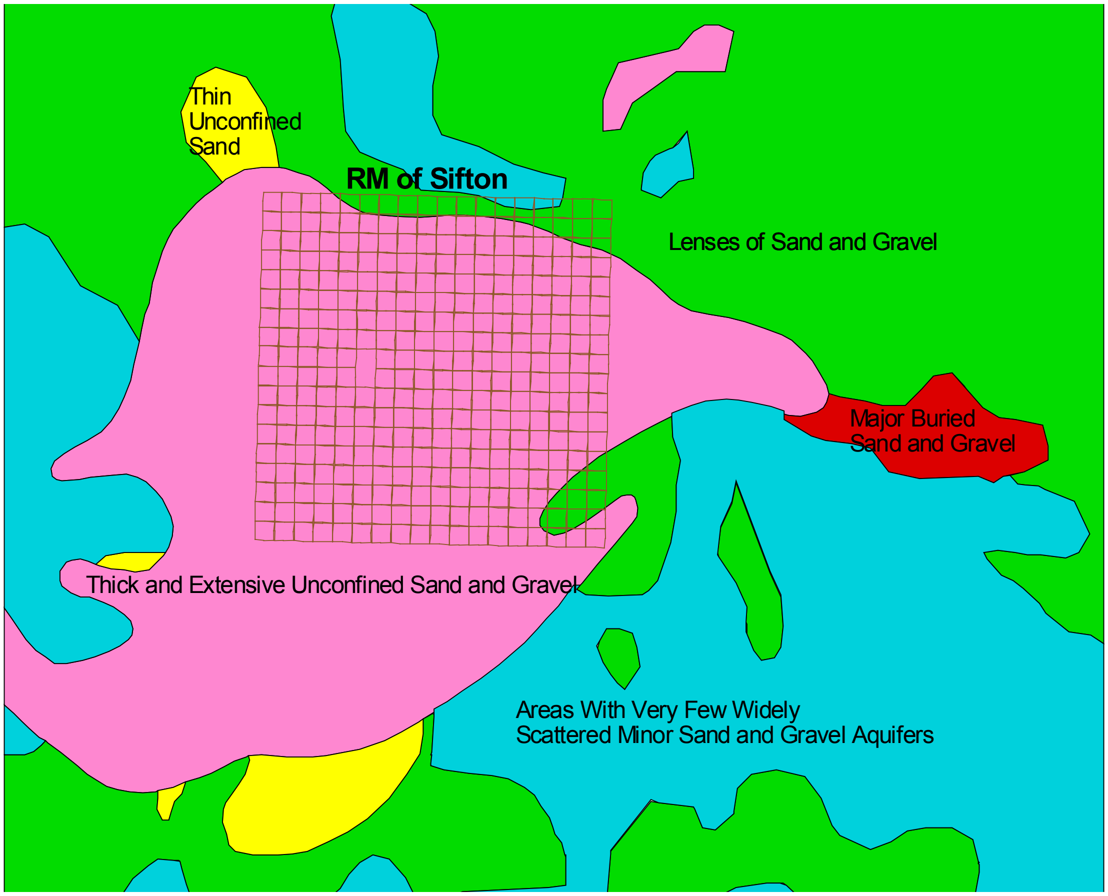

Figure 3.4 Sand and Gravel Aquifer in the R.M. of Sifton

3.2 Roland

- <u>General</u>

The Rural Municipality of Roland is located in the Central Plains of Manitoba. Figure 3.5a shows its location, and Figure 3.5b shows the land locations of the Municipality.

The population of the R.M. is approximately 990; the Town of Roland is the most populated area, with approximately 350 residents.

The traditional economic activity in the R.M. is agriculture and agriculture-related services and supplies. A total of 16 businesses are documented in the municipality. None of these significantly contributes to the input of nutrients in the R.M., except the fertilizer dealer.

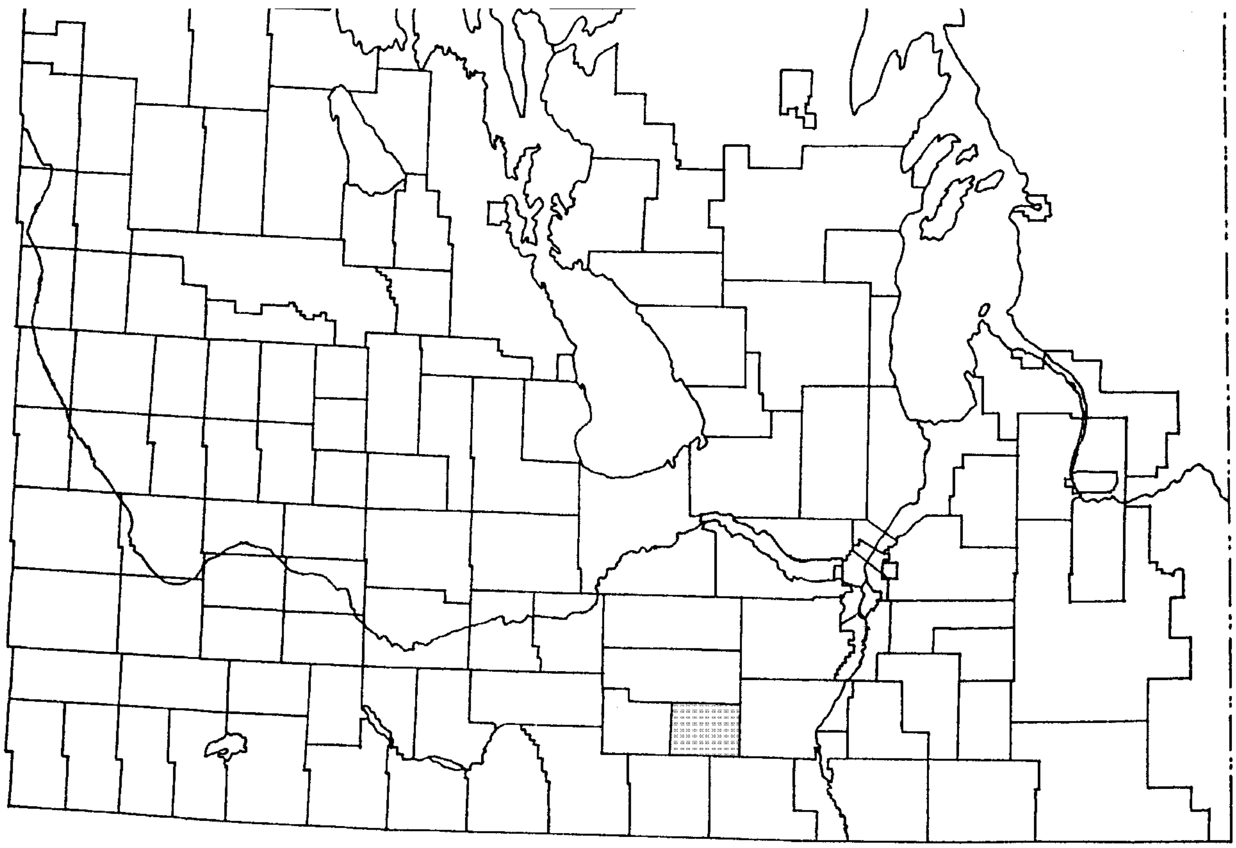

Figure 3.5a Location of the R.M. of Roland

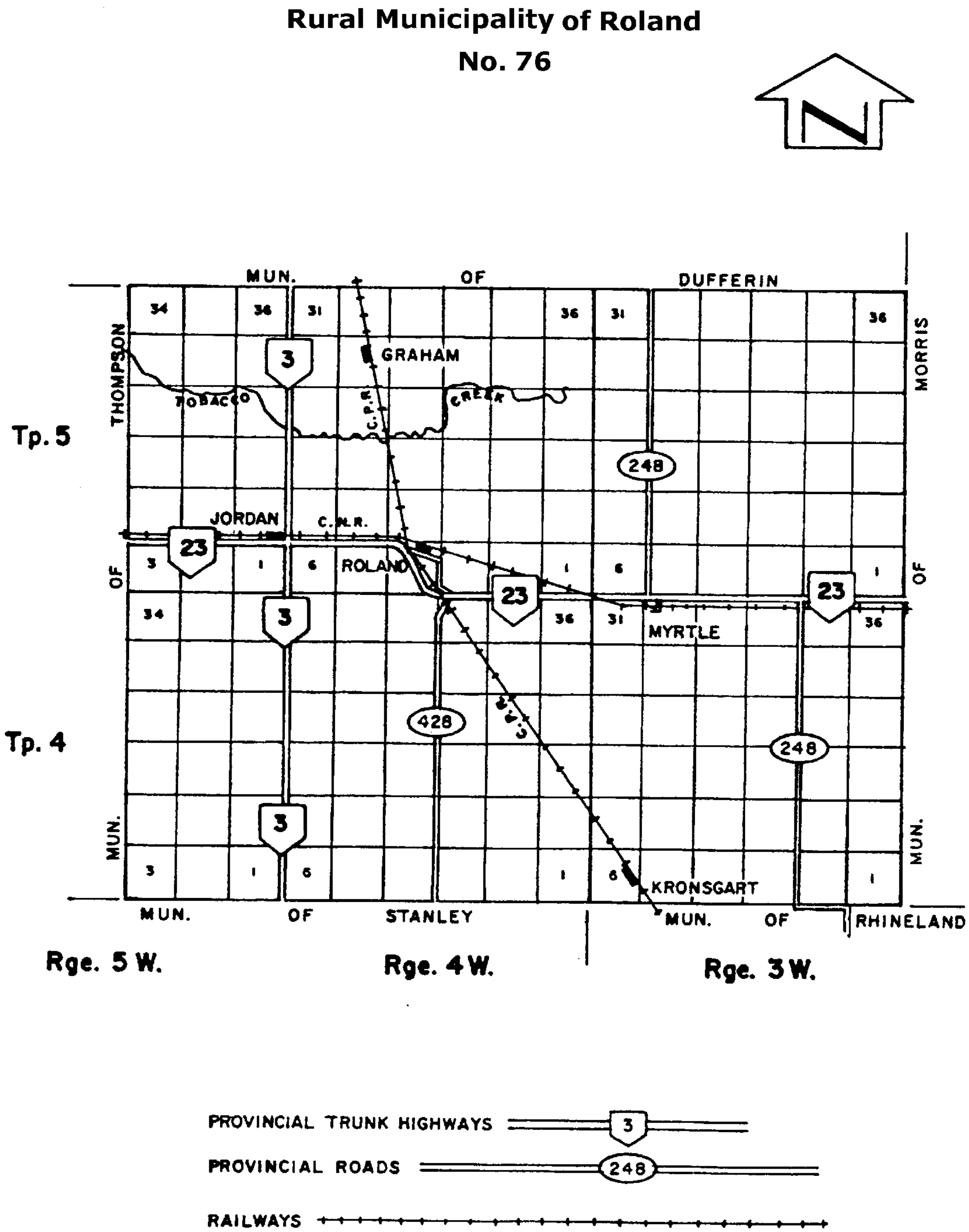

Figure 3.5b Land Locations in the R.M. of Roland

Water utilities service the Town of Roland and the Village of Myrthe. Outlying areas rely upon individual on-site wells. The major sources of water for the R.M. are the Winkler Aquifer and the Red River.

A sewage system services the Town of Roland. The wastewater from the village is treated in a domestic lagoon. The lagoon is located at NW2-5-4W and has a surface area of approximately five acres. The system serves approximately 350 people. In areas not covered by piped sewer, on-site septic fields are employed.

Regular garbage pickup service is available. Residential and commercial solid wastes are collected and disposed of at the R.M. of Roland waste disposal grounds, which cover five acres at SE3-5-4W.

- Topography and Soil information

The R.M. of Roland lies completely within the Red River Valley physiographic subsection (Canada –Manitoba Soil Survey, 1980) with an area of approximately 48,529 ha (Information Bulletin 97-13).

Elevations range from 305 m.a.s.l. in the west portion to a low of 260 m.a.s.l. in the east. The land is characterized as level, with an average slope of approximately 0.2 percent or less over 99.8 percent of the area. The land portion for the Town of Roland and drainage ditches were not considered in this percentage.

The dominant surficial soil in the RM of Roland is fine to moderately coarse textured deposits. Among the upper most soils clay occupies 63.7 percent, loam 28.8 percent, coarse loam 7.2 percent and sand 0.3 percent. The topsoil is usually underlain by clay in the west part of the R.M. and deep clay deposits are dominant in the east part. The soil in the RM of Roland is arable, up to 99 percent of land base is classified within the class 3 capability for agriculture (Class 1 - 21.3 percent, Class2 - 42.8 percent and Class 3 - 34.8 percent).

The vegetation is predominantly annual crops (cereal grains, canola, corn, sunflowers, beans, etc.), that cover 90 percent of the landbase. Forest, grassland and forage cover 5.5 percent of the landbase, with the remainder (4.5 percent) used for non-agricultural application (Figure 3.6).

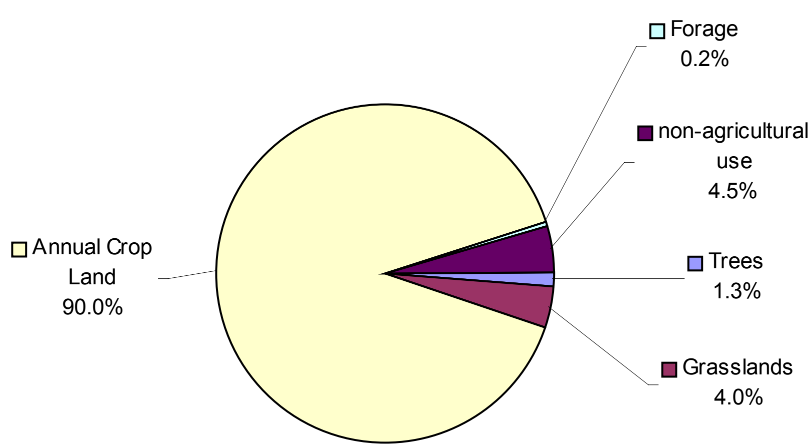

Figure 3.6 Land Use in the R.M. of Roland

- <u>Hydrological and Hydrogeological Information</u>

The average annual precipitation in the R.M. of Roland is 521 mm (399 mm rainfall and 122 mm snowfall). The drainage capacity of the soils in the R.M. varies between poor (22.7 percent) to imperfect (58.5 percent), resulting in inadequate soil drainage for most of the growing season.

The drainage system in the RM of Roland consists of natural creeks, including Tobacco Creek, Graham Creek, North Shannon Creek and Shannon Creek, and some artificial drains that are ordered from first to fifth (Figure 3.7). The dominant runoff direction is from west to east.

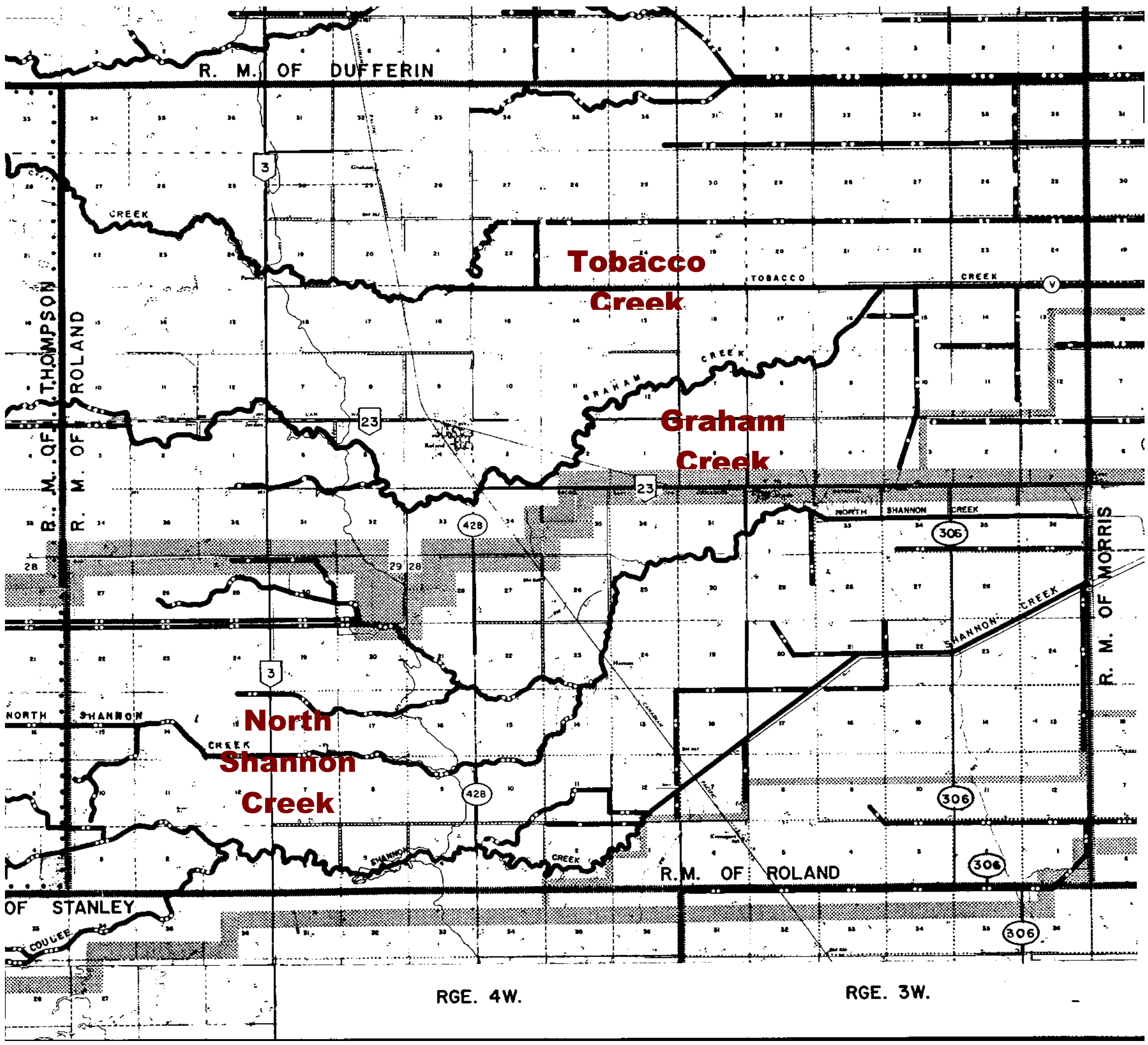

Figure 3.7 Drainage System in the R.M. of Roland

The R.M. of Roland contains plenty of groundwater stored both in bedrock aquifers situated more than 100 metres below ground, and in sand and gravel aquifers buried 30 to 60 metres below ground. Much of the stored groundwater in the area is not potable, however, because of its high salinity.

Three bedrock aquifer formations are found in the R.M. of Roland (Figure 3.8a). They are: the Limestone, Sandstone and Shale (Jurassic formation) occupying an area of approximately 68 percent; Carbonate Rock (Paleozoic Carbonate rock formation) approximately 28 percent and the Sandstone and Sand (Cretaceous Swan River formation) approximately six percent. The total dissolved solids (TDS) in the water from these bedrock aquifers are higher than 5000 mg/L, which makes water unsuitable for domestic use.

The sand and gravel aquifers in the R.M. of Roland are shown in Figure 3.8b. Lenses of sand and gravel aquifers underlie approximately 90 percent of the area. Water in this aquifer is not potable but may be acceptable for some livestock.

The only fresh water aquifer in the R.M. of Roland is the Winkler aquifer, which is a buried sand and gravel aquifer. The northern edge of the Winkler Aquifer touches the southwestern corner of the R.M. (Figure 3.8b). The fresh water supply from this aquifer is limited to within approximately 50 metres of the ground surface. The water in the deeper layer is saline (Table 1).

Table 3.1 Water quality change with depth in Winkler aquifer
(Well location: NE11-4-5W)

Test items	Sample Depth (meters below ground)		
	39-42	45-49	53-56
Na (mg/L)	57	88	1225
Ca (mg/L)	122	125	348
Mg (mg/L)	48	53	124
Cl (mg/L)	52	128	2300
SO_4 (mg/L)	226	240	366
HCO_3 (mg/L)	400	351	480
TDS (mg/L)	698	888	5176

Two municipal wells located at SE11-4-5W, drawing water from 18 to 32 metres below ground, serve the Town of Roland. Fresh water in the rural areas comes mainly from surface water sources such as the Red River and the Patterson Pit Reservoir.

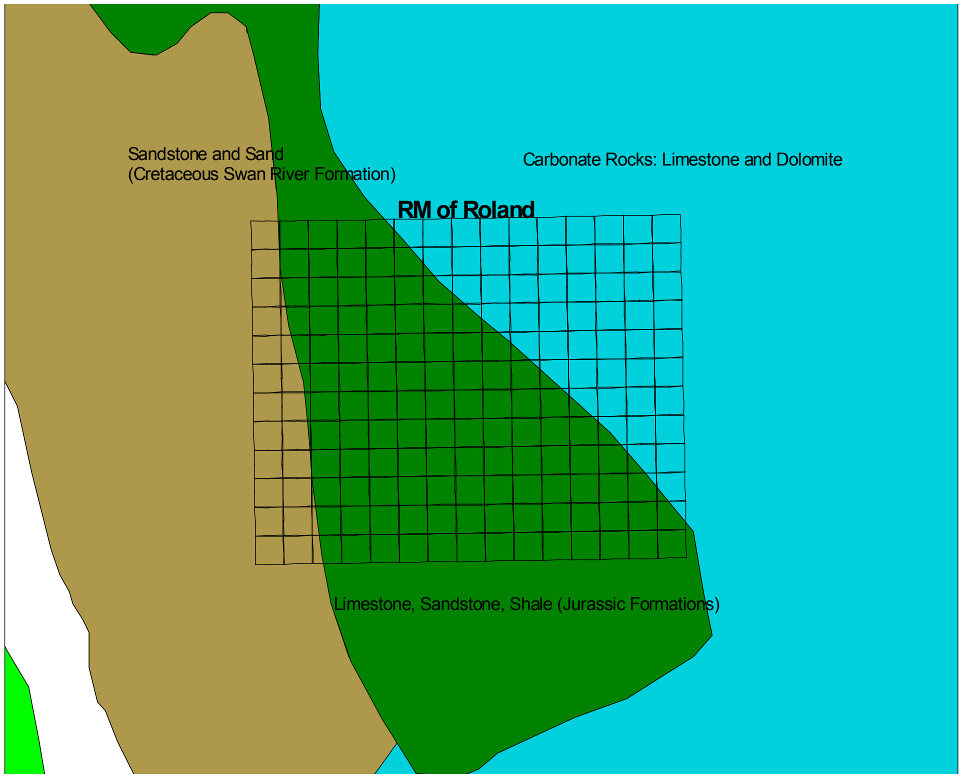

Figure 3.8a Bedrock Aquifer in R.M. of Roland

Figure 3.8b Sand & Gravel Aquifer in R.M. of Roland

3.3 Hanover

- <u>General</u>

The Rural Municipality of Hanover is located in the Eastman region of southeastern Manitoba. There are two additional municipalities incorporated within in this area: the City of Steinbach and the Town of Niverville. The location of the R.M. of Hanover is shown in Figure 3.9a. The land location map is shown in Figure 3.9b.

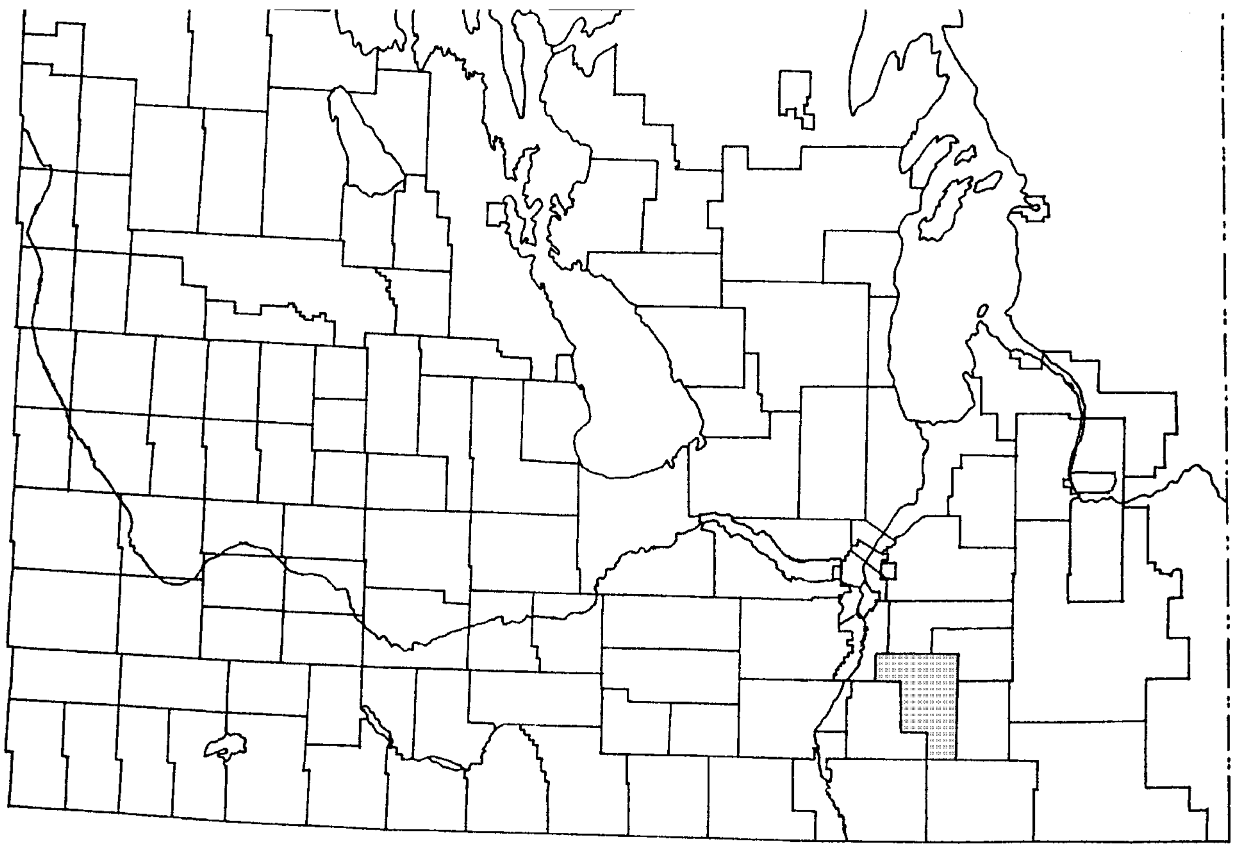

Figure 3.9a Location of the R.M. of Hanover

The R.M. of Hanover has a population of approximately 9,830. Agriculture is the predominant industry in the R.M., with most residents either directly employed in agriculture, or in agricultural businesses and support services. The economy in the R.M. of Hanover is characterized by diverse agriculture including dairy, hogs, poultry, honey, and potatoes, which has made Hanover a leader in the production of many of these products in Manitoba. Hanover has been highly productive in hogs since the 1940's, however in last twenty years the area has began to specialize in this commodity. This specialization created the need for agriculture-related services such as feed mills, transportation, farm implements and other agriculture services that make up the economic base of Hanover today (Excerpts from the book, "Hanover: One Hundred Years" by Lydia Penner). Several small towns and villages (Blumenort, Grunthal, Kleefeld, Mitchell, New Bothwell and Randolph) scattered in the R.M. provide agricultural and other services in addition to the Town of Niverville and the City of Steinbach.

Rural Municipality of Hanover
No. 40

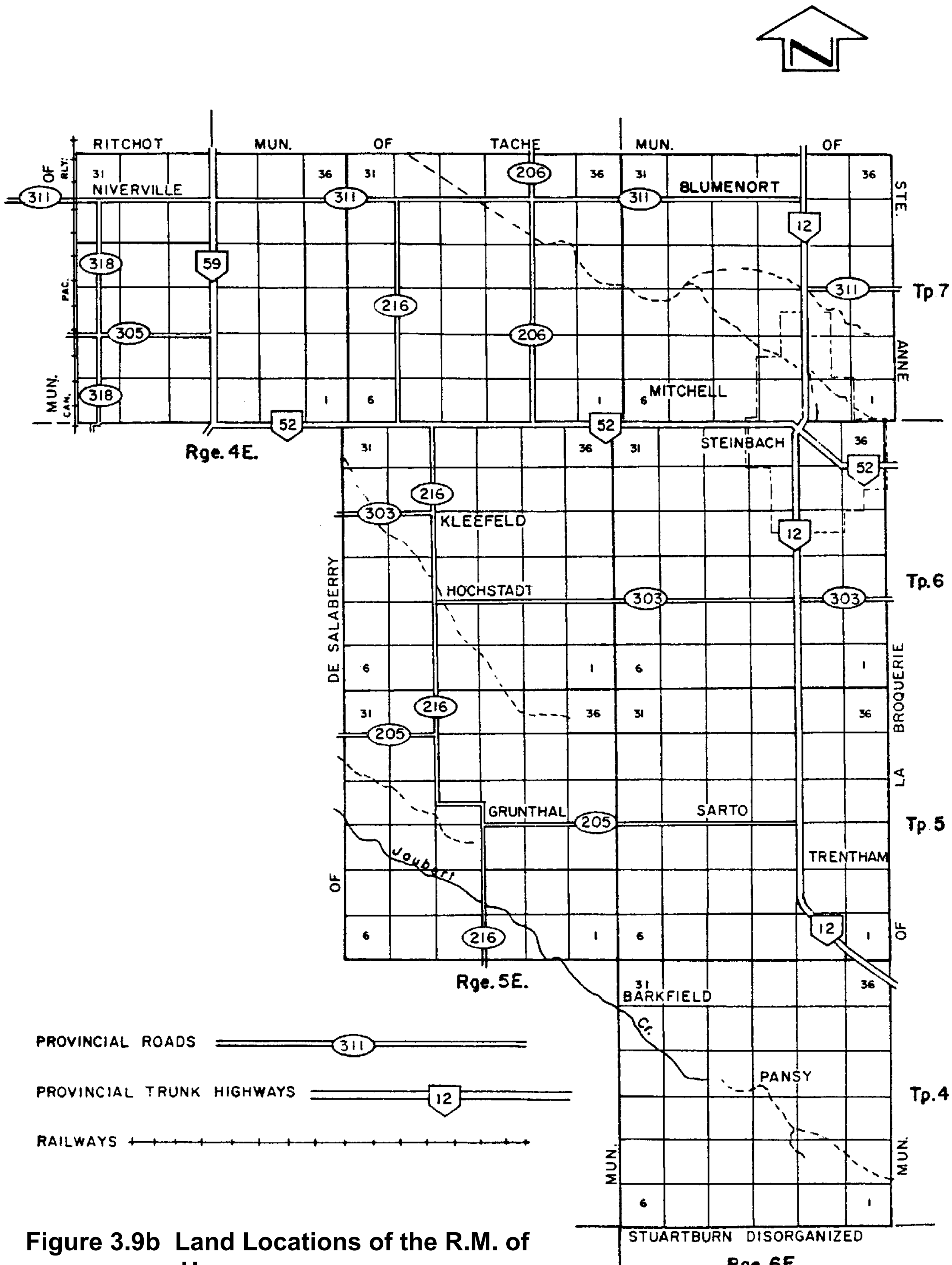

Figure 3.9b Land Locations of the R.M. of Hanover

The City of Steinbach is the largest population and service centre in the district, as well as the largest in southeastern Manitoba, with a population of approximately 8,500 and approximately 330 businesses. Among these businesses are Loewen Windows, Canada's largest wood window and door manufacturer, and Biovail Corporation, manufacturer of time-release medication, both of which are world-class manufacturers. Steinbach is the hub of economic activity in southeastern Manitoba and one of the fastest growing cities in the province.

The Town of Niverville is located the north-east of the R.M. of Hanover. The town has a population of approximately 1,600. There are 54 businesses. Niverville is known as the location of the first fully operational grain elevator in Western Canada. Now, a new modern elevator has replaced the original one and provides seeds and chemicals, as well as many agricultural services, to farms in the Niverville area.

Public or co-operative water systems are in place in Steinbach, Niverville, Grunthal, Blumenort, Mitchell, New Bothwell and Kleefeld. In the rural areas, water is supplied by individual wells on-site.

Sewage systems also exist in the communities listed above. Domestic sewage in these communities is treated in lagoons before being discharged into surface waterbodies. In addition to public lagoons, some enterprises use lagoons to treat their industrial wastewater. The locations of the lagoons in the district are listed in Table 3.2.

Among these lagoons, Steinbach lagoon is a state-of-art system, consisting of one aerated cell and four facultative cells. Blumenort lagoon is presently under expansion and a new lagoon is planned for Niverville.

Table 3.2 Lagoons in Hanover District

Community	Legal description	Community / business	Legal description
Grunthal	20-5-5E	Niverville	SW 30-7-4E
Kleefeld	19-6-5E	Steinbach	8-7-6E
New Bothwell	29-7-5E	Bothwell	SE 30-7-5E
Mitchell	1-7-5E	Country Meats & Sausage	35-7-6E
Blumenort	33-7-6E		

The R.M. of Hanover has a Class 2 municipal waste disposal ground located at NW 31-6-5E. The City of Steinbach operates a Class 1 Waste Disposal Ground located at NW ¼ 23-6-6E and an Eco-Centre for oil recycling purposes.

- Topography and Soil information

Physiographically, the studied area (the R.M. of Hanover, the City of Steinbach and the Town of Niverville) is located entirely in the Manitoba Plains and consists of two distinct landscapes divided between the level to very gently sloping Red River Valley in the northern part of the district and the gently sloping, slightly ridged terrain of the Southeastern Plain in the south (Canadian –Manitoba Soil Survey, 1980).

The elevation of the land surface varies from 290 m.a.s.l. in the southeast corner of the area, decreasing to about 232 m.a.s.l. in the northwest corner (Information Bulletin 98-23). The same bulletin showed that 98 percent of the rural land (not including water) is level with slopes of zero to two percent, while the rest of the land is very gentle with slopes of two to five percent.

The surficial soils are predominantly clay (35.2 percent) in the northern area (Red River Valley), sand (31.5 percent) in the southern area (southeastern Plains) and loam (18.6 percent) and coarse loam (11.3 percent) in between.

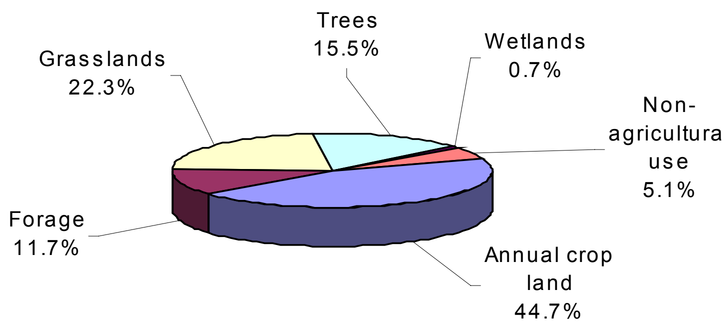

Figure 3.10: Land Use in the R.M. of Hanover

Much of the land in Hanover is not ideally suited to grain farming. Annual cropland, which is mainly located in the northern clayey area, covers 44.7 percent of the total available land. The vegetation on the course texture soils is mainly grassland, trees and forage which occupy 22.3 percent, 15.5 percent and 11.7 percent of the landbase, respectively (Figure 3.10).

- Hydrological and Hydrogeological information

The average annual precipitation is 510 mm (411 mm rainfall and 99 mm snowfall) in the R.M. of Hanover and the City of Steinbach, and 489 mm (393 mm rainfall and 96 mm snowfall) in the Town of Niverville.

The drainage condition in Hanover district is not good because of the low surface gradient. The soil drainage of the available land are ranged from rapid (3.2 percent), well (3.2 percent), imperfect (69.9 percent), poor (20.8 percent) to very poor (2.8 percent). The soils keep wet for significant part of the growing season. Surface waters drain very slowly in a northwesterly direction via Joubert and Tourond Creeks and their tributaries. Surface drainage for agricultural purposes is facilitated via a network of man-made drains constructed to enhance runoff and reducing the duration of surface ponding. The drainage system in the R.M. of Hanover is shown in Figure 3.11.

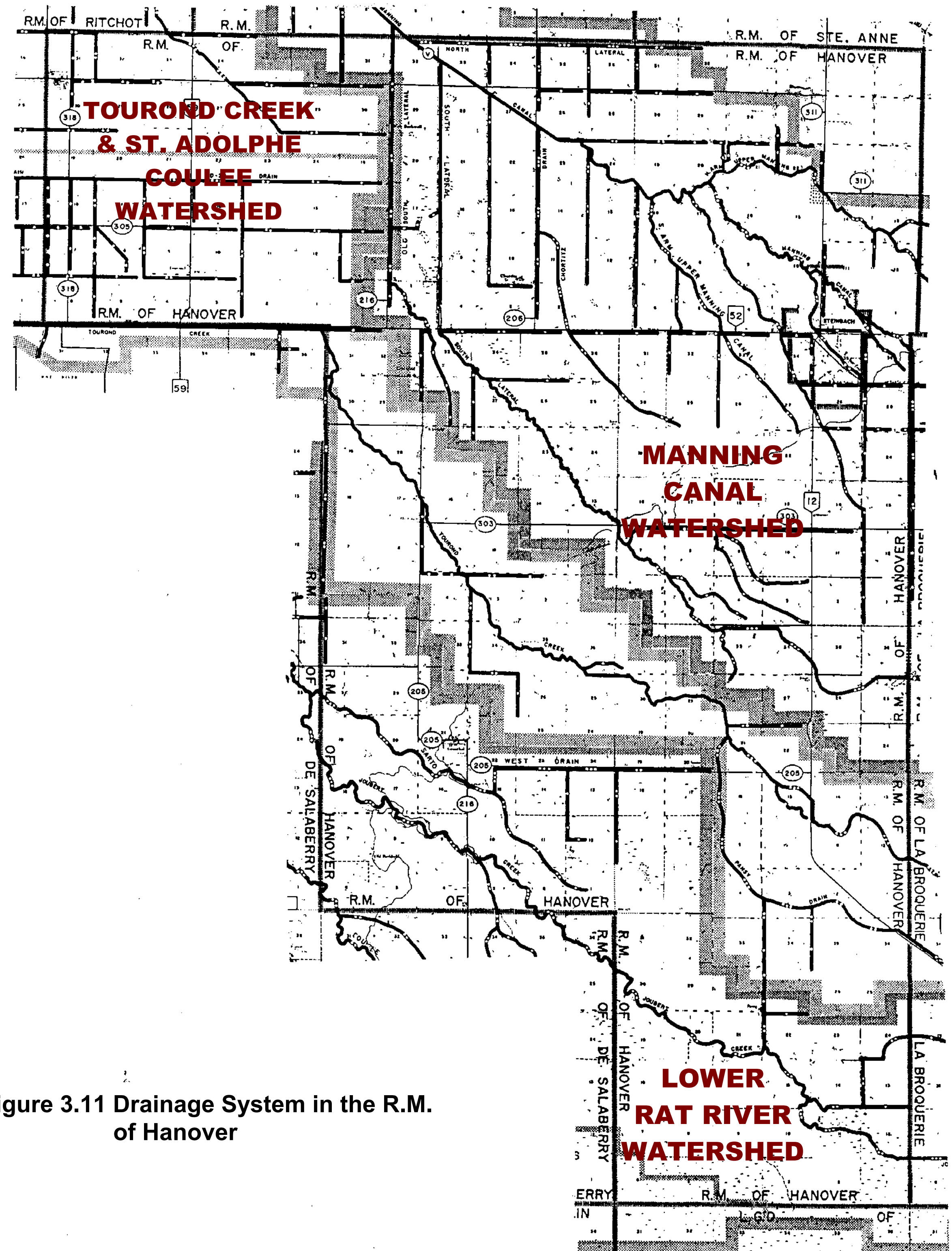

Figure 3.11 Drainage System in the R.M. of Hanover

The total groundwater supply in the district is abundant. The district employs mixed aquifers of Carbonate Rock and Sand & Gravel as water sources. Sand and gravel aquifers in the district are mainly lenses of sand and gravel. A small portion of a major buried sand and gravel aquifer is available in township five, range five.

The groundwater quality ranges from good to excellent. Based on the well logs provided by Manitoba Conservation, Water Resources, the total dissolved solids ranged from 117 to 372 mg/L in the samples from the carbonate aquifer, and ranged from 256 to 562 mg/L in the samples from the sand and gravel aquifer. Nitrate-nitrogen was reported from less than 0.01 to 0.24 mg/L in the samples from the carbonate aquifer and from 0.07 to 0.24 mg/L in the samples from the sand and gravel aquifer.

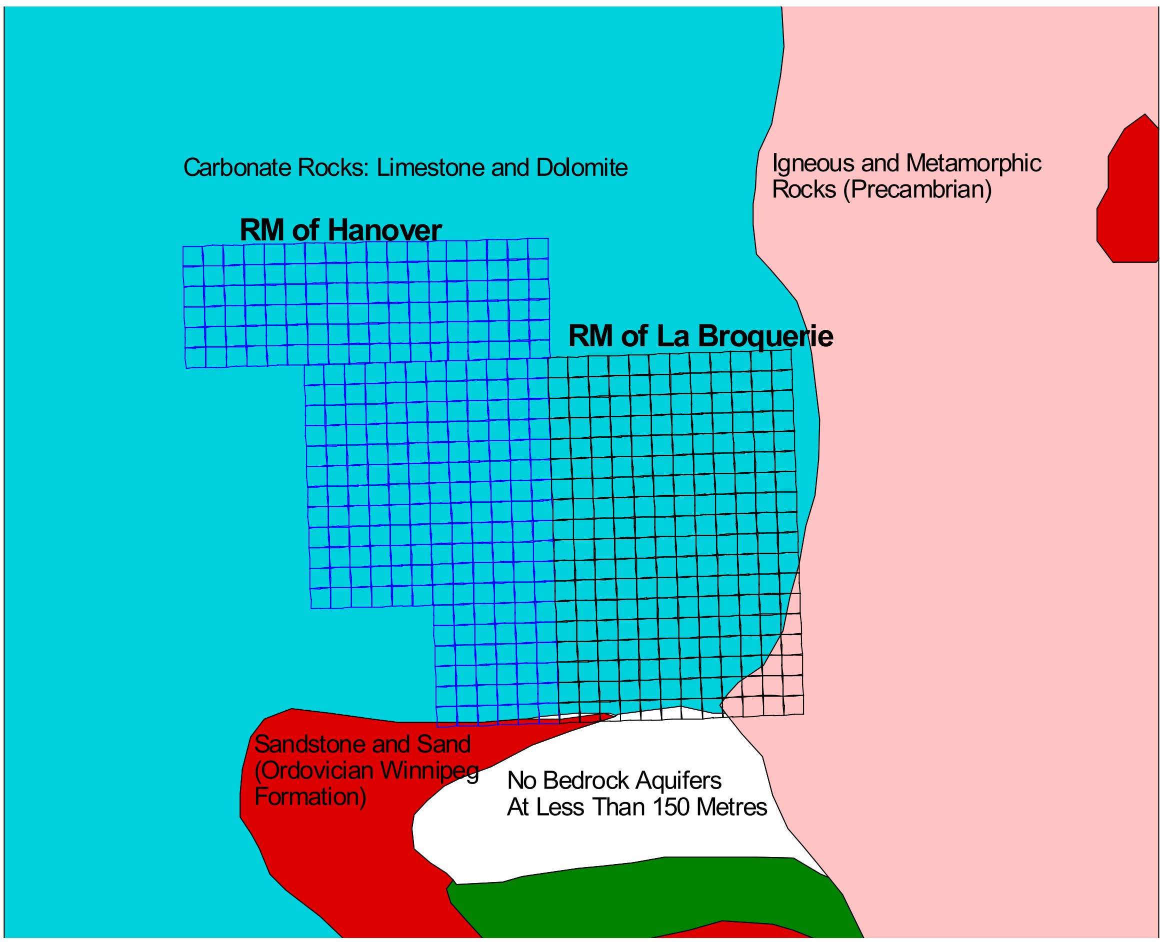

Figure 3.12a Bedrock Aquifers in the R.M.s of Hanover and La Broquerie

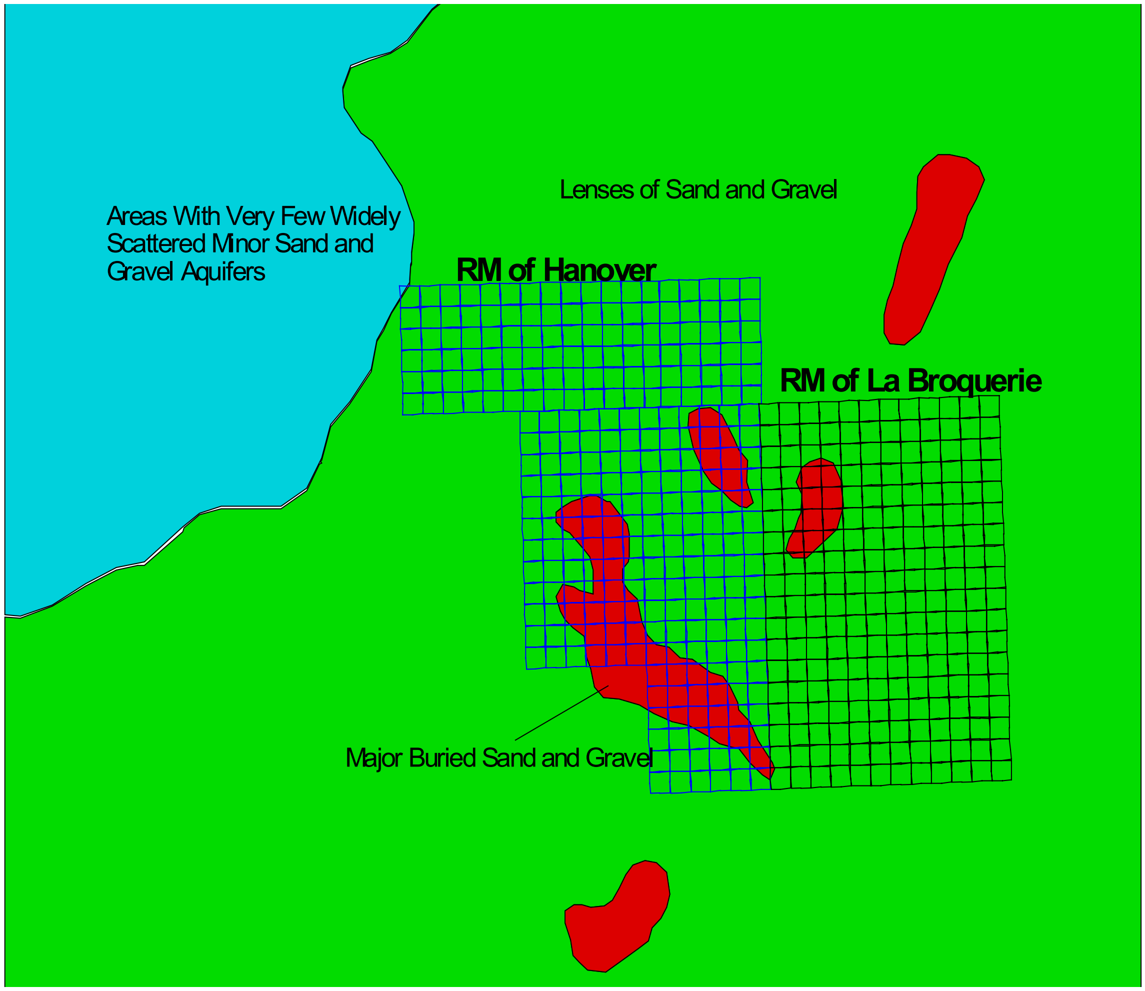

Figure 3.12b Sand and Gravel Aquifers in the R.M.s of Hanover and La Broquerie

3.4 La Broquerie

- General

The Rural Municipality of La Broquerie is located in south-eastern Manitoba. The Village of La Broquerie is the largest population and service centre in the R.M., as the population in the municipality is mainly rural and farm-based. Figure 3.13a shows La Broquerie's location in Manitoba, and Figure 3.13b shows its land descriptions.

The population of the R.M. of La Broquerie is approximately 2,500. The municipality has a diversified mix of agriculture, forestry, and livestock operations. The municipality is one of Manitoba's largest dairy centres with 36 dairy farms, in addition to 26 major pork producers, 26 beef producers, and seven poultry producers. There are 59 commercial businesses in the R.M., which are mainly service-orientated.

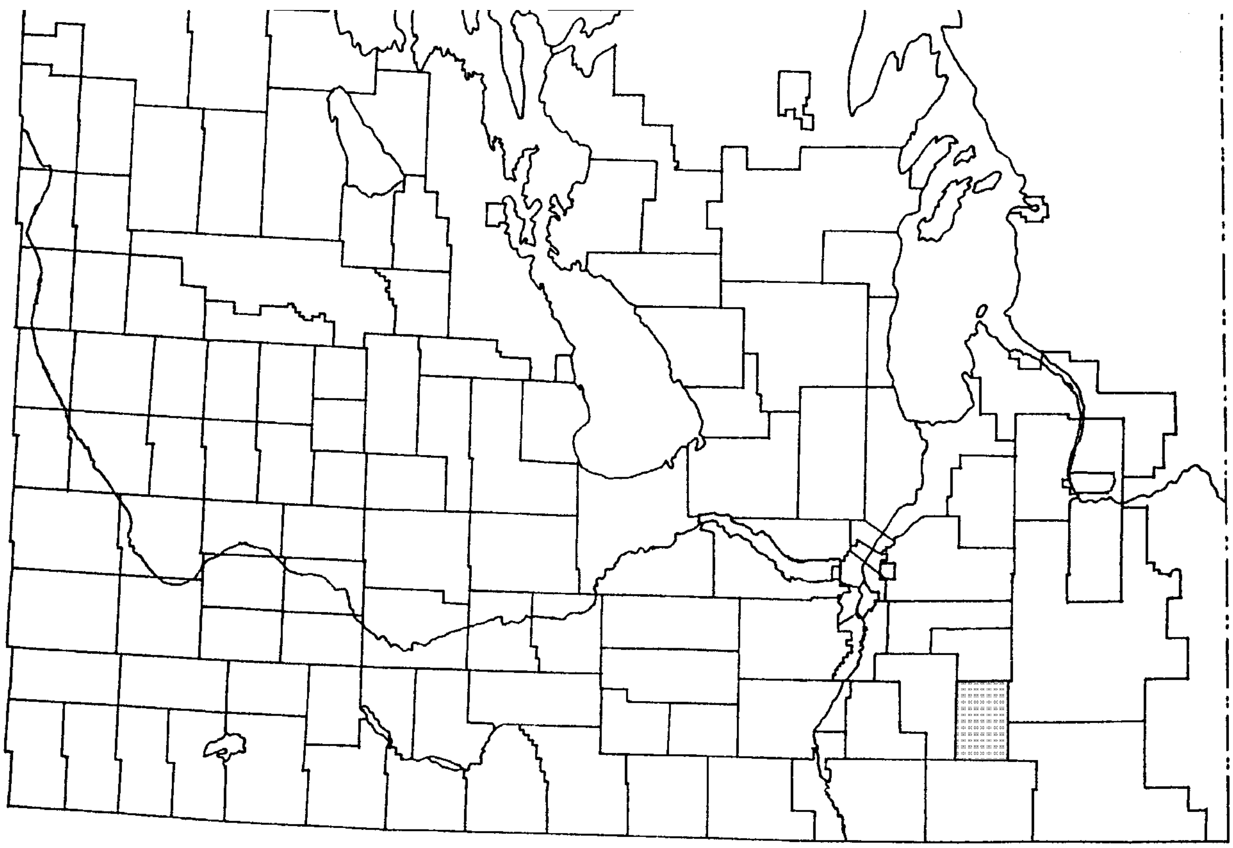

Figure 3.13a Location of the R.M. of La Broquerie

Rural Municipality of La Broquerie

No. 43

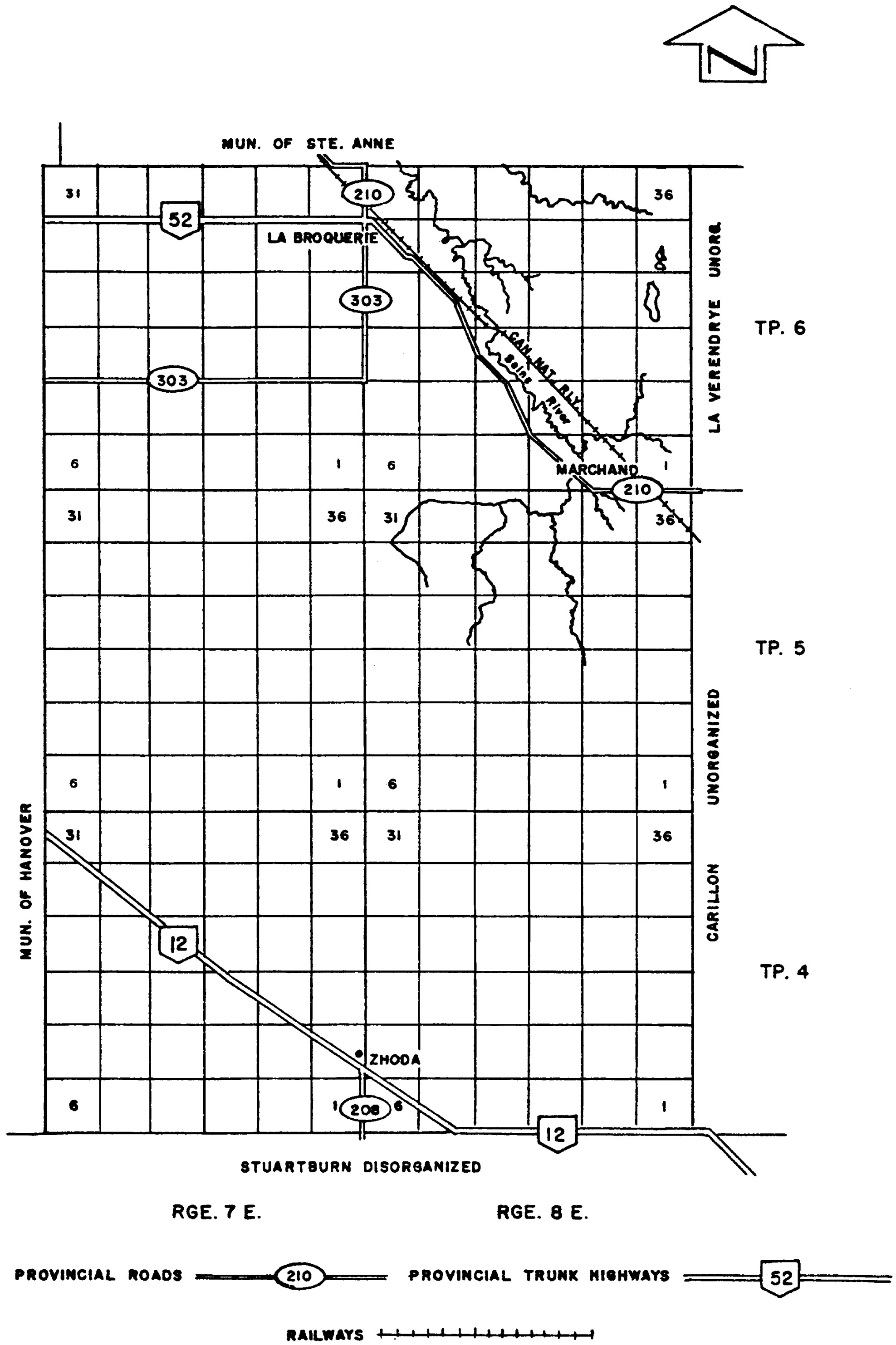

Figure 3.13b Land Locations in the R.M. of La Broquerie

No public water system is established in the R.M. of La Broquerie. Water supply in the municipality originates from individual wells on-site.

A sewage system is in place in the Village of La Broquerie, but not in the rural areas. There is a wastewater lagoon located at N½ 31-6-8E serving approximately 650 people in the village. In rural areas, sewage is handled by on-site septic fields.

Regular garbage pickup service is available at the Village of La Broquerie. The waste is delivered to the City of Steinbach waste disposal grounds.

- Topography and Soil Information

Physiographically, the R.M. of La Broquerie occurs almost entirely in the Southeastern Plain Section of the Manitoba Plain (Canada-Manitoba Soil Survey, 1980). A small portion of the Red River Valley touches the northwest corner of the municipality.

The elevation of the land surface varies from 315 m.a.s.l. in the southeast, decreasing gradually to 232 m.a.s.l. in the northwest (Information Bulletin 98-24). The same bulletin showed that more than 98 percent of the land in the R.M. is characterized as level (with slopes of 0-2 percent) and rest of the land is very gentle with slopes of 2-5 percent.

Soil materials in the R.M. of La Broquerie are primarily coarse textured. Coarse textured soils cover 72.0 percent of the total area, of which 64.6 percent are sands and 7.4 percent are coarse loams. Other textures occurring in the R.M. are medium texture (loams to clay loams, 8.5 percent) and organic (18.8 percent). Clay is very scarce, occupying only 0.7 percent of the area.

Much of the land in La Broquerie is not suitable for annual agriculture. Approximately 70 percent of the land is rated beyond class 4 for agricultural capability, mainly because of the limitation of moisture and excess water. The percentages of land use in the R.M. are shown Figure 3.14.

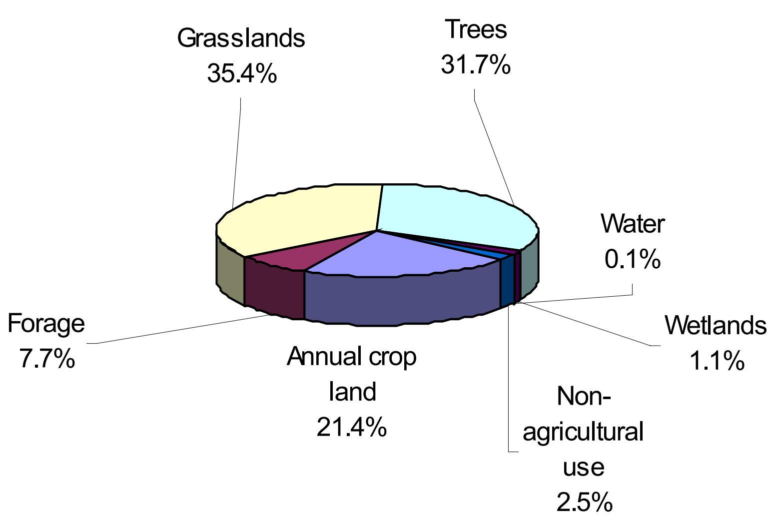

Figure 3.14 Land Use in the R.M. of La Broquerie

- Hydrological and Hydrogeological Information

The average annual precipitation in the R.M. of La Broquerie is 510 mm (411 mm rainfall and 99 mm snowfall).

The drainage condition in La Broquerie is poor because of the low surface gradient. The soil drainage ranges from rapid (2.0 percent), well (6.2 percent), imperfect (51.5 percent), poor (22.3 percent) to very poor (17.9 percent). The soils remain wet for a significant part of the growing season. The drainage system in the R.M. of La Broquerie is shown in Figure 3.15.

Groundwater supply is generally available throughout the R.M. and is abundant for existing requirements and for considerable new development (Figures 3.9a and 3.9b). In the northern two-thirds of the R.M. the main aquifer is formed by carbonate rock. Sand and gravel aquifers are common within the surficial deposits that overlie the carbonate rock aquifer and extensive sandstone aquifers underlie the carbonate rock aquifer at 55 m to 70 m below ground level.

In the southern one-third of the R.M., aquifers are formed by lenses and some fairly extensive deposits of sand and gravel interbedded in glacial till and other surficial deposits. An extensive flowing well and high well water levels exist in the northern part of the R.M.

Ground water quality in the area generally is good to excellent.

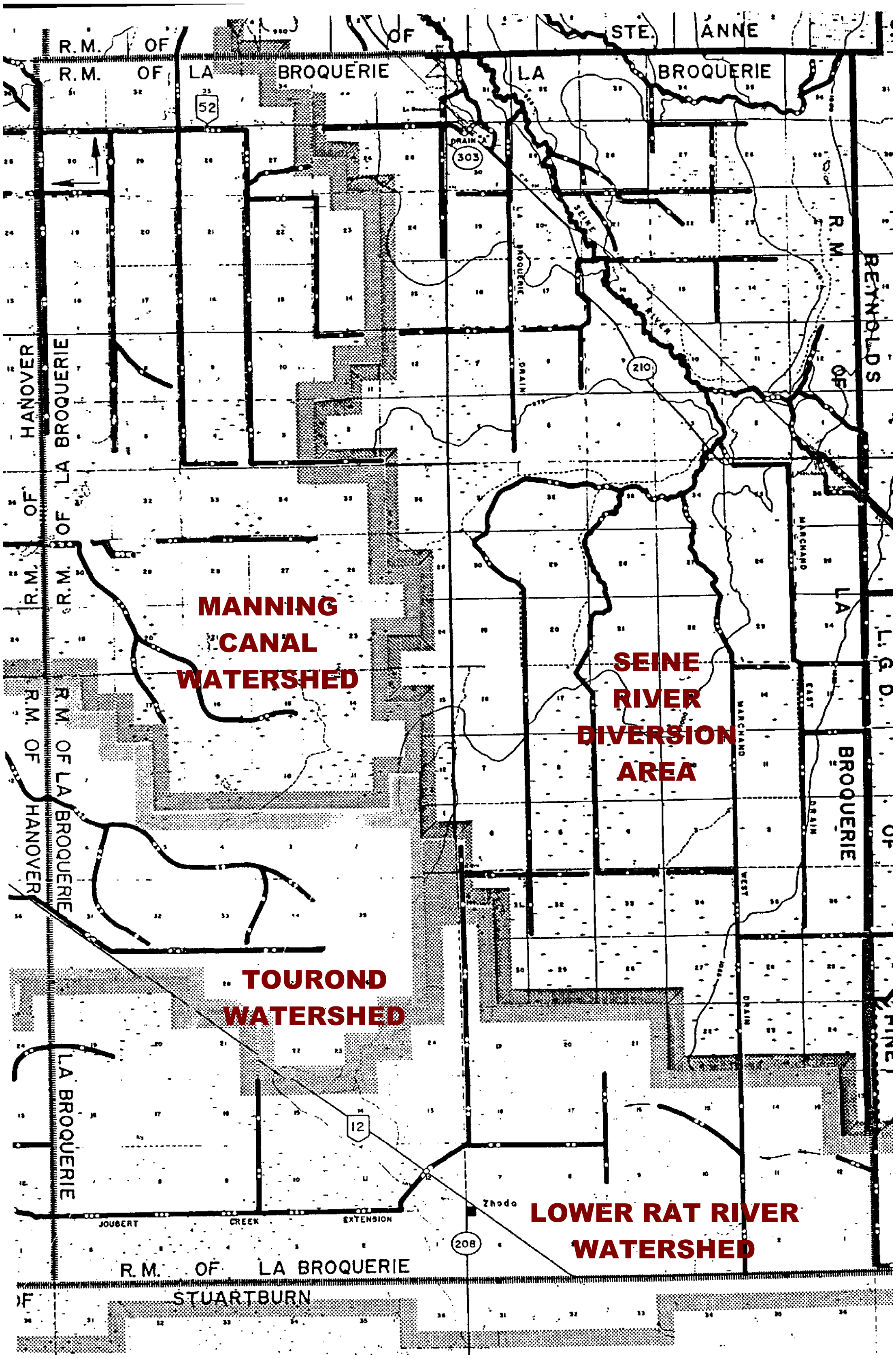

Figure 3.15 Drainage System in the R.M. of La Broquerie

4.0 METHODOLOGY

4.1 Case Farm Characteristics

Four farms were selected from the Rural Municipalities of Hanover, La Broquerie, and Sifton. Three farms were selected in the Rural Municipality of Roland. The specific location of the farms cannot be given due to confidentiality of information provided by producers. These farms were chosen through consultation with fertilizer dealers to identify farmers that performed annual soil testing. Soil test results provide an indication of the residual nitrogen and phosphorus levels in the soil. Through this consultation, it was estimated that approximately 10 percent of farmers perform annual soil testing, which made the selection of farmers willing to participate in the survey a difficult task. A personal visit was made to each producer during which the desired information was collected for the year 2000. Sufficient information was collected to estimate nutrient losses. The farmers' records were used for field activities, including crop yields, fertilizer and manure application, and for purchases and sales information of crops, livestock inputs, livestock products, and livestock.

4.1.1 R.M. of Hanover

Han A included 81 ha of wheat, 22 ha of grain corn, 107 ha of barley, and 84 ha of canola. Approximately 6 ha of land was fallowed. The livestock included 140 sows farrow to finish and 400 feeder hogs. Liquid manure for the farrow to finish operation is collected in an earthen manure storage while the manure for the feeder operation is collected by an concrete pit below the barn. No laboratory analysis was performed on the manure. Soil testing data is summarized in Table 4.2. Liquid manure (broadcast and incorporated) is applied annually to approximately 70 ha of land.

Han B included 174 ha of barley, 134 ha of oats, 60 ha of winter wheat, 64 ha of spring wheat, 348 ha of canola, 23 ha of grain corn, and 210 ha of alfalfa. The livestock included 221 dairy cows and 204 heifers. Approximately 12.7 million litres of liquid hog manure and 900,000 litres of chicken manure was purchased and spread onto fields. Approximately 1.4 million litres of milk was produced and sold by the farm. Manure is collected under a pit below the barn. No laboratory analysis was performed on the manure. Soil testing data is summarized in Table 4.2. Liquid hog manure (injected) was applied to approximately 250 ha and chicken manure (broadcast and incorporated) was applied to approximately 40 ha. Dairy manure (broadcast and incorporated) is applied twice annually to approximately 100 ha.

Han C included 143 ha of canola, 126 ha of grain corn, 124 ha of spring wheat, 12 ha of alfalfa, 136 ha of barley, and 26 ha of timothy. The livestock included 140 sows farrow to finish. Liquid hog manure is collected in an earthen manure storage. Approximately 3.4 million litres of liquid hog manure was purchased and spread onto fields. No laboratory analysis was performed on the manure. Soil testing data is summarized in Table 4.2. The purchased liquid hog manure (broadcast and incorporated) was applied to approximately 32 ha, while the liquid hog manure from the farm (injected) is applied annually to approximately 56 ha.

Han D included 77 ha of grain corn, 140 ha of barley, 50 ha of canola, 120 ha of alfalfa, and 60 ha of pasture. The livestock included 95 dairy cows, 98 heifers, 25 beef cows, and 45 beef steers. Approximately 800,000 litres of milk was produced and sold by the farm. Manure is collected using an earthen mole hill. No laboratory analysis was performed on the manure. Soil testing data is summarized in Table 4.2. Solid manure (broadcast and incorporated) is applied twice annually to approximately 34 ha of land.

Table 4.1 Farms from the R.M. of Hanover examined.

Hanover case farms	Livestock	Hectares	Soils in plan[1]
Han A	400 feeders, 140 sows farrow to finish	300	Glenella, Glenhope, Kergwenan, Malonton, Marquette, Nourse, Osborne, Plum Ridge, Poppleton, Red River, Scanterbury, Sprague
Han B	425 dairy	1014	Aneda, Dencross, Glenfields, Inwood, Kline, Lakeland, Lundar, Marquette, Meleb, Niverville, Osborne, Red River,
Han C	140 sows farrow to finish	567	Osborne, Red River, Scanterbury
Han D	80 dairy, 25 beef cows	447	Aneda, Foley, Glenhope, Gunton, Inwood, Kergwenan, Leary, Lenswood, Malonton, Nourse, Pelan, Poppleton, Spearhill, Sundown, Venlaw, Weiden

[1] Canada-Manitoba Soil Survey, 1993.

Table 4.2 Soil Testing Data Collected from Farms in the RM of Hanover.

Case Farm	Year	Depth (cm)	Field[1]	Nitrogen (kg/ha)	Phosphorus (kg/ha)[3]	Case Farm	Year	Depth (cm)	Field[1]	Nitrogen (kg/ha)	Phosphorus (kg/ha)
Han A	1999	0-60	1	73	29	Han C	2000	0-60	1	244	135
			2	64	54				2	106	99
			3	54	61				3	325	135
			4	45	106				4	325	135
			5	72	63				5	136	74
			6	64	56				6	139	43
			7	33	18				7	135	39
			8	27	18				8	135	39
			9	35	40				9	180	40
			10	38	20				10	103	22
			11	58	106				11	128	56
	2000	0-60	1	44	13				12	147	25
			2	97	49				13	140	40
			3	58	63				14	140	40
			4	N/A[2]	N/A				15	140	40
			5	N/A	N/A	Han D	2000	0-45	1	29	6
			6	69	36				2	44	53
			7	54	20				3	57	18
			9&10	34	34				4	43	12
Han B	1999	0-60	1	209	69	Han B	2000	0-60	14	46	30
			2	230	200				16	40	25
			3	242	94				17	137	33
			4	87	9				18	19	9
			5	92	12				5	70	8
			6	118	51				7	101	20
			7	74	17				8	22	22
			8	64	44				9	210	22
			9	58	22				10	25	19
			10	45	18				10	61	18
			11	124	47				12	19	19
			12	140	175				19	72	43
			13	87	9				20	109	21
			14	109	56				15	110	57
			15	85	36						

[1]Not all fields are sampled annually. [2]N/A=not available. [3]Phosphorous: 0-15 cm depth only.

4.1.2 RM of La Broquerie

Lab A included 102 ha of barley, 23 ha of flax, 92 ha of canola, 77 ha of grain corn, 14 ha of silage corn, 8 ha of greenfeed, 54 ha of alfalfa, 58 ha of mix hay, and 80 ha of pasture. The livestock included 75 beef cows, 11 heifers, 2 bulls, and 70 calves. No laboratory analysis was performed on the manure. Soil testing data is summarized in

Table 4.5. Solid manure (broadcast and incorporated) is applied twice annually to approximately 60 ha of land.

Lab B included 148 ha of barley, 32 ha of peas/oats for feed, 59 ha of sunflower, 128 ha of grain corn, 42 ha of silage corn, and 166 ha of alfalfa. The livestock included 278 milking cows, 270 heifers, and 2 bulls. Approximately 3.2 million litres of milk was produced and sold by the farm. An earthen manure storage collected the liquid manure while solid manure is collected and spread onto fields. Liquid manure composition was 0.6 kg N and 0.7 kg P per 1000 litres. Soil testing data is summarized in Table 4.5. Solid manure (broadcasted) and liquid manure (broadcast and incorporated) are applied twice annually to approximately 84 ha of land.

Lab C included 736 ha of native/pasture and 284 ha of alfalfa/grass. The livestock included 40,000 weanling pigs and 650 beef cattle. The liquid hog manure is collected in an earthen manure storage. Approximately 16.3 million litres of manure was sold and removed from the farm. The composition of the liquid hog manure was 1.8 kg N and 0.32 kg P per 1000 litres. Phytase is added to the feed to lower the phosphorus content of the manure. Soil testing data is summarized in Table 4.5. Liquid manure (broadcasted) is applied annually to approximately 565 ha of land.

Lab D included 51 ha of barley, 42 ha of spring wheat, 60 ha of canola, and 73 ha of grain corn. The livestock included 350 sows farrow to finish. The liquid hog manure is collected in an earthen manure storage. The composition of the hog manure was 1.5 kg N per 1000 litres. Soil testing data is summarized in Table 4.5. Liquid manure (injected) is applied annually to approximately 120 ha of land.

Table 4.4 Farms from the RM of La Broquerie Examined.

La Broquerie case farms	Livestock	Hectares	Soils in plan[1]
Lab A	75 cow/calf	428	Kiplin, La Broquerie, Malonton, Pansy, Poppleton
Lab B	450 dairy	575	Beaverdam, Davidson, Giroux, Greenwald, La Broquerie, Leary, Malonton, Marchand, McKinley, Pelan, Poppleton, Prawda, Weiden
Lab C	40,000 weanlings	1020	Beaverdam, Berlo, Inwood, Kergwenan, Kircro, Malonton, Meleb, Pansy, Pelan, Poppleton, Prawda, Sirko, Sprague, Sundown
Lab D	350 sows farrow to finish	226	Foley, Garson, Glenhope, Gunton, Inwood, Leary, Malonton, Nourse, Pelan, Poppleton, Spearhill

[1] Canada-Manitoba Soil Survey, 1985.

Table 4.5 Soil testing data collected from farms in the RM of La Broquerie.

Case Farm	Year	Depth (cm)	Field[1]	Nitrogen (kg/ha)	Phosphorus (kg/ha)[3]
Lab A	1998	0-60	1	20	9
			2	29	7
			3	69	27
			4	65	25
	1999	0-60	1	87	10
			2	92	18
			3	N/A[2]	N/A
			4	117	8
			5	87	11
			6	90	16
			7	51	13
Lab B	1999	0-60	1	36	20
			2	36	20
			3	64	19
			4	61	18
			5	52	25
			6	40	8
			7	48	11
			8	53	22
Lab D	1999	0-25	1	24	27
		0-60	2	58	36
		0-60	3	94	117
		0-25	4	57	20
		0-30	5	106	22
	2000	0-60	1	33	47
	2002		2	94	72
	2000		3	60	27
			4	11	31
	2002		5	172	83

Case Farm	Year	Depth (cm)	Field[1]	Nitrogen (kg/ha)	Phosphorus (kg/ha)
Lab C	2001	0-60	1	33	98
		0-30	2	9	15
		0-30	3	45	55
		0-60	4	36	25
		0-30	5	8	24
		0-30	6	6	21
		0-30	7	145	135
		0-30	8	55	135
		0-60	9	39	31
		0-60	10	44	36
	2002	0-60	11	13	28
			9	99	43
			9	63	13
			12	9	30
			10	19	13
			6	51	26
			3	46	46
			13	15	6
			14	39	45
			15	51	13
			16	3	3
			17	11	18
			18	45	45
			19	9	16
			20	9	43
			2	11	49
			2	16	16

[1]Not all fields are sampled annually.
[2]N/A=not available.
[3]Phosphorous: 0-15 cm depth only.

4.1.3 RM of Roland

Rol A included 298 ha of wheat, 222 ha of canola, 89 ha of flax, and 59 ha of oats. *Rol B* included 16 ha of wheat, 44 ha of oats, and 64 ha of flax. *Rol C* included 98 ha of potatoes, 38 ha of onions, and 33 ha of wheat. None of these farms had livestock. Soil testing data is summarized in Table 4.7.

Table 4.6 Farms from the RM of Roland.

Roland case farms	Hectares	Soils in plan[1]
Rol A	668	Red River, Osborne, Scanterbury
Rol B	124	Scanterbury, Denham, Rignold
Rol C	170	Gnadenthal, Hochfeld, Nuenberg, Reinfeld,Chortitz, Neuhorst, Reinland, Birkenhead, Blumengart, Jasset, Rosengart

[1] Canada-Soil Survey, 1988.

Table 4.7. Soil Testing Data Collected from Farms in the RM of Roland.

Case farm	Year	Depth	Field[1]	Nitrogen (kg/ha)	Phosphorus (kg/ha)
Rol A	1999	0-60 cm	1	40	13
			2	25	20
			3	37	20
			4	60	16
	2000	0-60 cm	1	36	20
			2	28	22
			3	N/A[2]	N/A
			4	104	16
			5	115	20
			6	101	18
			7	25	8
			8	33	8
Rol B	2000	0-60 cm	1	19	37
			2	36	25
Rol C	1999	0-46 cm	1	63	70
			2	182	63
			3	57	70
			4	176	67
			5	191	99
			6	211	34
			7	156	31
	2000	0-46 cm	8	71	16
			9	73	22
			10	80	38
			11	87	94
			12	154	54
			13	238	112
			14	110	38

[1]Not all fields are sampled annually.
[2]N/A=not available.
[3]Phosphorous: 0-15 cm depth only.

4.1.4 RM of Sifton

Sif A included 58 ha of oats, 32 ha of barley, 15 ha of grass forage, 98 ha of alfalfa forage, 172 ha of native hay, 206 ha of alfalfa hay mix, 7 ha of greenfeed, 8 ha of oats-alfalfa, and 352 ha of pasture. The livestock included 175 beef cows, 26 heifers, 5 bulls, 158 calves, and 4 horses. No laboratory analysis was performed on the manure. This farm does not conduct annual soil testing. Solid manure (broadcast and mostly incorporated) is applied twice annually to approximately 46 ha of land.

Sif B included 33 ha of oats, 132 ha of barley, 132 ha of grass forage, 180 ha of alfalfa forage, 306 ha of native hay, and 173 ha of pasture. The livestock included 170 beef cows, 42 heifers, 10 bulls, and 160 calves. No laboratory analysis was performed on the manure. Soil testing was conducted for only three fields at 0-15 cm in spring 2002. Nitrogen values were 21, 26, and 28 kg/ha and phosphorus levels were 21, 17, and 18 kg/ha. Solid manure (broadcast and mostly incorporated) is applied twice annually to approximately 40 ha of land.

Sif C included 40 ha of oats, 12 ha of rye, 118 ha of barley, 416 ha of native hay, and 1087 ha of pasture. The livestock included 170 beef cows, 26 heifers, 5 bulls, and 153 calves. No laboratory analysis was performed on the manure. This farm does not conduct annual soil testing. Solid manure (broadcast and mostly incorporated) is applied twice annually to approximately 40 ha of land.

Sif D included 27 ha of oats, 40 ha of canola, 54 ha of barley, 118 ha of alfalfa, 89 ha of alfalfa/grass mix, and 427 ha of pasture. The livestock included 220 beef cows, 35 heifers, 6 bulls, and 210 calves. No laboratory analysis was performed on the manure. This farm does not conduct annual soil testing. Solid manure (broadcast and some incorporated) is applied twice annually to approximately 32 ha of land.

Table 4.8 Farms from the RM of Sifton

Sifton case farms	Livestock	Hectares	Soils in plan
Sif A	175 cow/calf	939	Souris, Oak Lake[1]
Sif B	170 cow/calf	1000	Souris, Oak Lake, Cromer
Sif C	170 cow/calf	1020	Souris, Oak Lake, Grande Clairiere
Sif D	220 cow/calf	755	Souris, Oak Lake, Lyleton

[1]Canada-Manitoba Soil Survey, 1989.

4.2 Farm-Scale Nutrient Balance

A nutrient balance model was developed to summarize the nutrient flows of a farm-scale from information collected for 2000. The model was based on nutrient balances performed on several locations around the world by Frissel (1978). The model was separated into three major components (plant, animal, and soil) in order to evaluate the flow of nutrients in each pool. The various components of each pool were summarized in the literature review. The soil pool was further separated into two components, available soil nutrients and soil organic matter. The original model described by Frissel included a nutrient transfer by weathering of soil fraction and a nutrient input by uptake from atmosphere, which were not included in the nutrient balance model for this study. From the literature review, it was concluded that the transfer of nutrients by weathering of soil fraction would be minimal and would not significantly influence the overall transfer of nutrients in the soil pool. The literature review indicated that the nutrient uptake from atmosphere could vary from less than 1 kg/ha/year to 7 kg/ha/year. For the purpose of this study, this nutrient input will therefore be ignored.

The flow of nutrients occurs in one of three ways: input, output, or transferred (Figure 2.1 of the literature review). An accounting of nutrient inputs (purchased feed, purchased seeds, purchased fertilizer, purchased animal manure, and biologically fixed nitrogen) and managed outputs (animals, crops, manure moved off farm, and losses to environment or additions to soil storage) was completed for all farms in each of the four municipalities. Transferred nutrients were produced on the farm and transferred within the farm boundaries, such as manure produced by farm animals applied to fields on the farm.

The nutrient concentration of various inputs and outputs are defined in Table 4.9. Standard values and producer knowledge of purchased products were typically used for fertilizer nutrient concentration. The basis for the selected values for nutrient concentrations of animals, manure composition (if not provided by producer), legume fixed nitrogen, and atmospheric deposition was provided by the literature review. Values used for N fixation and atmospheric deposition are summarized in Table 4.9. Nutrient concentrations assumed for animal products, marketed crops, and nitrogen fixed by legumes may vary from actual values resulting in differences between actual and calculated nutrient balances.

Table 4.9 Estimates for N fixation and atmospheric deposition of N and P (kg/ha/).

	N	P
Nitrogen fixation		
Non-symbiotic[1]	0.9	-
Alfalfa[2]	220	-
Atmospheric Deposition	5	0.1

[1]Includes cropland, seeded and natural pasture, and summerfallow.

[2]Assumes a yield of 3 tonne/hectare.

In the plant and available soil nutrient components, the model separates the transfer by net nutrient uptake from soils in two portions of the plant, root and top. For the purpose of this study, the net nutrient uptake combined the root and top portions of the plant. Therefore only one value was used to describe the net nutrient uptake from soils. The transfer by consumption of harvested crops included the transfer by grazing of forage. All nutrient uptake and removal by crops were estimated using values from the Canadian Fertilizer Institute. Crops that were produced in 2000 but were stored on the farm to be sold the following years were considered an output from the plant component (output by primary products).

Table 4.10 Nutrient concentrations and assumptions used for estimating nutrient balance.

Nutrient inputs/outputs	Concentration	
	Fraction nitrogen	Fraction phosphorus
Livestock Products		
Milk[1]	0.0050	0.001
Eggs[2]	0.0167	0.002
Livestock		
Beef cattle (<1000 lbs)	0.027	0.0073
Beef cattle (>1000 lbs)	0.024	0.0065
Dairy cattle (replacement herd)	0.029	0.0083
Dairy cattle (milking herd)	0.025	0.0072
Swine (<100 lbs)	0.025	0.0056
Swine (100 to 300 lbs)	0.024	0.0047
Swine (>300 lbs)	0.023	0.0047
Poultry	0.028	0.0058
Crops, feeds, seeds, or forages	Individual analysis or CFI[3]	
Commercial fertilizer	Individual analysis	
Manure	Individual analysis, Manitoba or Alberta Producer Guidelines	

[1]Density of milk is assumed to be 1035 kg/m^3 (Dairy Chemistry and Physics).
[2]Average weight of an egg is assumed to be 60 g per egg (Manitoba Egg Producers).
[3]Canadian Fertilizer Institute.

Output of livestock was calculated using average animal weights, which were either provided by the producers or estimated using Manitoba Guidelines for Hog, Poultry, Beef and Dairy producers. Output of livestock products, such as milk and eggs, was provided by the producer and were therefore not estimated.

The flow of manure nutrients on a farm scale can occur in three ways: purchased from another farm (input), sold from the farm (output), or spread onto fields within the farm boundaries (transfer). Frissel's budget divided the transfer of manure into transfer by application and transfer by droppings on grazed areas. For this study, these two manure transfers were combined into transfer by application.

For dairy and beef manure nutrient contents, unless provided by the producer, the nutrient content was estimated using values of daily nitrogen and phosphorus production from the Manitoba Guidelines for Beef and Dairy producers. Total yearly manure production (in kilograms) was estimated using values provided by Alberta Agricultural Operation Practices Act. A value of 10 kg total N/tonne of manure was used for beef and 5 kg total N/tonne of manure for dairy. From the total yearly manure production, an estimate of inorganic nitrogen was determined, again using values provided by Alberta Agricultural Operation Practices Act (2.6 kg N/tonne for beef and 2.1 kg N/tonne for dairy). Organic N was determined from the difference between total N and inorganic N. Based on information provided by Manitoba Agriculture and Food, the N available to crops was determined from the sum of inorganic N and 30 percent of organic N. The nitrogen available in the first year was considered a transfer to the available soil nutrients in the model. The remaining N (total N minus crop available N) was considered a transfer to the soil organic matter. For phosphorus, it was estimated that half of the manure P would be a transfer in the available soil nutrients and the remaining half a transfer in the soil organic matter in the model.

The nutrient content of hog manure, unless provided by the producer, was estimated using values of nitrogen and phosphorus production from the Manitoba Guidelines for Hog producers. Table 4.11 summarizes these values on a yearly basis in kilograms per year and kilograms per 1000 litres. From the estimate of total nitrogen production, 70 percent was assumed inorganic N and the remaining 30 percent as organic N. This assumption was based on average values of nutrient analysis of manure in Manitoba, as described in the literature review. In some cases, total manure nitrogen and phosphorus were also determined using manure application rates provided by the producer and assuming typical nitrogen and phosphorus concentrations, if not provided. Determinations of crop available N (transfer to available soil nutrients) and remaining N (transfer to soil organic matter) was described above. The split for the transfer of manure P to the soil component was also previously described.

Table 4.11 Annual hog manure nitrogen and phosphorus production (Manitoba Agriculture, 1998).

Livestock		Nitrogen		Phosphorus	
	A.U. factor	kg/year/pig	kg/1000 litres	kg/year/pig	kg/1000 litres
Farrow to finish	1.25	90.9	4.0	58.7	2.6
Farrow to wean	0.313	24.0	2.9	16.7	2.0
Farrow to nursery	0.250	18.2	2.6	13.8	1.9
Weanling	0.033	1.5	1.8	1.5	1.8
Finisher/grower	0.143	10.4	3.4	7.5	2.4

Output of manure nitrogen losses from storage and application was estimated using values provided by the Manitoba Guidelines for Livestock producers and is summarized in the literature review. Losses of nitrogen due to volatilization were divided into losses before and during manure application. Nitrogen losses during manure application were referred to as an output by volatilization of ammonia from the soil component.

Values of N denitrification were estimated using Table 2.18 of the literature review. This table provided estimates of the percentage of inorganic fertilizer plus precipitation N that is denitrified according to percent soil organic matter content and soil drainage classification. Soil organic matter content and soil drainage classification were determined for the soils from each farm using soil survey information. For this study, the percentage of N denitrified from cropland was calculated from the sum of the soil nitrate concentration (obtained from soil testing information), average inorganic fertilizer application rate, and mineralized N. Summerfallowed soils were assumed to have similar denitrification rates as cropland. The denitrification rate of manured soils was estimated by doubling the denitrification rate of cropland. Denitrification of alfalfa, seeded and natural pastures was estimated at 5 kg/ha/year. Cropland one year after alfalfa was assumed to have a denitrification rate 5 kg/ha/year greater than cropland, while cropland four years after alfalfa was assumed to have a similar rate of denitrification to cropland.

Approximately 10 percent of available N was assumed lost by leaching for cropland. This value was doubled for summerfallowed soils. Leaching loss from seeded and natural pastures was estimated as 2 kg/ha/year.

From the literature review, rates of mineralization and immobilization for cropland were estimated as 75 kg/ha/year and 25 kg/ha/year, respectively. For summerfallowed soils, rates of mineralization and immobilization were estimated as 80 kg/ha/year and 5 kg/ha/year, respectively. Table 2.38 of the literature review provided estimated values of the mineralization/immobilization of alfalfa and grasses and cropland one and four years after alfalfa and grasses.

N and P losses by runoff of available nutrients and organic matter were estimated using values from the literature review (Table 4.12).

Table 4.12 Estimated N and P runoff losses of available nutrient and organic matter.

	N losses (kg/ha)		P losses (kg/ha)	
	Available nutrients	Organic matter	Available nutrients	Organic matter
Cropland	1	1	0.5	0.5
Seeded pasture	1	1	0.3	0.3
Natural pasture	1	1	0.3	0.3
Summerfallow	2	1.5	0.5	0.5

4.3 Municipal-Scale Nutrient Balance

A similar nutrient balance was developed for each of the four municipalities described in the farm-scale nutrient balance. The municipal balance was developed using Statistics Canada data from the 2001 census.

4.3.1 Livestock

Census data for livestock inventories only indicate the number of livestock present at the time that the census questionnaire was completed. To determine the total annual nitrogen and phosphorus removed from livestock, typical yearly cycles and removal rates were estimated in consultation with representatives from Manitoba Agriculture and Food (beef, dairy, poultry, and hog specialists). Average animal weights were also estimated using values provided by Manitoba Guidelines (Table 4.13). Fractions of N and P used for each livestock type and weight category to determine nutrient removal were previously described in the farm-scale nutrient balance (Table 4.10).

From the census data, hog inventory was divided into boar inventory, sow inventory, and market pig inventory. It was determined that a more accurate estimate of nutrient removal and manure production would be accomplished be dividing the sow and market hog inventories. Sow inventory was divided into gestating sow, nursing sow, and gilt, while market hog was divided into weanling, grower, and finisher. The total number of market hogs was divided into three to estimate the numbers of weanlings, growers, and finishers. For the sow inventory, using values provided by the Manitoba Guidelines for Hog Producers, it was assumed that 79 percent were gestating sows, 15 percent nursing sows, and 6 percent gilts. For the RM's of Roland and Sifton, hog inventories could not be divided into boar, sow, and market pigs, because of suppressed data. An average weight and turnover rate was therefore estimated to calculate the N and P outputs by hogs.

In the RM of Hanover, chicken inventory was divided into three categories; (1) broilers and roasters, (2) pullets, and (3) laying hens. For the remaining three municipalities, the chicken inventory was not divided because of suppressed data. An average weight and turnover rate was therefore estimated to calculate the N and P outputs by chickens.

Table 4.13 Livestock cycles, removal rates, and weights used to estimate total annual livestock inventories.

Livestock	Average weight (kg)	Fraction removed/year	Livestock	Average weight (kg)	Fraction removed/year
Cattle and calf			**Hog**		
Bull	900	0.3	Boar	160	0.55
Dairy cow	600	0.3	Gestating sow	150	0.45
Beef cow	550	0.17	Nursing sow	160	0.45
Dairy heifer	386	0	Gilts	125	0
Beef heifer	364	0.8	**Market Hog**		**Annual cycle**
Slaughter heifer	409	1	Weanling	13.5	2
Steer	364	0	Grower	35	2
Calf	135	0.6	Finisher	75	2
Chicken and hens		**Annual cycle**	**Turkeys**		**Annual cycle**
Broilers, roasters	5	7.5	All turkeys	12	2
Pullets	3	2			
Laying hens*	1	4			

*Annual egg production was estimated as 5.6 cycles/year for each laying hen.

Based on typical calculations for a 100 milking cow herd from the Manitoba Guidelines for Dairy Producers, it was assumed that 85 percent of the dairy cow inventory were milk producing cows and the remaining 15 percent, dry cows. Milk production was estimated from total milk production in Manitoba (293,800,000 litres) and the total number of milk producing cows (36,000) provided by Manitoba Agriculture and Food, resulting in a value of 8,160 litres of milk produced per cow. Therefore, the number of milking cows from each municipality was multiplied by 8,160 litres per cow to estimate annual litres of milk production, which was converted to kilograms using a milk density of 1,035 kg/m^3.

4.3.2 Commercial Fertilizers

Three different methods were used to calculate nitrogen and phosphorus inputs by commercial fertilizers. The first method used Manitoba Crop Insurance Corporation values for 2000, accessible from the Manitoba's Management Plus Program website (http://www.mmpp.com). Estimates were made using the average nitrogen and phosphate application rates from Crop Insurance data and extrapolating these rates for the total cropland area for each municipality. The Crop Insurance registration form does not require farmers to complete the fertilizer portion of the form. Therefore, only a portion of the farmers fill out this section of the from, which include information about average fertilizer application rates by crop type. Total land insured by crop insurance and fertilized area for each R.M. are summarized in Table 4.14.

Table 4.14 Summary of Crop Insurance data for 2000.

Municipality	Land insured by Crop Insurance (hectares)	Fertilized (hectares)	% of crop insured land
Hanover	20,039	16,370	82
La Broquerie	3,020	2,439	81
Roland	40,615	38,479	95
Sifton	9,691	5,730	59

The second method to estimate average N and P application rates used total fertilizer purchases (in dollars) for Manitoba and for the municipalities, provided by Statistics Canada (Table 4.15). Total tonnage of fertilizer for the province was provided by Manitoba Agriculture, Agriculture Statistics. The tonnes of fertilizer sold for each R.M. was calculated using these values. The percentage of N and P in fertilizer was determined for a ten-year period using information provided by Canadian Consumption, Shipments, and Trade (Agriculture and Agri-Food Canada, 2000). This information divided the tonnage of fertilizer into tonnes of N, P, and K. Using the average percentage values, an estimate of the tonnage of N and P were calculated for each RM. Average N and P application rates (kg/ha) were then calculated using the hectares of land fertilized in each R.M. provided by Statistics Canada.

Table 4.15 Total commercial fertilizer purchases and tonnage for 2001.

	$	tonnes
Manitoba	291,214,275	837,000
Hanover	2,694,256	7,744*
La Broquerie	508,028	1,460*
Roland	3,461,341	9,949*
Sifton	532,857	1,532*

*Calculated values.

Table 4.16 Total cropland, tame or seeded pasture, and fertilized area from Statistics Canada for 2001.

	Hectares of cropland	Hectares of tame or seeded pasture	Hectares of fertilized land
Hanover	45,197	4,299	31,493
La Broquerie	12,217	2,775	7,145
Roland	42,036	297	37,498
Sifton	27,636	6,721	10,451

The third method was dependent on information provided by fertilizer dealers. A questionnaire was delivered to four fertilizer dealers in each of the four municipalities. Each dealer was to provide an indication of average N and P application rates for each individual client by crop type. For each client, blends of fertilizer sold and tonnes, and approximate land base fertilized was also requested. Average application rates were calculated for each fertilizer dealer using weighted application rate averages from approximate fertilized area for each individual client. Average application rates were also calculated for each fertilizer dealer, based on approximate fertilized area, using the tonnes of N and P determined from the fertilizer blends sold to each client.

The three methods were compared for the RM of Sifton and are summarized in Table 4.17. The three methods produced similar results for both N and P application rates for this municipality. Therefore, for consistency, census data from Statistics Canada was used for estimating the N and P application rates for all the municipalities. Table 4.18

provides a summary of the application rates estimated from the census data and includes application rates provided by Crop Insurance.

Table 4.17 Comparison of the three methods for estimating application rates (kg/ha) of N and P for the RM of Sifton.

Statistics Canada		Crop Insurance		Fertilizer dealer questionnaire	
N	P	N	P	N	P
53	8	60	13	56	9

Table 4.18 Summary of N and P application rates (kg/ha) estimated from Statistics Canada census 2000 data.

	RM of Hanover		RM of La Broquerie		RM of Roland		RM of Sifton	
	N	P	N	P	N	P	N	P
Stats Canada	89	14	74	12	96	15	53	8
Crop Insurance	92	15	70	13	89	15	60	13

4.3.3 Manure as Fertilizer, Manure Production and Losses

The hectares of land utilized for manure spreading, categorized by method of application, was provided by Statistics Canada (Table 4.19).

Table 4.19 Hectares of manured land and method of application (Statistics Canada, 2001).

Municipality	Manured hectares by method of application				
	Solid Spreader	Irrigation System	Liquid Spreader on surface	Liquid Spreader injected	Total hectares
Hanover	5,170	206	6,083	4,535	15,994
La Broquerie	2,089	0	3,174	645	5,908
Roland	293	0	348	0	641
Sifton	2,822	0	0	0	2,822

N and P application rates for manure were calculated using N and P values after storage losses, produced by livestock and the total hectares of manured land.

Manure production was calculated using the same method described for the Farm-Scale balances. Estimates of N and P production on a daily basis were provided by the Guidelines for Hog, Beef, Dairy, and Poultry producers in Manitoba. Numbers of animals for each livestock category were divided using the method described previously in *Livestock* section. As the total N content of beef and cattle manure differ, a weighted average was used to estimate the total N content of cattle manure from the inventories of beef and dairy cattle. The fraction of inorganic N and organic N in manure was estimated from values provided by the literature review.

It was assumed that all cattle produced solid manure, hogs liquid, layers liquid, broilers and pullets solid, and turkeys solid. As the chicken inventory was not divided into three categories as described above in the *Livestock* section for the RM's of Roland, Sifton, and La Broquerie, it was assumed that half of the total inventory would be laying hens and the remaining half, pullets and broilers. Manure produced by laying hens is generally in a liquid form, whereas manure produced from broilers and pullets is generally in a solid form.

The estimation of crop available N and P was described previously in the farm-scale budget. Storage and application losses were estimated using values provided by the literature review.

4.4.4 Grain Flow Model

A spatial grain flow model was developed by Warkentine & Associates to estimate the flow of grains and oilseeds to and from each rural municipality. As a foundation the model uses Agri-Cad®, a proprietary supply and disposition system linked directly to GIS mapping software. Agri-Cad® is a farm level supply and disposition table for the major grains and oilseeds or each of the over 500 rural municipalities in Western Canada estimated from 1986 to present. As a foundation, the system uses Statistics Canada (STC) supply and disposition data and other available public information, including STC Small Area data, Census of Agriculture data and Provincial Government data, to estimate supply and disposition for each R.M. in Western Canada.

The spatial grain flow model allows Canadian Grain Commission (CGC) grain deliveries by delivery point to be converted into useable data by municipality to be included as another major addition to the above supply and disposition estimates. These data are used to estimate the volume of crops produced and sold, and input for feed for each municipality. It was from these estimates that nutrient uptake and removal was calculated. The input of seeds was ignored for this study. The methodology for the spatial grain flow model is outlined below.

4.4.4.1 Conceptual Model

The model assumes that the volume of grains and oilseeds flowing to each delivery point in western Canada is a function of:

- the total elevator storage capacity;
- the spring wheat freight rate including the freight adjustment factor;
- the rail car spot segregated by multi-car freight rate incentive categories;
- 0-24 cars
- 25-49 cars
- 50-99 cars
- 100+ cars
- the level of competition between delivery points; and
- regional grain production.

4.4.4.2 Modeling Process

The model process involves a simultaneous comparison of actual grain delivery data by grain delivery point with potential deliveries of grains and oilseeds using proprietary Geographical Information System (GIS) software. The software simultaneously captures grain around each delivery point in an increasing radius until each delivery point has received its' full allotment of grain. This process simulates market behaviour by modeling the competitive interaction between delivery points.

The modeling procedure involves two stages. The first stage is an econometric model, which quantifies the relationship between non-durum wheat deliveries and (1) elevator storage capacity, (2) freight rates and (3) rail car spots.

4.4.4.2.1 Stage One - Econometric Model for Non-Durum Wheat

The Canadian Grain Commission (CGC) publishes primary elevator delivery data by delivery point for 7 crops (Non-durum wheat, durum wheat, barley, oats, rye, flax and canola). Although each of these crops could theoretically have a different flow pattern, only the draw areas for non-durum wheat are estimated. Non-durum wheat represents the largest portion of total grain delivered to the primary elevator system and is delivered to virtually every delivery point. As a result, it becomes the ideal crop for estimating grain delivery draw areas.

These CGC grains and oilseeds delivery data is compiled by delivery point and amalgamated to additional data by delivery point including total elevator storage capacity, CWB total freight costs, and elevator rail car spots. These data become the foundation for the econometric model.

The following econometric equation is estimated:

$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6$
Where,

Y = Non-durum wheat deliveries
X_1 = total elevator storage capacity
X_2 = Spring wheat freight rate including the CWB freight adjustment factor
X_3 = rail car spot 0-24 cars
X_4 = rail car spot 25-49 cars
X_5 = rail car spot 50-99 cars
X_6 = rail car spot 100+ cars

The estimated non-durum wheat deliveries ($\hat{y}$) are then used as a parameter for each delivery point in the second stage of the modeling process: the GIS model for non-durum wheat.

4.4.4.2.2 Stage Two - GIS Model for Non-Durum Wheat

The second stage of the model involves proprietary GIS software. The model uses the output $\hat{y}$ parameter from the econometric model in stage one to determine the speed at which it simultaneously captures grain around each delivery point in an increasing radius. This capturing process compare the actual grain delivered to each delivery to the available potential grain deliveries within each municipality. These potential grain deliveries are estimated from a detailed interim supply and demand table for each municipality.

During the calibration process, the grain capturing parameter for each delivery point can then be adjusted up or down, if required, to insure that each delivery point captures the actual known (CGC) non-durum wheat deliveries. When the increasing radius capturing process encounters a competing delivery point in the increasing radius capturing process, the boundary between the two delivery regions is formed. The process continues until all delivery points have been allocated their actual volume of non-durum wheat deliveries. In this way the GIS model simulates market behaviour by simulating the competitive interaction between delivery points.

4.4.4.2.3 Interim Farm Supply & Disposition Table by Municipality

The estimation of the detailed interim farm level supply and disposition table is done through the use of the proprietary Agri-Cad® supply and disposition system which is linked directly to GIS mapping software.

Agri-Cad® is a farm level supply and disposition table for the major grains & oilseeds for each of the over 500 RMs in western Canada estimated from 1986 to the present. As a foundation, the system uses Statistics Canada (STC) supply and disposition data, but it differs significantly in a number of areas. First, the system uses all available public information including STC Small Area data, Census of Agriculture data and Provincial government data to estimate supply and disposition for each rural municipality in Western Canada. In comparison, STC only estimates supply and disposition by province.

Second, the system is closed. A closed system means that all supply and disposition of grains and oilseeds is accounted for within each municipality making the system much more accurate. In the case of the STC provincial supply and disposition estimates, Feed, Waste & Dockage is estimated as the residual. The Agri-Cad® system, however, uses livestock and poultry numbers to estimate feed usage by municipality for each livestock and poultry subclass. In addition, dockage is estimated separately using Canadian Grain Commission terminal elevator data and waste is included as part of the feed use estimates.

As a result, total available potential marketings for each rural municipality becomes the residual. These potential marketings are compared to actual grain deliveries for each delivery point in the GIS modelling process.

These potential marketings are converted into a matrix of centroid points, one for each square mile, using GIS software. In order to further improve accuracy, the data is distributed throughout the crop growing region of each municipality using a vegetative cover map. This distribution matrix is then used as the underlying foundation for the capturing process of the GIS modelling process.

This GIS grain capturing process essentially converts CGC grain delivery data by point to data by delivery region. This allows the delivery data to be used in the interim farm level supply and demand table to separate potential marketings into two categories: (1) to the primary elevator system (CGC data), and (2) outside the primary elevator system to the US by truck, the primary processors by truck, and to the livestock/poultry sector by truck (residual data).

4.4.4.2.4 New Farm Supply & Disposition Table by Municipality

The ability to separate potential marketings into two categories results in a new farm level supply and disposition table by municipality estimating intra and inter provincial trucking movements of grains and oilseeds. The system now uses marketings outside the primary elevator system as the residual while the marketings to the primary elevator system originate from the actual CGC marketings by delivery point. Since the grain flows outside of the primary elevator system are primarily by truck, this marketing residual essentially estimates the movement of grain into and out of municipalities by truck.

4.4.4.2.5 Estimation of Supply/Disposition for Other Major Grains and Oilseeds

The delivery regions for the remaining six crops other than non-durum wheat are then assumed to be similar to non-durum wheat. Although this is generally a reasonable assumption for the majority of the other major grains and oilseeds, there are potentially some exceptions. For example, in Saskatchewan, a higher proportion of durum wheat is exported through Thunder Bay as opposed to the West Coast compared to non-durum wheat. This is reflected in the freight rates which results in potentially different draw areas for durum wheat compared to non-durum wheat as these delivery points.

A non-durum wheat map of delivery regions with the appropriate delivery data is then overlaid a rural municipality map and actual grain deliveries by municipality are then calculated for durum wheat, oats, barley, rye, canola and flaxseed. These actual deliveries are then compared to the potential marketings in each municipality to estimate the trucking flows outside the primary elevator marketing system.

4.4.5 N fixation, Denitrification, Leaching, Runoff, Mineralization/Immobilization and Atmospheric Deposition

Estimates for all of these inputs, outputs, and transfers were previously discussed for the farm-scale budgets. All values were estimated using information provided by the literature review.

4.5 Non-Agricultural Nutrient Loads

In order to put the nutrient loading to the environment into perspective, non-agricultural nutrient loads were estimated. These loads are the N and P contained in the discharge from municipal and industrial sources that treat domestic sewage and wastewater from food processing and other industrial activities. The populations within each RM and the wastewater lagoons described earlier in this report. The methodology for evaluating the nutrient discharge from these lagoons is outlined in Appendix C.

5.0 RESULTS AND DISCUSSION

5.1 Farm-Scale Nutrient Balance

The nutrient balance for all farms from all four municipalities is summarized in Tables 5.1 and 5.2 for the four municipalities. In general, the plant component for all farms was almost balanced. This was expected as all crops produced by a farm can be either sold or fed to livestock. As the balances were conducted for only one year, any crops that were produced in 2000 and that remained in storage were assumed sold. A portion of the plant component would also remain on the fields after harvest. Any imbalance in the plant component was due to the input of seeds or seedlings.

Imbalances in the animal component were observed for all farms with livestock. It was expected that the animal component should be balanced, as any input of feed would be removed either as manure (including volatilization) or as animal products. All livestock producers generally keep accurate records of the output of animals and animal products and the input of feed for livestock. In some cases, the nutrient content of the purchased feed was not available and was therefore estimated. Various feed companies were contacted in order to provide a more accurate estimate of the nutrient content for the various livestock farms. During the interview process, it was also observed that most producers estimated the tonnage of harvested crops transferred for consumption by livestock. Manure production was calculated using average values provided in the literature, making it possible to either over- or underestimate the volume of manure produced. Inaccurate estimates of any of these factors would significantly affect the supplies and removals of the animal component resulting in an imbalance.

The soil component, divided into available soil nutrients and soil organic matter, varied considerably in all farms. The input by N fixation, outputs by denitrification, leaching, runoff losses, and transfers by mineralization, immobilization, and fixation in soil mineral fraction were all estimated based on values from the literature review. A large deficiency exists in selecting appropriate values from the literature for all these factors. All of these will vary significantly in soils varying in texture, landscape position, different cropping systems, etc. As most of these estimates were provided through personal communication with various soil and plant experts, many if not all of these estimates used for this study cannot be rigorously defended by scientific literature. Also, the study was based on one year of information. If a farm experienced a bad crop year during this period, yields would be much lower than expected which would increase the nutrients in the available soil nutrient pool instead of being transferred by plant uptake. Some low crop yields observed for case farm Rol A, for example, probably explain the high levels of residual available soil nitrogen. Nonetheless, important information was provided by this study.

Table 5.1 Summary of nutrient balances for farms in RM of Hanover (Han) and La Broquerie (Lab).

	RM of Hanover								RM of La Broquerie							
Farms	**Han A**		**Han B**		**Han C**		**Han D**		**Lab A**		**Lab B**		**Lab C**		**Lab D**	
Plant component	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Supplies	135*	24	163	22	86	15	215	27	75	13	207	27	247	27	127	23
Removals	134	24	163	22	84	14	214	27	74	12	207	27	247	27	126	23
Supplies-Removals	*1*	*0*	*0*	*0*	*2*	*1*	*-1*	*0*	*1*	*1*	*0*	*0*	*0*	*0*	*1*	*0*
Animal component																
Supplies	118	33	69	12	63	8	100	19	13	2	118	25	202	26	238	50
Removals	79	21	39	8	34	8	47	10	14	4	101	21	212	34	228	57
Supplies-Removals	*39*	*12*	*30*	*4*	*29*	*0*	*53*	*9*	*-1*	*-2*	*17*	*4*	*-10*	*-8*	*10*	*-7*
Soil Component																
Supplies	171	34	232	34	158	34	239	29	88	22	220	35	237	29	191	64
Removals	172	25	231	22	168	16	247	28	111	13	245	28	292	28	184	24
Supplies-Removals	*-1*	*9*	*1*	*11*	*-10*	*19*	*-8*	*1*	*-22*	*9*	*-25*	*7*	*-55*	*1*	*7*	*40*
Available soil nutrients																
Supplies	204	30	278	34	211	35	305	36	152	28	275	38	256	26	214	48
Removals	199	34	298	31	201	21	335	40	121	18	316	43	417	49	212	38
Supplies-Removals	*5*	*-4*	*-20*	*3*	*10*	*13*	*-30*	*-4*	*31*	*10*	*-42*	*-5*	*-161*	*-23*	*2*	*10*
Soil organic matter																
Supplies	80	18	151	22	72	15	181	24	43	9	171	28	243	25	91	29
Removals	86	11	130	17	91	12	159	20	95	12	154	20	137	17	86	11
Supplies-Removals	*-6*	*7*	*21*	*6*	*-19*	*3*	*22*	*4*	*-53*	*-3*	*17*	*8*	*106*	*8*	*5*	*18*

*kg/ha/year

Table 5.2 Summary of nutrient balances for farms in RM of Roland (Rol) and Sifton (Sif).

	RM of Roland						RM of Sifton							
Farms	**Rol A**		**Rol B**		**Rol C**		**Sif A**		**Sif B**		**Sif C**		**Sif D**	
Plant component	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Supplies	100*	17	174	23	176	24	58	6	63	7	88	10	72	8
Removals	98	16	171	21	174	24	57	6	64	7	88	10	73	8
Supplies-Removals	*2*	*1*	*3*	*2*	*2*	*0*	*1*	*0*	*-1*	*0*	*0*	*0*	*-1*	*0*
Animal component														
Supplies	0	0	0	0	0	0	33	4	37	4	46	6	29	3
Removals	0	0	0	0	0	0	18	5	19	5	16	4	29	8
Supplies-Removals	*0*	*0*	*0*	*0*	*0*	*0*	*15*	*-1*	*18*	*-1*	*30*	*2*	*0*	*-5*
Soil Component														
Supplies	145	10	183	19	224	37	73	8	80	10	102	11	94	13
Removals	135	17	195	24	222	25	74	7	85	7	107	11	93	9
Supplies-Removals	*10*	*-7*	*-12*	*-5*	*2*	*13*	*-1*	*1*	*-5*	*3*	*-5*	*1*	*1*	*4*
Available soil nutrients														
Supplies	200	18	217	25	247	39	136	15	156	18	179	20	163	19
Removals	162	20	222	26	249	27	110	13	136	15	184	22	153	18
Supplies-Removals	*38*	*-2*	*-6*	*-1*	*-2*	*12*	*26*	*2*	*20*	*3*	*-5*	*-2*	*10*	*1*
Soil organic matter														
Supplies	59	5	80	9	90	11	66	9	83	11	118	15	97	13
Removals	87	11	86	12	87	11	93	12	108	14	118	15	108	14
Supplies-Removals	*-28*	*-5*	*-6*	*-3*	*3*	*0*	*-27*	*-3*	*-25*	*-3*	*0*	*0*	*-11*	*-1*

*kg/ha/year

The available soil nutrients in the RM of Hanover ranged between 10 to -30 kg N/ha/year and 13 to -4 kg P/ha/year. For the RM of Roland, available soil nutrients ranged between 38 to -6 kg N/ha/year and 12 to -2 kg P/ha/year. This suggests that the accumulation of available soil nutrients in a municipality such as Roland, where a small amount of manure is applied to soil, can and does occur. The accumulation of available nutrients is not reserved to agricultural systems that utilize manure as fertilizer, as in the case with most farms in the RM of Hanover. The application of commercial fertilizers can result in the build-up of residual soil nutrients. This scenario was also observed in the soil test results from producers in the RM of Roland. For example, case farm Rol C had high levels of N and P (0-46 cm), having values of ranging between 71 to 238 kg

N/ha and 16 to 112 kg P/ha. Some of the case farms from the RM of Hanover also had high levels of soil test N and P. An important point from the case farm Han C in Hanover was that the fields having the highest levels of residual N and P had never received manure but had been summerfallowed. Research data described in the literature review has shown that summerfallowed soils can lose significant amounts of nutrients by leaching, resulting in a build-up of nutrients at greater depths. A reduction in residual soil nutrients can be accomplished by better nutrient and soil management practices.

Imbalances in soil organic matter varied considerably in all farms. For farms in the municipalities of Hanover and La Broquerie with high livestock numbers, changes in soil organic matter varied from -19 to 22 kg N/ha/year and 3 to 7 kg P/ha/year (Hanover) and -53 to 106 kg N/ha/year and -3 to 18 kg P/ha/year (La Broquerie). Organic matter varied from -28 to 3 kg N/ha/year and -5 to 0 kg P/ha/year for farms in Roland. A wide range was also seen for farms in Sifton, -27 to 0 kg N/ha/year and -3 to 0 kg P/ha/year.

In general, the farms in Hanover and La Broquerie all raised livestock and contributed more organic matter to the soil pool than the farms in Roland, which had no livestock. The Sifton farms all contained livestock as well, however these farms are not managed as intensely (fertilizer inputs are low) and the organic matter imbalance was similar to the Roland farms. The feed for the livestock in Sifton is primarily supplied within the farm and feed inputs are low.

Mineralization and immobilization are two important factors that can influence the increase or decrease of soil organic matter. As was previously mentioned, both of these factors were estimated based on the available information that was provided by the literature review. Overestimating or underestimating values of mineralization and immobilization will greatly impact the changes in soil organic matter. Another important factor that influenced soil organic matter was the calculation used to determine the percentage of manure nutrient available in the first crop year (inorganic) and the percentage of manure transferred to the soil organic pool. The calculation used to determine the crop available N in the first year, provided by Manitoba Agriculture, was equivalent to inorganic-N + 30 percent organic-N. This formula was used to calculate the crop available N for all the different livestock. Racz (pers. comm.) indicated that the use of this formula for all livestock manure might not be very accurate as the split of organic and inorganic N would likely vary considerably for the various manures. The nutrients available to crops from manure can be dependent on several factors, including the type of manure. The process appears too complex to be explained by one simple calculation. Unfortunately, no information was found to provide a better estimate of the percent of different manure nutrients available to crops in the first year. The estimate of 50 percent available P and 50 percent organic P, provided by Manitoba Agriculture, was also used for all livestock manure. Again arguments can be made to the suitability of this estimate for the different manures.

A summary of the total nitrogen and phosphorus inputs and outputs for farms in all the municipalities was done (Tables 5.3 and 5.4). The percent contribution of the inputs and outputs are summarized in Tables 5.5 and 5.6. The calculated losses include all losses by volatilization, denitrification, leaching, and runoff. The large values observed for the calculated losses of nitrogen are an indication of the uncertainty and error associated with estimating these values. The estimation of these values is an inexact process. Residual losses include nutrients that would remain in the soil component. The residual losses are also indicative of the inaccuracy of estimating losses, as some values are negative, indicating that estimates for calculated losses were too high

Total inputs for farms in Hanover ranged from 148 to 177 kg N/ha and 21 to 39 kg P/ha, while inputs ranged from 115 to 162 kg N/ha and 8 to 29 kg P/ha for farms in Roland. Total inputs for farms La Broquerie ranged from 53 to 295 kg N/ha and 10 to 69 kg P/ha, and ranged from 38 to 56 kg N/ha and 1 to 3 kg P/ha for farms in Sifton. The total inputs and residual values of P are higher for farms in Hanover and to a lesser extent, La Broquerie, because of the large input of P from purchased feed.

Fertilizer inputs in the RM of Hanover ranged from 16 to 56 percent of N and 28 to 59 percent of P, resulting in average application rates ranging from 23 to 88 kg N/ha and 9 to 17 kg P/ha. In the RM of Roland, fertilizer inputs were much higher, ranging from 63 to 95 percent of N and 100 percent of P, resulting in average application rates ranging from 81 to 156 kg N/ha and 8 to 29 kg P/ha. All of the case farms examined in Hanover utilized manure as fertilizer, which explains the lower inputs of fertilizer when compared to farms in Roland. Farms in Sifton had low average fertilizer application rates, ranging from 6 to 11 kg N/ha and 1 to 4 kg P/ha and rates ranged from 33 to 51 kg N/ha and 11 to 18 kg P/ha for farms in La Broquerie. Only a small portion of the land base was used for cropland by farms in the RM of Sifton, resulting in low rates of fertilizer application.

Table 5.3 Summary of total nitrogen and phosphorus inputs and outputs (kg/ha/year) for farms in RMs of Hanover and La Broquerie.

	RM of Hanover								RM of La Broquerie							
Farms	**Han A**		**Han B**		**Han C**		**Han D**		**Lab A**		**Lab B**		**Lab C**		**Lab D**	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Total Inputs	**177**	**39**	**150**	**25**	**157**	**28**	**148**	**21**	**53**	**15**	**89**	**19**	**139**	**10**	**295**	**69**
Fertilizer	84	12	45	9	88	17	23	12	33	15	34	11	-	-	51	18
Feed	87	27	13	5	43	4	17	9	-	-	-	-	64	10	238	50
Manure	-	-	27	11	15	7	-	-	-	-	-	-	-	-	-	-
Fixation	1	-	60	-	6	-	102	-	14	-	50	-	70	-	1	-
Deposition	5	<1	5	<1	5	<1	5	<1	5	<1	5	<1	5	<1	5	<1
Total Outputs	**81**	**16**	**50**	**10**	**45**	**9**	**64**	**11**	**34**	**7**	**32**	**6**	**72**	**15**	**169**	**33**
Crops	59	12	42	8	33	6	53	9	34	7	-	-	-	-	82	6
Animals products	22	4	8	2	12	3	11	2	0.5	<1	32	6	33	8	87	17
Manure	-	-	-	-	-	-	-	-	-	-	-	-	40	7	-	-
Inputs-Outputs	*96*	*22*	*100*	*15*	*112*	*19*	*83*	*10*	*19*	*8*	*57*	*13*	*65*	*-5*	*127*	*35*
Calculated losses	58	1	75	1	92	1	48	1	42	1	65	1	87	1	110	1
Residual[1]	*38*	*21*	*25*	*14*	*20*	*18*	*35*	*9*	*-23*	*7*	*-8*	*12*	*-22*	*-6*	*17*	*34*

[1]Residual does not represent inputs/outputs to soil pool due to errors of inputs/outputs in animal pool.

Table 5.4 Summary of total nitrogen and phosphorus inputs and outputs (kg/ha/year) for farms in RM of Roland and Sifton.

	RM of Roland						RM of Sifton							
Farms	**Rol A**		**Rol B**		**Rol C**		**Sif A**		**Sif B**		**Sif C**		**Sif D**	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Total Inputs	**115**	**8**	**131**	**14**	**162**	**29**	**38**	**1**	**43**	**3**	**56**	**4**	**47**	**2**
Fertilizer	109	8	81	14	156	29	7	1	6	2.5	11	4	11	2
Feed	-	-	-	-	-	-	0.6	0.1	0.4	0.4	-	-	-	-
Fixation	1	-	45	-	1	-	26	-	32	-	40	-	31	-
Deposition	5	<1	5	<1	5	<1	5	<1	5	<1	5	<1	5	<1
Total Outputs	**67**	**12**	**120**	**16**	**112**	**15**	**1**	**0**	**2**	**0.5**	**6**	**1**	**13**	**2**
Crops	67	12	120	16	112	15	-	-	-	-	5	1	11	2
Animals products	-	-	-	-	-	-	1	-	2	0.5	1	<1	2	-
Inputs-Outputs	*48*	*-4*	*11*	*-2*	*50*	*14*	*37*	*1*	*41*	*2.5*	*51*	*3*	*34*	*0*
Calculated losses	37	1	25	2	48	1	24	0.7	29	1	26	1	32	1
Residual[1]	11	-5	-13	-4	2	13	13	0.3	13	1.5	25	2	1	-1

[1]Residual does not represent inputs/outputs to soil pool due to errors of inputs/outputs in animal pool.

Purchased feed was a large input for farms, especially hog farms, in the municipalities of Hanover and La Broquerie. For two hog farms in Hanover, Han A and Han C, the input from feed ranged from 27 to 49 percent of N and 15 to 69 percent of P. For hog farms from La Broquerie, Lab C and Lab D, feed ranged from 46 to 81 percent of input N and 72 to 99 percent of P. The input from feed for dairy and beef farms in Hanover, Han B and Han D respectively, were very similar with 9 to 11 percent of N and 20 to 40 percent of P. Farms in RM of Sifton produce a large majority if not all of the feed for their livestock within the farm boundaries, which explains the low contribution of purchased feed in the total inputs.

Only two farms had inputs of manure, Han B and Han C. The contribution of this manure to the total inputs was 18 percent of N and 45 percent of P for Han B, and 10 percent of N and 25 percent of P for Han C.

Inputs by nitrogen fixation were a significant factor for farms that grew crops capable of symbiotic N fixation and having a high percent of their land base with these crops. Inputs by fixation ranged from 26 to 73 percent of N resulting in additions of 14 to 102 kg N/ha. Farms from Sifton had the highest percent contribution of N inputs from fixation, likely due to the low inputs of commercial fertilizer and purchased feed. Farms with no crops capable of N fixation had additions of 1 kg/ha, resulting in one percent or less of total N inputs from fixation. Rates of N fixation were based on estimates provided by the literature review. It is possible that these rates do not reflect the actual capacity of crops capable of symbiotic N fixation. Therefore, over or underestimates of the rates of N fixation used for these various farms is possible.

Inputs by atmospheric deposition ranged between 2 and 12 percent of total N inputs and <1 to 9 percent of total P inputs for all farms. Farms from the RM of Sifton had generally a greater percent contribution to total inputs by deposition, likely due to the low inputs of commercial fertilizers and purchased feed. A value of 5 kg N/ha and 0.1 kg P/ha was used to estimate atmospheric deposition for all farms in all municipalities. It is possible that atmospheric deposition could vary significantly between these four municipalities, resulting in an increase or decrease percent contribution to the total inputs.

Total outputs for farms in the RM of Roland ranged from 67 to 120 kg N/ha and 12 to 16 kg P/ha. The output by crops was the largest source of outputs from this municipality, ranging from 59 to 83 percent of N and 53 to 91 percent of P. The outputs for farms in Hanover were divided between crops and animal products, with crops having a higher percent output than animal products. The highest output values observed in La Broquerie and Sifton were from the calculated losses, due to low outputs of crops and animal products. The highest residual P value from the RM of Roland, Rol C, was 13 kg P/ha. This value was comparable to residual P values for farms from Hanover, which ranged from 9 to 21 kg P/ha. The residual N values for farms from Hanover were the highest when compared to the three other municipalities, ranging from 20 to 38 kg N/ha. Three of the four farms from La Broquerie had residual P values, ranging from 7 to 34 kg P/ha.

The magnitude of the losses, particularly nitrogen, as a percentage of total outputs illustrates the importance of developing good data for this factor. Changing the value of the estimated losses can significantly change the residual values. Prior to using a nutrient balance model as a farm management or regulatory tool, careful consideration must be given to the accuracy of estimates for nutrient losses.

The intensive livestock farms in Hanover and La Broquerie that demonstrated a net surplus of nutrients appear to have the ability to improve this situation, particularly with respect to phosphorous. An elimination of fertilizer inputs would either eliminate or significantly reduce the nutrient surpluses. In addition, through the use of feed management, such as the use of phytase (see subsequent discussion, Section 5.2, Municipal-Scale Nutrient Budget) to reduce phosphorous, the input of nutrients from feed can be reduced.

Table 5.5 Summary of total nitrogen and phosphorus inputs and outputs, as a percent of total, for farms in RM of Hanover and La Broquerie.

	RM of Hanover								RM of La Broquerie							
Farms	**Han A**		**Han B**		**Han C**		**Han D**		**Lab A**		**Lab B**		**Lab C**		**Lab D**	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Inputs																
Fertilizer	47	28	30	34	56	59	16	48	62	100	38	58	-	-	17	26
Feed	49	69	9	20	27	15	11	40	-	-	-	42	46	99	81	72
Manure	-	-	18	45	10	25	-	-	-	-	-	-	-	-	-	-
Fixation	1	-	40	-	4	-	69	-	26	-	56	-	51	-	<1	-
Deposition	3	3	3	1	3	1	4	2	12	<1	6	<1	3	1	2	2
Outputs																
Crops	33	31	28	31	21	22	36	43	45	45	-	-	-	-	28	24
Animal products	12	11	6	7	8	8	8	11	<1	<1	33	33	20	49	30	25
Manure	-	-	-	-	-	-	-	-	-	-	-	-	25	47		
Calculated losses	33	3	50	4	59	4	32	5	55	7	67	5	55	4	37	2
Residual	22	55	16	58	12	66	24	41	<1	48	<1	59	<1	<1	5	49

Table 5.6 Summary of total nitrogen and phosphorus inputs and outputs, as a percent of total, for farms in RM of Roland and Sifton.

	RM of Roland						RM of Sifton							
Farms	**Rol A**		**Rol B**		**Rol C**		**Sif A**		**Sif B**		**Sif C**		**Sif D**	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Inputs														
Fertilizer	95	100	62	100	96	100	18	83	15	93	20	97	23	95
Feed	-	-	-	-	-	-	2	8	1	3	-	-	-	-
Fixation	1	-	34	-	1	-	68	-	73	-	71	-	66	-
Deposition	4	<1	4	<1	3	<1	12	9	11	4	9	3	11	5
Outputs														
Crops	59	91	83	88	69	53	-	-	-	-	9	27	25	65
Animal products	-	-	-	-	-	-	2	11	4	17	1	4	3	12
Calculated losses	32	9	17	12	30	4	64	51	67	28	46	21	69	23
Residual	9	<1	<1	<1	1	43	34	38	29	55	44	48	3	<1

5.2 Municipal-Scale Nutrient Budget

The nutrient balance for all four municipalities is summarized in Table 5.7. A summary of the total N and P inputs and outputs for all municipalities was also done (Table 5.8). The plant component, as with the case farms, was balanced as it was assumed that there was no net surplus/deficit of plant products.

A significant imbalance in the animal component was observed for the RM's of Hanover and La Broquerie. Both of these municipalities have large livestock populations and the input of feed, estimated from values from Statistics Canada, may have been underestimated. The other factor that would affect the animal component, manure production, may have been overestimated. Manure production was calculated using daily manure N and P values from Manitoba guidelines and livestock inventory provided by Statistics Canada and would likely be more accurate than the estimate used to calculate the input of feed. Therefore, the input of feed was increased or decreased to balance out the animal component (Tables 5.9 and 5.10). Modification to the input of feed does not change any values for the soil component.

Table 5.7 Summary of nutrient balances (kg/ha/year) for municipalities of Hanover, La Broquerie, Roland, and Sifton.

Municipality	Hanover		La Broquerie		Roland		Sifton	
Plant component	N	P	N	P	N	P	N	P
Supplies	60*	10	56	7	105	17	45	6
Removals	60	10	56	7	105	17	45	6
Supplies-Removals	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Animal component								
Supplies	102	17	106	16	12	2	22	3
Removals	116	31	130	34	4	1	21	6
Supplies-Removals	*-15*	*-14*	*-24*	*-20*	*8*	*1*	*1*	*-3*
Soil Component								
Supplies	128	34	118	37	139	18	50	9
Removals	99	11	96	8	139	18	67	7
Supplies-Removals	*29*	*23*	*22*	*29*	*0*	*0*	*-17*	*2*
Available soil nutrients								
Supplies	167	29	161	29	178	23	110	14
Removals	137	25	144	23	164	21	120	14
Supplies-Removals	*30*	*4*	*17*	*6*	*15*	*2*	*-10*	*0*
Soil organic matter								
Supplies	79	20	88	24	62	8	76	11
Removals	80	10	83	11	77	10	84	11
Supplies-Removals	*-1*	*10*	*5*	*13*	*-15*	*-2*	*-8*	*0*

*kg/ha

Table 5.8 Summary of total nitrogen and phosphorus inputs and outputs (kg/ha/year) for municipalities of Hanover, La Broquerie, Roland, and Sifton.

Municipality	Hanover		La Broquerie		Roland		Sifton	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Total Inputs	**133**	**21**	**106**	**15**	**111**	**15**	**22**	**2**
Fertilizer	42	7	21	3	83	13	9	1
Feed	83	14	74	12	9	2	2	1
Fixation	4	-	6	-	14	-	6	-
Deposition	5	<1	5	<1	5	<1	5	<1
Total Outputs	**49**	**10**	**28**	**6**	**68**	**13**	**8**	**2**
Crops	20	4	2	<1	67	12	6	1.5
Animal products	29	6	26	6	1	1	2	0.5
Inputs-Outputs	*85*	*11*	*78*	*9*	*44*	*2*	*14*	*0*
Calculated losses	**70**	**1**	**81**	**1**	**36**	**1**	**30**	**1**
Residual	15	10	-3	8	8	1	-16	-1

The RM of Hanover is characteristic of intensive livestock systems, with very high inputs and low outputs (Frissel, 1978). Purchased feed was the largest input of N and P followed by fertilizer (Table 5.10). A very low decrease in organic N and an increase in organic P were observed while both available N and P increased (Table 5.9). Calculated losses were the highest output from this RM. High losses of volatilization and denitrification occurred due to the presence of manure. Residual values were 29 kg N/ha and 23 kg P/ha.

The RM of La Broquerie is also characteristic of intensive livestock system. Purchased feed was the largest input of N and P. An increase in both organic N and P as well as available N and P were observed for this RM. Calculated losses were the highest output, with high losses of volatilization and denitrification occurring due to the presence of manure. Residual values were 22 kg N/ha and 29 kg P/ha.

The RM of Roland is characteristic of an intensive cropping system, with high inputs and outputs. The high outputs are due to the high removal of crops, which results in a better balance between inputs and outputs as more nutrients are accounted for. A decrease in both organic N and P was observed, while available N and P increased (Table 5.9). The increase in available N is similar to the increase in La Broquerie, while the increase in available P is similar to that in Hanover. Calculated losses accounted for 35 and 7 percent of outputs, for N and P respectively (Table 5.11). Denitrification was the largest loss output, accounting for 78 percent of the calculated losses. No residual nutrients were observed.

The RM of Sifton is characteristic of an extensive agricultural system, with low inputs and outputs. Fertilizer was the highest N input accounting for 44 percent of total inputs while feed provided the highest P inputs, accounting for 66 percent (Table 5.11). N fixation and atmospheric N deposition were important inputs for this RM, contributing 28 and 24 percent, respectively. A slow decrease in organic and available N was observed. Organic P was also increasing at a slow rate. The decrease in organic N is likely due to the low inputs of fertilizers on cultivated lands. Calculated losses for N were the largest output accounting for 79 percent, while the highest P output was from crops. Calculated losses for N were higher than the total inputs, resulting in residual losses of N. The values used to estimate calculated losses for this RM were likely too high. Calculated losses of P were only 2 kg/ha.

Table 5.9 Summary of nutrient balances (kg/ha/year) for municipalities of Hanover, La Broquerie, Roland, and Sifton with modifications to input of feed for livestock.

Municipality	**Hanover**		**La Broquerie**		**Roland**		**Sifton**	
Plant component	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Supplies	60*	10	84	11	105	17	74	10
Removals	60	10	84	11	105	17	74	10
Supplies-Removals	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Animal component								
Supplies	116	31	130	37	4	1	21	6
Removals	116	31	130	37	4	1	21	6
Supplies-Removals	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Soil Component								
Supplies	128	34	118	37	139	18	50	9
Removals	99	11	96	8	139	18	67	8
Supplies-Removals	*29*	*23*	*22*	*29*	*0*	*0*	*-17*	*1*
Available soil nutrients								
Supplies	167	29	161	29	178	23	110	14
Removals	137	25	144	23	164	21	120	14
Supplies-Removals	*30*	*4*	*17*	*6*	*15*	*2*	*-10*	*0*
Soil organic matter								
Supplies	79	20	88	24	62	8	76	11
Removals	80	10	83	11	77	10	83	10
Supplies-Removals	*-1*	*10*	*5*	*13*	*-15*	*-2*	*-7*	*1*

Table 5.10 Summary of total nitrogen and phosphorus inputs and outputs (kg/ha/year) for municipalities of Hanover, La Broquerie, Roland, and Sifton with modification to input of feed for livestock.

Municipality	Hanover		La Broquerie		Roland		Sifton	
	N	P	N	P	N	P	N	P
Total Inputs	**148**	**35**	**130**	**36**	**104**	**14**	**22**	**5**
Fertilizer	42	7	21	3	83	13	9	2
Feed	97	28	98	33	2	1	2	3
Fixation	4	-	6	-	14	-	6	-
Deposition	5	<1	5	<1	5	<1	5	<1
Total Outputs	**49**	**10**	**28**	**6**	**68**	**13**	**8**	**2**
Crops	20	4	2	<1	67	12	6	1.5
Animal products	29	6	26	6	1	1	2	0.5
Inputs-Outputs	*99*	*24*	*102*	*30*	*36*	*1*	*14*	*3*
Calculated losses	**70**	**1**	**80**	**1**	**36**	**1**	**31**	**1**
Volatilization	39	-	48	-	1	-	17	-
Denitrification	21	-	19	-	28	-	7	-
Leaching	8	-	11	-	5	-	6	-
Runoff	2	1	2	1	2	1	1	1
Residual	**29**	**23**	**22**	**29**	**0**	**0**	**-17**	**2**

Table 5.11 Summary of total nitrogen and phosphorus inputs and outputs, as a percent of total, for municipalities of Hanover, La Broquerie, Roland, and Sifton.

Municipality	Hanover		La Broquerie		Roland		Sifton	
	N	P	N	P	N	P	N	P
Inputs								
Fertilizer	28	19	16	9	80	93	44	32
Feed	66	81	76	90	2	6	4	66
Fixation	3	-	5	-	14	-	28	-
Deposition	3	>1	3	1	4	1	24	2
	100	100	100	100	100	100	100	100
Outputs								
Crops	14	11	1	1	65	90	16	25
Animal products	20	18	20	16	>1	>1	5	10
Calculated losses	47	2	62	2	35	7	79	16
Residual	19	69	17	81	>1	3	>1	49
	100	100	100	100	100	100	100	100

Table 5.10 indicates that reducing fertilizer inputs, especially nitrogen, in the municipalities of Hanover and La Broquerie can reduce the surplus of nitrogen. Once again, this is consistent with the results of the farm level budgets. The estimated nitrogen surplus in both municipalities could be eliminated with a reduction in chemical fertilizers.

A comparison of census data from Statistics Canada for the total commercial fertilizer purchases between the 1996 and 2001, indicates a reduction in sales for the RM of Hanover and Sifton and an increase in Roland and La Broquerie (Table 5.12). Several fertilizer dealers in the RM of Hanover had indicated a decrease in sales due to the expansion of the hog industry resulting in the greater utilization of manure as fertilizer.

Table 5.12 Comparison of the total commercial fertilizer purchases in Census years 1996 and 2001.

Municipality	1996	2001	% Change
	$ x 1,000		
Hanover	3,460	2,690	-22
La Broquerie	435	510	+17
Roland	3,110	3,460	+11
Sifton	600	530	-12

A reduction in fertilizer phosphorous for Hanover and La Broquerie would appear to have little effect in balancing the flow of phosphorous, as feed supplies 90 percent of phosphorous input.

Strategies to reduce the concentration of P in manure should greatly improve the P balance in Hanover and La Broquerie. Studies have found that the amount of P excreted can be significantly decreased by the addition of microbial phytase in the diet, which releases some of the bound P making it available to the pig (Jongbloed *et al*., 1992; Cromwell *et al*., 1993). The amount of inorganic P that must be added to meet the available P requirement is reduced, and P excretion can be decreased by 30 to 50 percent (Bridges *et al*., 1995; Carter *et al*., 1996). The magnitude of the response to microbial phytase has been shown to be influenced by the source of P, dietary level of available P, the amount of phytase added, and the ratio of calcium to P (Lei *et al*., 1994; Kornegay, 1996).

More precise feed formulations, especially for hogs, would help decrease the input of N and P from feed in RM of Hanover and La Broquerie. The use of synthetic amino acids in feed has been shown to decrease the N content of feedstuffs by 2 to 3 percentage points. The Netherlands, which has strict guidelines for reducing outputs of N, have been using synthetic amino acids in feed for several year to help reduce N losses, including losses by volatilization. As the use of synthetic amino acids is not a common practice in Manitoba, an increase in feed costs by one to two dollars per tonne would be expected. The extra cost would eventually decrease with an increase in its popularity and use among producers. Volatilization loss for Hanover and La Broquerie was the highest among all the calculated losses. Other technologies also exist to help reduce volatilization losses, such as the use of synthetic or straw covers for earthen manure storages.

The increased residual organic N and P in Hanover and La Broquerie on a municipal basis was generally consistent with the results of the farm-scale budgets.

Increases in soil organic matter (SOM) or reductions in rate of loss of SOM such as noted for the intensive livestock areas (Hanover and La Broquerie) can result in better soil structure, leading to greater infiltration of water, less runoff, and less dissolved P and particulate P entering surface waters. Organic matter also has a large capacity to hold and store water for plant use. Thus, loss of nutrients to surface waters, at equivalent soil nutrient levels, could be less for areas such as Hanover and La Broquerie than for areas without manure, such as Roland. A study by Edwards and Daniel (1994) showed that P runoff losses from fields applied with inorganic fertilizers were higher (2.68 kg/ha) than from fields applied with poultry manure (1.98 kg/ha). Another study found that the application of fertilizer resulted in the largest amount of P transfer under crops of corn and forages (Simard *et al*., 2001).

As was previously mentioned in Section 5.1, Farm-Scale Nutrient Balance, the large values observed for the calculated losses of nitrogen are an indication of the uncertainty and error associated with estimating these values. The large residual values can also be indicative of errors in estimating these losses. The residual N for Sifton was a negative value, suggesting that the calculated losses were overestimated. More accurate information is required to better estimate losses, such as field-based studies on soils varying in texture, cropping and management practices, etc.

Additions of phosphorous to soil in excess of crop removal increase phosphorous concentrations in soil. The increase in phosphorous concentration, at least initially, is limited to surface horizons. The phosphorous in excess of crop removal is distributed among three pools: (1) highly insoluble P minerals, (2) organic phosphorous, and (3) soluble or easily extractable P. The relative distribution of the added phosphorous among the three pools depends on factors such as the soil type and forms of P added. Inorganic forms of added P are found mainly in the mineral and soluble or easily extractable pool. In contrast, P added in manures usually increases P concentrations of P in all three pools. For example, P in excess of crop removal for both Hanover and La Broquerie Municipalities, which have high densities of livestock operations, was distributed in all three pools.

Phosphorous is transported to waters via three main processes:

1) Erosion of soil into surface waters. The P-enriched soil particles release P to the water.
2) Runoff of dissolved P. Concentration of dissolved P in runoff increases with increases in concentration of soluble or easily extractable P in soil.
3) Leaching to groundwater. Leaching of P can occur at very highly soluble or easily extractable P concentrations in soils with low P fixation capacities.

The potential for P loss from soil to water bodies, via all three processes, increases with increases in soluble or easily extractable P, but losses are also greatly affected by type and method of application, and by soil properties such as texture, pH and landscape characteristics which affect runoff and P retention. Therefore, the use of a single soil test threshold for various soil types, cropping systems, etc. is not appropriate. A practical approach is to use both source and transport factors that affect P loss and develop site-specific indexes (Called “P Index”) that can be used for P thresholds and management strategies on a site-specific basis. Unfortunately, Manitoba does not have site-specific “P Indexes” by which P accumulation, such as observed for soils in some municipalities, could be assessed. Research to provide data to develop P Indexes for the soil and climatic conditions encountered in Manitoba, has not been conducted here or elsewhere.

Although soil-test P alone does not accurately predict P losses, soil-test P level is one of the main factors in the “P Index”, and one of the most effective management factors to reduce P loss to waters is to prevent excessive accumulations of soil-test P. Our studies indicated that the available (soluble or extractable) P fraction was increasing at an average rate of 4 to 6 kg P/ha/yr. for soils in Hanover and La Broquerie. Soils, which have not been heavily manured and/or fertilized with commercial P fertilizers, contain about 30 kg P/ha soil-test P. Based on the above, and if P management practices do not change, soil test P would double in about 5 to 8 years for soils in these municipalities. Environmental guidelines, established elsewhere for similar jurisdictions, vary from about 50 to 100 mg/kg soil-test P ($NaHCO_3$ – ext. P) or about 100 to 200 kg P/ha soil-test P. Guideline limits of 50 mg kg^{-1} would be reached in about 12 to 18 years, whereas guideline limits of 100 mg/kg could be reached in about 30 to 40 years if P management practices were not altered.

It is possible to reduce increases in the available P pool by reducing inputs of commercial P fertilizer. However, producers need to add small amounts of P fertilizer (5 kg P/ha) with the seed crops to provide P for early season growth. About 7 and 3 kg P/ha on average were added as commercial P fertilizer in Hanover and La Broquerie, respectively. Therefore reductions in commercial P fertilizer application, even to very low levels of about 2 kg P/ha (as could perhaps be achieved by use of foliar P fertilizers for crops in the seedling stage) will still result in continued increases in soil-test P at present levels of feed purchases, etc. In contrast, reductions in the use of commercial fertilizers can be used to enhance sustainability in intensive crop production areas such as Roland, an area in which soil-test P is also increasing.

It should be noted that the study included only one year of data and that P loadings, removals, etc. were calculated as averages per hectare for the entire land area in crop, hay, pasture or summerfallow land in the municipality. Loadings of P vary greatly among fields (Racz and Fitzgerald). Thus, rates of soil-test P are likely to vary greatly among fields as well. This was confirmed during the study of the case farms. Producers need to monitor soil-test P levels, and if soil-test P levels are increasing, producers need to implement management strategies to reduce excessive accumulations of P, particularly if the increase is rapid. Management strategies that could be implemented include:

1) Growing crops with a high P removal.
2) Keeping annual applications as low as practical (avoid single large applications of P).
3) Reducing P content of feed where practical.
4) Use of natural pasture for manure utilization.
5) Reducing use of commercial P fertilizer where possible.

It may be possible to reduce P inputs to particular fields by the export of manure P. Most of P in manure is associated with the solids. Separation of solids from liquid would provide a solid high in P, which could be used as a compost or as a P fertilizer elsewhere.

Traditional “conservation” farming practices that reduce wind and water erosion are critical in reducing nutrient losses and environmental impacts from agricultural crop production. The following practices will minimize N and P entering water bodies:

- maximizing crop reside cover;
- grassed waterways;
- vegetative filter strips adjacent to watercourses;
- establishing and maintaining riparian areas;
- elimination of summerfallow;
- the use of cover crops;
- wind barriers, including trees, tall grasses and annual barrier plants such as corn or sunflowers; and
- appropriate crop rotations.

The transport of nutrients to surface water can also be reduced through a reduction in land drainage and the maintenance of wetlands.

More research, using field-based studies, is needed to provide a better understanding of losses of both N and P. The build-up of N and P is increasing in the Hanover and La Broquerie and changes are required to decrease the rate of increase. The RM of La Broquerie would provide an excellent study area for conducting detailed site-specific research. Research would focus on the development of a site-specific P-index, calculating losses of both N and P and strategies in reducing this losses, strategies for exporting manure, etc. The data collected from this research could therefore be implemented to decrease residual N and P in other municipalities such as Hanover.

The current system implemented by Manitoba Agriculture and enforced by Manitoba Conservation for regulating the application of manure is based on nitrogen. Regulations (42/98) from the Environment Act provide for the application of manure to land. The regulation includes the following:

"No person shall apply livestock manure to land in an agricultural operation,

a) Other than as a fertilizer; or
b) At a rate of application such that the concentration of nitrate nitrogen in the soil exceeds,
    1) For annual crops in medium to heavy (sandy loam to clay) textured soils, 157.1 kg/ha (140 lbs/acre) within the top 0.6 m (two feet) of soil at any location on the land;
    2) For annual crops in lighter (loamy sand to sand) textured soils, 101 kg/ha (90 lbs/acre) within the top 0.6 m (two feet) of soil at any location on the land;
    3) For alfalfa crops, 308.5 kg/ha (275 lbs/acre) within the top 0.6 m (two feet) of soil at any location on the land;
    4) For alfalfa-grass mixtures or grass forage crops, 224.4 kg/ha (200 lbs/acre) within the top 0.6 m (two feet) of soil at any location on the land; and
    5) For any other combination of crop or forage crop and soil condition, the amount necessary to meet the annual nitrogen requirements for the particular crop in that soil".

Many crop producers argue that these limits are too low to produce high yielding crops and question why these limits only apply to manure fertilizer. Crop producers that only apply inorganic fertilizers have no application restrictions to prevent the build-up of residual nitrate nitrogen in their soils. The soil test results from the case farms indicated that nitrate-nitrogen does accumulate in soils that have received inorganic fertilizer. These results are consistent with the results of McGill and Ewanek (Table 2.23) that found very high levels of soil nitrate on fields that had only been fertilized with inorganic fertilizers.

Regulating only N encourages N losses by volatilization during manure storage and application. As volatilization losses increase from manure, the producer is allowed to increase manure application rates, which decreases application costs. Increased losses by volatilization decreases the N:P ratio of the manure, resulting in high P addition to soils. As P is found mostly in the solid manure form, P losses are minimal. A better N:P balance of manure can be achieved by reducing volatilization losses and will prevent the accumulation of P in soils. Storage covers and manure injection are effective in reducing volatilization losses.

5.3 Environmental Risk Assessment of Residual Nutrients

Maps provided by Soils and Terrain Bulletins for the municipalities of Hanover, La Broquerie, Roland, and Sifton (Agriculture and Agri-Food Canada), provide an assessment of the environmental risks associated with the increase of residual nutrients. These maps were created to address concerns for land under irrigated crop production and the possibility that surface and/or groundwater may be impacted. The potential environmental impact assessment provides a relative rating of land into four classes (minimal, low, moderate, and high) based on an evaluation of specific soil factors and landscape conditions that determine the impact potential.

Soil factors considered are those properties that determine water retention and movement through soil. Topographic features are those that affect runoff and redistribution of moisture in the landscape. Soil texture, hydraulic conductivity, salinity, geological uniformity, depth to water table and topography are specifically considered. The maps are based on the dominant soil series for each soil polygon, in combination with the dominant slope class from the terrain layer database. The nature of the subclass limitations and the classification of subdominant components are not shown at this generalized map scale.

The most detailed soil information currently available was selected as the data source for the digital soil layer for each municipality. The maps for the RM's of Hanover, La Broquerie, and Roland were created using comprehensive detailed soil maps (1:20,000 to 1:50,000 scale) while the map for RM of Sifton was created using older, reconnaissance scale soil maps (1:126,720 scale). These older maps were compiled on a soil association basis, in which soil landscape patterns were identified with unique surficial geological deposits and textures. Each soil association consists of a range of different soils ("associates") each of which occurs in a repetitive position in the landscape. Therefore comparisons between the Sifton map and maps for the other three municipalities should not be made.

The following table provides the percentage of each impact class for the four municipalities.

Table 5.13 Potential environmental impact[1].

Class	Hanover	La Broquerie	Roland	Sifton
	Percent of RM			
Minimal	36.8	1.1	85.0	3.3
Low	30.5	23.4	7.5	2.1
Moderate	4.3	3.7	6.6	3.8
High	26.5	65.5	0.3	83.1
Organic	0.5	6.3	0.0	0.0
Unclassified	1.4	0.0	0.6	7.6
Water	0.0	0.0	0.0	0.0
Total	100	100	100	100

[1]Based on dominant soil, slope gradient, and slope length of the respective soil and terrain maps.

The slope gradient in all four municipalities is relatively level; 98 percent or more of land in Hanover, La Broquerie and Roland is classified as zero to two percent slope. In Sifton, almost half of the land is in this level classification and almost half is sloped from two to five percent. The differences in potential environmental impact between the studied municipalities is primarily due to soil types. La Broquerie and Sifton contain predominantly coarse textured soils (72 and 92 percent, respectively), while Roland contains clay to loam soils over 93 percent of its land area. Hanover contains a mix of soil types. The potential environmental impact ratings in Table 5.13 therefore primarily reflect the relative risk to groundwater leaching.

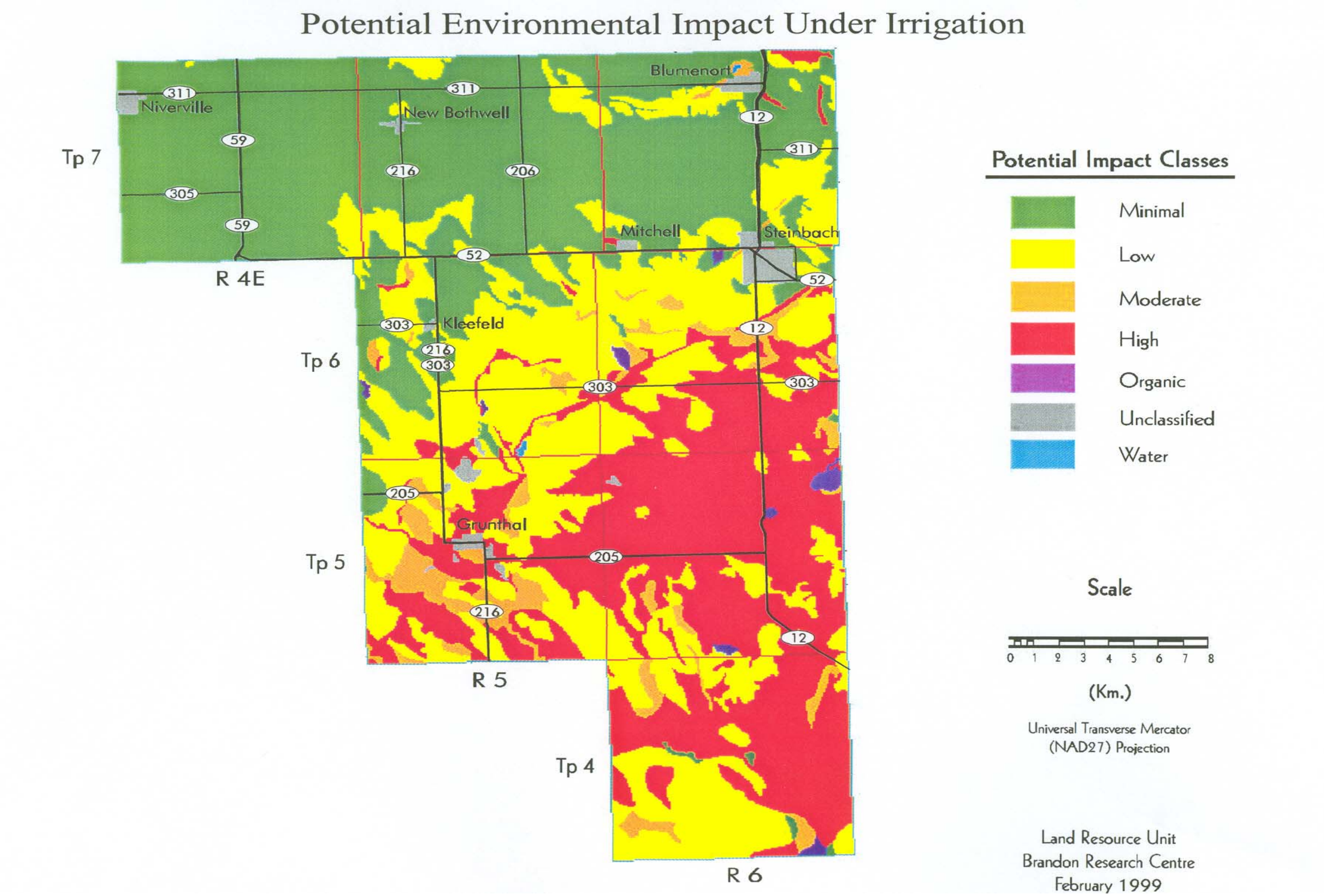

Figure 5.1 Potential Environmental Impact for the R.M. of Hanover.

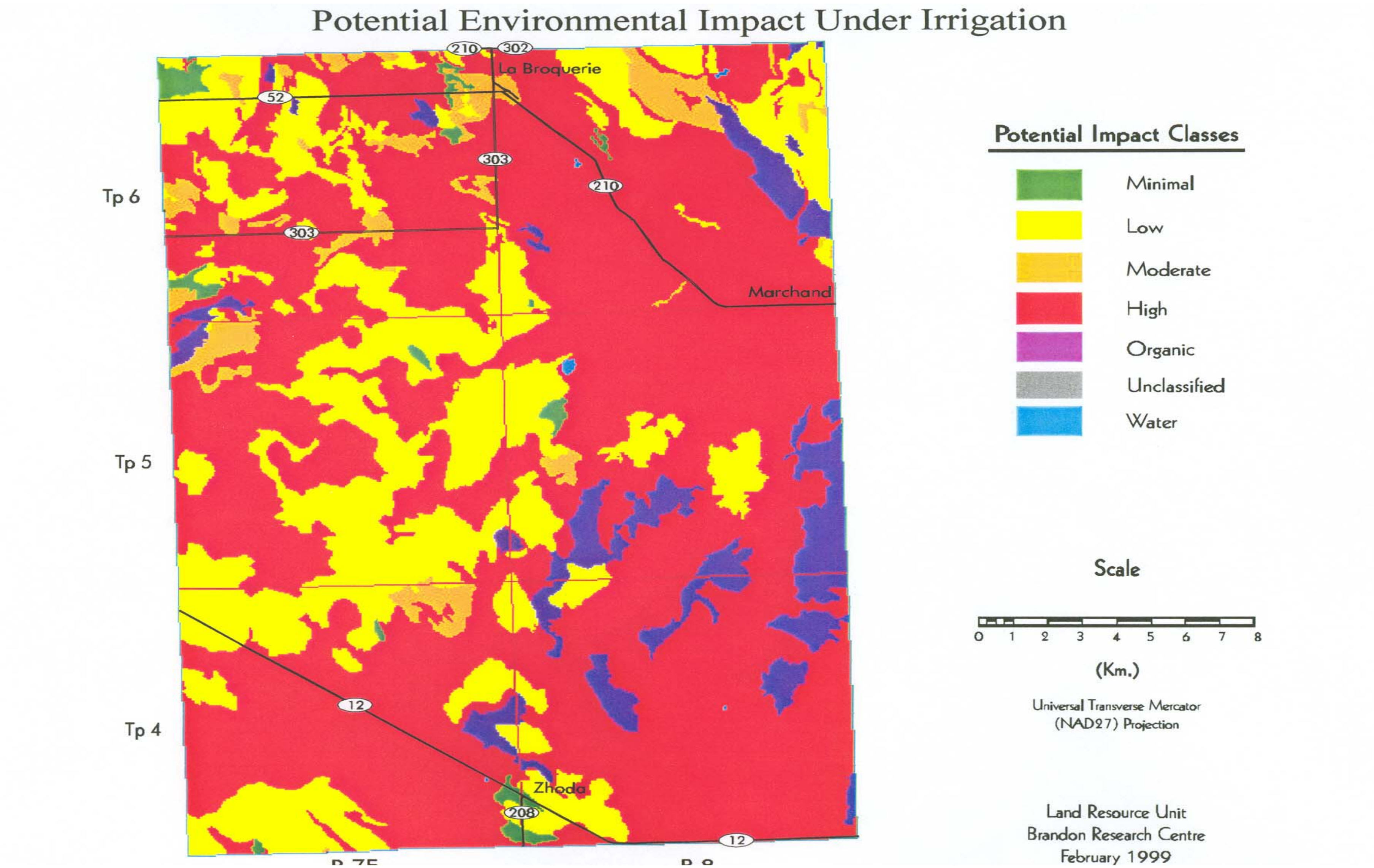

Figure 5.2 **Potential Environmental Impact for the R.M. of La Broquerie.**

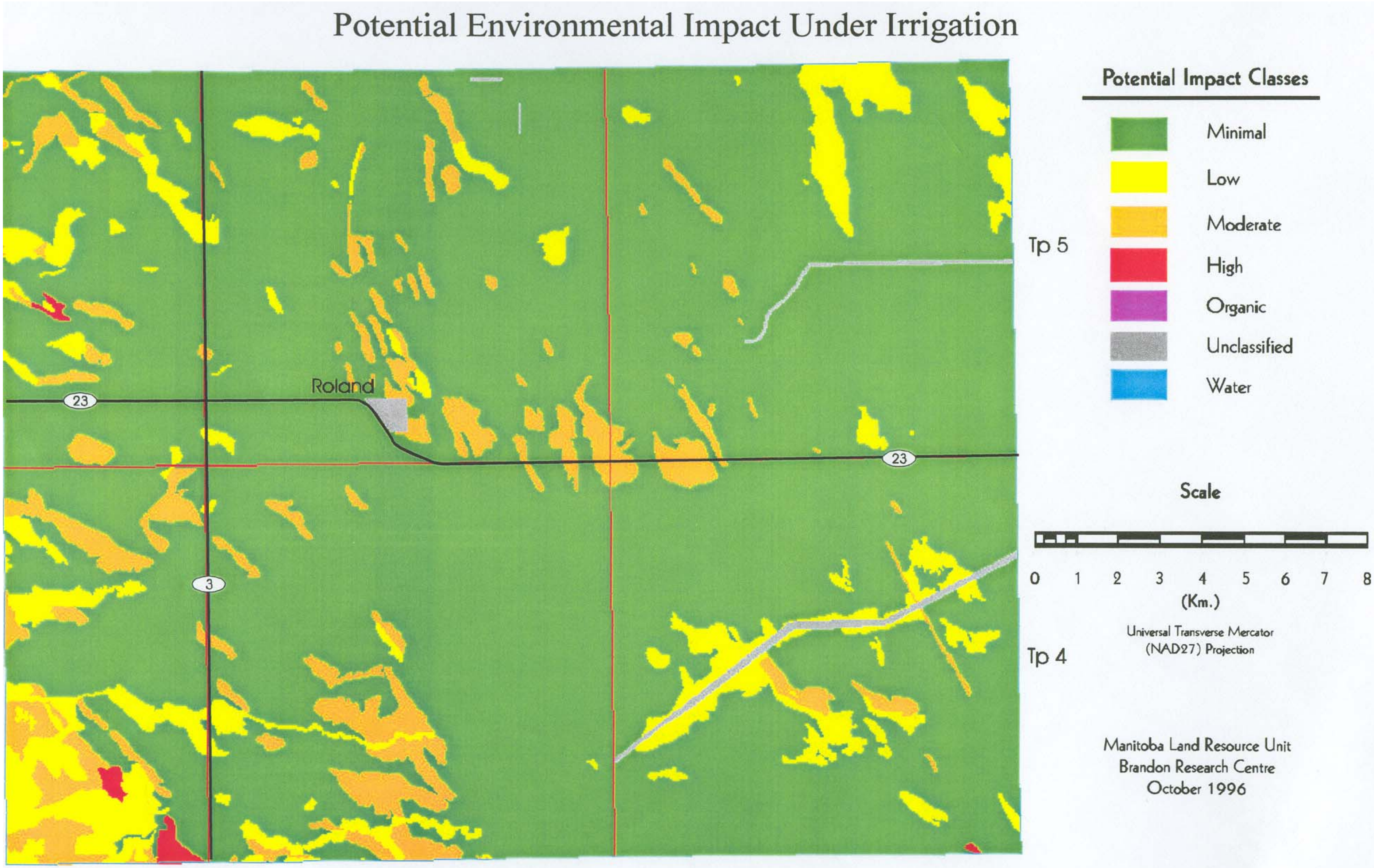

Figure 5.3 Potential Environmental Impact for the R.M. of Roland.

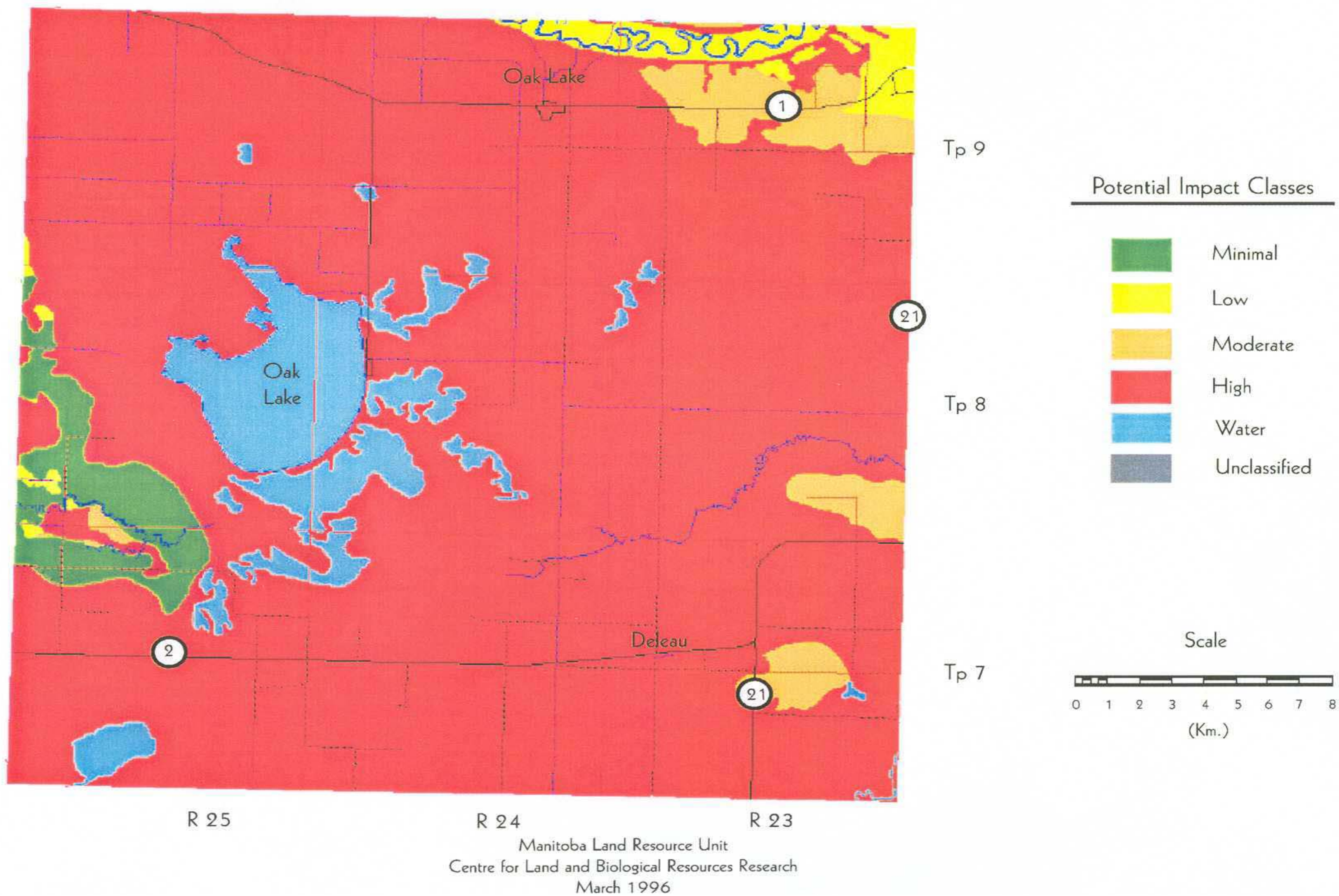

Figure 5.4 Potential Environmental Impact for the R.M. of Sifton.

5.4 Non-Agricultural Nutrient Loads

In many areas, the organic wastes from residential and municipal sources comprise the bulk of the N and P released into the environment from non-agricultural sources. Municipal sewage lagoons and residential septic fields are the two primary sources.

The nutrients from residential septic-disposed systems experience two fates. Solids in the septic tank (septage) settle out and are periodically removed. This septage is normally transported and discharged into municipal lagoons. The balance of the liquid from the septic field is intended to leach in the underlying soils.

The objective of this component of the study was to estimate the scale of non-agricultural sources so that these nutrients could be considered within an approximate context relative to agricultural sources. A significant component of non-agricultural nutrients from waste are discharged as a point source from lagoons. This waste is generated from all industrial activities producing organic wastes, served by the lagoon, as well as the septage from rural residents. It was therefore decided that a valid comparison of this lagoon discharge, which directly enter surface waters, should be made with respect to the estimates of agricultural runoff, which are also a direct source of nutrients to surface waters.

Information on the discharge of nutrients from sewage lagoons was difficult to obtain in Manitoba. Although information on licensed lagoons is generally available from Manitoba Conservation, the files on several of the lagoons studied were unavailable at the Manitoba Conservation library. Much of the information in this report was received directly from the Rural Municipalities. Information available on licensed lagoons includes a basic description of the lagoons, including the size and location, some characteristics of the influent and effluent and annual treated waste volume.

If the size of the lagoon was unknown, the annual waste volumes from the lagoons were estimated on the basis of the lagoon size or the number of people and businesses the lagoon served.

Until recently licensed lagoons have been required to monitor only total solids, coliforms, and Biological Oxygen Demand (BOD) prior to discharge. The discharge of N and P has not been a consideration, hence relatively little data is available. Data from the lagoons in Mitchell, New Bothwell, Bothwell Cheese Co-op, Blumenort, Steinbach, and La Broquerie were adopted from the “Seine River Diversion Water Quality Model” provided by Manitoba Water Resources Service Department. The nutrients in the remaining lagoons were extrapolated from similar lagoons. The “Manual for Land Application of Treated Municipal Wastewater and Sludge” (Manual EPS 6-EP-84-1) was also used to estimate nutrient discharge. The detailed data for all lagoon discharges is outlined in greater detail in Appendix C.

The annual discharge of nutrients from municipal and industrial lagoons is outlined in Table 5.14. These values were estimated as the product of the estimated concentrations of the nutrients multiplied by the estimated annual discharge volume. This table also indicates the estimated nutrient load from agricultural fields due to runoff.

In the three municipalities that are lightly populated, La Broquerie, Roland, and Sifton, the non-agricultural nutrients are very small in comparison to agricultural ones, ranging from 0.1 to 2.1 percent. Hanover, on the other hand, was quite different. The population in Hanover is much greater and there is a considerable amount of industrial activity that produces organic waste and the resulting nutrients. The non-agricultural nutrients discharged into surface watercourses were approximately 28 percent of estimated agricultural runoff in Hanover.

Table 5.14 Municipal Point Source N and P Contribution.

	Hanover	La Broquerie	Roland	Sifton
Lagoon N, tonnes	43.1	1.0	0.1	0.1
Lagoon P, tonnes	16.1	0.4	0.05	0.06
Runoff N, tonnes	150.3	56.8	88.0	122.9
Runoff P, tonnes	57.4	19.4	43.1	44.8
%, Lagoon N/Runoff N	28.7	1.8	0.1	0.1
%, Lagoon P/Runoff P	28.0	2.1	0.1	0.1

The N and P concentration of septage is higher that of normal sewage. The exact quantity of septage entering each of the town sewage lagoons varies somewhat with the number of households using the lagoon and septage production rates for each household. It is unlikely however that any variances in the amount of nutrients entering from septage would have significantly impacted the estimates of the annual discharges of N and P.

The data in Table 5.14 indicates that point nutrient loads from heavily urbanized and/or industrialized rural areas, such as Hanover, can be quite significant in relation to non-point source loads from agriculture. Efforts to maintain surface water quality must therefore consider these point sources, as they can often be easier to control than non-point sources.

5.5 The Dutch approach to reduce the mineral nutrient surplus and ammonia volatilization.

Beginning in the 1980s the Dutch government embarked on a policy to address manure nutrient application to land and ammonia emissions. The first measures were aimed at minimizing mineral surpluses in soils and in the country as a whole. The government developed a unique system to reduce the country's manure nutrient surplus, called the Minerals accounting system (Minas). An overview of this system is presented in summary below. Detailed information about this and other policies are in the Appendix.

Under Minas, the farmer records exactly how much nitrogen and phosphorus enters the farm (input) and how much leaves the farm (output). Information is included to help farmers estimate the N and P content of all of their livestock. The difference between mineral inputs and outputs is the farm's mineral account. A negative budget (input<output) essentially means that the soil nutrients have been depleted. A surplus (input>output) indicates a potential build-up that increases the risk of leaching or runoff losses. Each year, a farmer must complete a mineral return stating his/her mineral account. All farmers must complete a record including all chemical fertilizers, manure nutrients, and other organic fertilizers, such as compost. The structure of Minas is similar to the nutrient budgets of total nutrient inputs (feed, livestock, manure, chemical fertilizers, N fixation) and outputs (livestock, manure, livestock products, crops) performed in out Regional Nutrient Balance study for all the farms and four municipalities. Minas disregards the nutrient flows (transfers) within the farm systems such as the application of animal manure on crop or forage land.

A certain quantity of minerals is always lost when fertilizers are applied to land (i.e. gaseous and leaching). Standard losses are included in Minas which takes into account inevitable losses from the farm. Losses are defined as the difference between inputs and outputs where outputs include standardized allowable losses as outlined in Table 5.15. Standard losses are expressed as kilograms of N and P per hectare. If a farm's mineral surplus after losses is higher than the loss standard, the farmer will be charged a levy over the difference. Levies are to discourage farmers from exceeding the loss standards for phosphate and nitrogen. The levies are sufficiently high that it is more economical for a farmer to take measures to reduce the mineral surplus than to pay the levies each year (Table 5.16). In this way, Minas strongly encourages farmers to reduce their mineral surpluses but still preserves flexibility to make farm management choices.

At the time the regulation was set in place, levels of residual soil nutrients were very high. The Dutch government avoided the implementation and regulation of upper soil nutrient limits since it would have had a sudden and detrimental impact on both intensive crop production and the livestock industry. Rather, the government developed a nutrient balance system that focused on bringing nutrient application and removal in balance and then with progressive reductions in allowable losses brought in gradual reductions in soil nutrient levels. This system allowed producers the opportunity to farm at a high level of productivity and intensity. The system is very condusive to progressive nutrient adjustments, it impacts all forms of fertilizer inputs and allows farmers to operate as business managers.

Table 5.15 Current Minas loss standards for N and P (kg/ha/year)

Year	Phosphate loss standard		Nitrogen loss standard					
	Arable land	Grassland	Arable land	Arable land clay/peat	Arable land dry sand/loess	Grassland	Grassland clay/peat	Grassland dry sand/loess
2001	35	35	150	125	125	250	250	250
2002	30	25	150	100	110	220	190	220
2003 >	20	20	100	60	100	180	140	180

Table 5.16 Dutch levies on surpluses exceeding the loss standards in Canadian dollars per kg.

Phosphate	2002	2003
0 – 10 kg/ha	$ 14.00	$ 14.00
> 10 kg/ha	$ 14.00	$ 14.00
Nitrogen		
0 – 40 kg/ha	$ 1.80	$ 3.60
> 40 kg/ha	$ 3.60	$ 3.60

The compilation of all yearly records of N and P inputs and outputs allows producers to easily identify the major source of nutrient surpluses. Once identified, the producer can develop strategies to reduce inputs or increase the export of nutrients. More precise fertilizer recommendations and the replacement of inorganic fertilizers by manure has led to a 30 percent reduction in fertilizer use over recent years. The redistribution, reprocessing, and export of manure has also increased. However, manure reprocessing on a large scale has not expanded to original expectations in spite of many promotional measures. Manure reprocessing has turned out to be far more expensive than was initially thought. The costs for the development of new technology and operational costs for treatment processes have been much high than expected, and the outlets for the reprocessed manure products have been difficult to find.

5.5.1 Regulatory Methodologies

The purpose of any regulation is to provide an enforceable framework that will ensure that the level of nutrients entering the ecosystem does not exceed the capacity of the ecosystem to assimilate these nutrients. Since nutrients entering the ecosystem will generally originate from the soil pool, preventing a buildup of nutrients in the soil becomes the obvious method of regulating soil nutrients.

There are two general methods that can be used to achieve this objective:

1. Establishing precise upper limits for soil N and P. When soil nutrients exceed these critical levels, a producer is in non-compliance.
2. A nutrient balance approach that seeks to balance outputs with inputs, thereby preventing any buildup of nutrients. This is the approach used in The Netherlands.

Both approaches both have the potential to safeguard the environment. There are, however, different implications to the implementation of these approaches.

5.5.1.1 Maximum Soil Levels (Manitoba System)

This is the system that the Province of Manitoba has implemented in the existing Manure and Mortalities Management Regulation. Upper levels of 90 kg/ha nitrate-nitrogen are specified for sandy soils, while 140 kg/ha nitrate-nitrogen is used for medium- to fine-textured soils that produce annual crops. Higher limits are permitted for forage crops. A key requirement in the regulation is the need to ensure that these limits are not exceeded at any time during the year. Manitoba Conservation conducts annual random audits by soil testing fields to ensure limits are not exceeded.

The Manitoba regulation was implemented in 1998 and producers have identified several concerns. A key issue is that intensive crop producers have found that the specified upper levels of nitrate-nitrogen in the soil are too low and are limiting the production of high-yielding crops. In addition, the Manure Management Plans have been structured around the assumption that soil sampling, and the application of crop nutrients according to simplistic formulas, is common crop nutrient management. The results of this study confirm that in normal crop production enterprises, soil sampling is used on a very limited basis and that crop producers use a complex group of factors to decide the level of nutrient application. The Manitoba Manure Management Plans therefore appear to be inconsistent with common practices used for crop nutrient management.

Research conducted by McGill and Ewanek described in the Literature Review, as well as some of the case farms in this study, indicated that the accumulation of nitrate throughout the soil profile occurs for various cropping practices, including soils that have never received manure. The regulation of nutrients to protect the environment needs to apply to all sources of nutrients, not just manure.

Farmers wanting to practice intensive crop management are finding that the current regulatory methodology is limiting their ability to achieve target economic returns under the present soil limits for manure application. Strict adherence to the existing environment regulation may impede the expanded utilization of manure as a crop fertilizer by crop producers. This would be detrimental to agriculture in general since manure utilization can increase the organic matter content of soil with time.

5.5.1.2 Nutrient Balance Approach to Regulating Nutrients (Dutch System)

The methodology used in The Netherlands and described previously is an alternative method that could be used to regulate crop nutrients. This methodology is similar to the analysis of the farms in the Regional Nutrient Balance study, which are summarized in Tables 5.17 and 5.18.

Essentially, all N and P that enters the farm (inputs) must be recorded. Standardized tables would assist in calculating the nutrient content of grains, forages, etc. Similarly, all nutrients leaving the farm (outputs) would also be determined, once again with the assistance of standardized tables to estimate the nutrients in livestock and other farm products. Allowable losses would be specified in the regulation. These losses would vary with soil type, topography, geography and possibly crop type. Where outputs plus losses are less than inputs, a surplus of nutrients would exist and the farmer would be in non-compliance. There are several impacts regarding the implementation of a nutrient balance regulation.

The instantaneous soil nutrient status is ignored. Presumably, this is the primary reason that this method was selected in The Netherlands. Soil P levels in The Netherlands in the mid-1990s were described as “saturated” with P. Since typical soil P levels were well beyond desirable levels, there was no point in regulating P on the basis of safe upper limits. Rather a system that focused on decreasing P applications was implemented. This is not the case in Manitoba, however. Nutrient levels of P for many soils can be increased to enhance crop production without increasing the risk to the environment.

Because soil P levels are not directly considered with this method, the selection of the standard loss values becomes especially important, as they directly influence surpluses, non-compliance and potential fines.

This method of regulating nutrients probably provides the greatest flexibility to crop producers. Intensive crop producers with high nutrient inputs will normally also have high outputs, affording them the ability and freedom to manage their farms to maximize economic returns. Years where poor weather impacts yields and outputs however could result in surpluses and non-compliance. Adjustments can be made in the subsequent year.

For a nutrient budget method to be used reliably, accurate record keeping is critical. The fact that an improvement to the current practice is needed was apparent from the results of our Regional Nutrient Balance study. Several of the producers interviewed for this study could not provide accurate records of nutrient inputs, such as purchased feed, and/or nutrient outputs, such as the sale of crops. The implementation of levies for nutrient surpluses would force producers to accurately record all nutrient inputs and outputs in order to ensure that their farms’ nutrients are balanced.

The cooperating producers from this study were checked for non-compliance using the Dutch standard loss values of N and P. These results are summarized in Tables 5.17 and 5.18, respectively. The Dutch standard N loss of 100 kg/ha/year is high as it accounts for losses via volatilization. The Dutch view N losses by volatilization a serious environmental concern as these contribute to increases in acid rainfall events. In Manitoba, N volatilization is presently not seen as an environmental concern. Volatilization estimates, therefore, have been excluded from the Calculated Losses and have been combined with the Total Outputs. Only one producer would be in non-compliance if the Dutch standard N loss were implemented in Manitoba.

Hypothetical Manitoba standard loss values of N have been estimated from averages of the Calculated Losses (denitrification, leaching, and runoff), excluding volatilization, from both the farms and the municipalities' nutrient budgets. Loss by denitrification was the loss that varied the most among producers within each of the four municipalities, as it was dependent on residual levels of soil N and application rates of both fertilizer N and manure N. Based on these values and a review of residual values, a range between 30 and 50 kg N/ha/year seems acceptable for standard N losses for Manitoba. Using 30 kg N/ha, 9 of the 15 producers would be in non-compliance, indicated with positive residual values, with one producer being over by only 1 kg/ha. Using 50 kg/ha, 5 of the 15 would be in non-compliance. A standard loss of 75 kg/ha has also been included. Using 75 kg/ha, only 2 of the 15 producers would be in non-compliance.

Calculated Loss of P was estimated at 1 kg/ha/year for all the producers in each of the four municipalities. Using the standard P loss from the Dutch system of 20 kg/ha/year, only 2 of the15 producers would be in non-compliance. It is difficult to estimate an acceptable P loss value for Manitoba as some soils are P deficient and benefit from the accumulation of P over time. The question arises as to what are acceptable losses considering both good agronomic practices and potential environmental hazard. Hypothetical values of 5, 10 and 15 kg P/ha/year were included for comparison in Table 5.18. Using 5 kg P/ha/year, 8 of the 15 producers would be in non-compliance, while 6 and 3 would be in non-compliance if 10 and 15 kg P/ha were implemented, respectively.

5.5.2 Conclusion

Both Regulatory Methodologies of soil nutrient limits and nutrient budgets have their advantages and disadvantages. The main disadvantage of the regulating by soil nutrient limits is that producers are prevented from applying manure at rates that match the uptake of high yielding crops. Producers growing crops on sensitive soils (i.e. sandy soils) are restricted to upper nitrate levels of 90 kg N/ha while crops on medium to heavy textured soils are restricted to 140 kg/ha.

Many producers have argued that this level severely limits their crop yields whenever other conditions are favourable for excellent production. Producers wanting to increase yields are unable to do so using manure nutrients and are forced to supplement crop production with chemical fertilizers in addition to manure or to rely on chemical fertilizers exclusively to avoid this limitation. Studies summarized in the literature review indicated that losses by denitrification in flooded soil conditions can vary between 70 to 150 kg N/ha/day. As heavy clay soils have poor drainage, the combination of snowmelt and spring rains can result in conditions that favour denitrification. Studies have also shown the influence of carbon in manure to increase the rate of denitrification. A large portion of the manure nitrogen can therefore be lost before the crops can utilize them when soils are managed according to soil nutrient limits. This can result in soil nutrient losses being equal or greater than maximum soil limits.

A recent presentation at the Manitoba Agronomist Conference on the fertility of hybrid versus conventional canola indicated that hybrid varieties produce 25 percent higher yields than traditional or parent varieties under higher N fertility regimes. It was indicated that levels of residual soil N and applied fertilizer N should range between 140 to 200 kg/ha. Under the current Manitoba regulation, producers with hybrid canola would have difficulty achieving potential yields.

It is also possible for producers, who follow strict manure management practices, to have high levels of nitrate after a cropping season due to an unexpected increase in the rate of N mineralization. This phenomenon was observed in the South Tobacco Creek Manured Watershed Runoff Study where they found high levels of soil nitrate (90 kg N/ha) before the application of manure. They suspected that tillage of the previous alfalfa crop could have released a significant amount of N since decomposition of ploughed alfalfa stands can lead to increased nitrate levels.

Producers applying manure to ensure that these upper limits are not exceeded, often find that the crops are deficient in nutrients. The goal of these limits enforced by Manitoba Conservation is to ensure that manure nutrients do not buildup, increasing the potential for losses. However, there is no measure of N with increasing depth, which would provide a more accurate assessment of what could be lost. These limits, however, should not prevent producers from achieving yields that are typically observed using inorganic fertilizers. This study clearly showed that the accumulation of both N and P can occur in soils, regardless of the source of N and P. The present regulatory system therefore needs to be changed to address these issues. A range of upper level values, based on various soil conditions, soil types, transport factors, receptor sensitivity, etc., should be provided that would allow producers some flexibility in dealing with manure application rates. The soil system is very complex and not clearly understood. By forcing producers to follow these upper limits without a clear understanding of the soil science and the factors that affect the many soil processes does not seem justified. Hopefully, if upper limits of P are introduced to the system, a more scientific approach will be used to develop them and that these levels will not become detrimental to the valuable livestock industry of Manitoba, but protect the environment to a much greater degree than present guidelines and/or regulations.

The Dutch methodology could help producers to better understand the flow of nutrients within their farms. Using the current standard losses from the Dutch, 2 of the 15 case farms studied would be in non-compliance for nitrogen and only 1 of the 15 would be in non-compliance for phosphorus. More local research is required to better estimate standard allowable losses of N and P in Manitoba that will prevent the excessive accumulation in soils and allow producers to manage high yielding crops. Nutrient surplus levies could be used to encourage producers to seek ways to better nutrient balance inputs, such as improved feed formulations, and nutrient outputs, such as manure export. The Dutch system could allow intensive crop managers, in particular, to target high yields without the risk of consistently being in non-compliance with the regulations.

Under normal farming practices, producers supply a level of nutrients that they anticipate will achieve or nearly achieve a “target” yield. This target yield is normally an optimistic yield projection that is approximately 10 to 15 percent greater than their long term average yield. The amounts of nutrients supplied are estimated, based on many factors that include crop prices, fertilizer prices, etc. Existing soil nutrient status is normally of secondary importance to producers, as indicated by the small number of producers that soil test.

The probability of consistently meeting a target yield that is 10 to 15 percent higher than long term average yields is, of course, not possible. Yields, in fact, are just as probable to be below average levels. The result is that a significant nutrient surplus is highly probable in a year with poor yields. However in real life, the opportunity exists to correct this by reducing nutrient application the following year. A nutrient management regulation, therefore, must acknowledge this inevitable situation as well as other factors such as denitrification and mineralization. It would be difficult to defend charges that a producer is in non-compliance of soil N levels with only one year of sampling data due to the extreme variability of soil conditions and influence of crop performance. Charges of being in non-compliance should be enforced after a period of time, for example 5 years, so that if a producer is in non-compliance for most of that period, he/she would be charged a fine. Some flexibility needs to be implemented in the regulations to prevent this from happening.

To ensure nutrients are properly managed and monitored, any regulatory methodology must involve soil testing. Annual soil testing to two feet should be supplemented with periodic testing to four feet, as outlined in the Farm Practices Guidelines. In addition, supervision by a registered professional agrologist would assure the public that nutrients are being properly managed within the context of best management practices and to develop long-term site specific strategies.
A single value for an environmental limit or even two limits such as Manitoba has for nitrate, does not adequately consider most source and transport factors and other factors such as recipient sensitivity. Limits for soils in areas without groundwater or with non-sensitive surface waters do not need be as stringent as land with slightly sensitive surface and/or underlying groundwater. Transport factors and likelihood of impact are normally considered in establishing environmental limits for any potential contaminant. A single value (or even two) may not protect the environment in sensitive areas and may be overly restrictive in non-sensitive areas, leading to environmental contamination in the first instance and possible inefficiencies in production in the second instance.

The adoption of a system of limits such as suggested by Sharpley *et. al*. (1999) for both N and P would consider source and transport factors that would allow for the implementation of varying site-specific strategies. Source factors should include soil testing, fertilizer application rate and method, and organic source application rate and method. Transport factors should include soil erosion, soil runoff class, and distance form watercourses.

Table 5.17 Summary of nitrogen budgets for cooperating producers . Dutch standard N losses have been included to identify the number of producers in non-compliance with the Dutch system. Three Manitoba standard N losses have also been included to identify producers in non-compliance. (all values in kg/ha).

											Dutch N		Hypothetical Manitoba N Losses and Corresponding Residuals					
	Inputs	Outputs	Volatilization	Total Output	I - O	Calc Loss	Denitrification	Leaching	Runoff	Residual*	Loss Standard	Residual*	N	Residual*	N	Residual*	N	Residual*
Han A	177	81	24	105	72	34	26	6	2	38	100	-28	30	42	50	22	75	-3
Han B	150	50	10	60	90	65	52	10	3	25	100	-10	30	60	50	40	75	15
Han C	157	45	11	56	101	81	68	10	3	20	100	1	30	71	50	51	75	26
Han D	148	64	16	80	68	32	21	9	2	36	100	-32	30	38	50	18	75	-7
Lab A	53	34	6	40	13	36	21	13	2	-23	100	-87	30	-17	50	-37	75	-62
Lab B	89	32	29	61	28	36	20	14	2	-8	100	-72	30	-2	50	-22	75	-47
Lab C	139	72	51	123	16	36	28	6	2	-20	100	-84	30	-14	50	-34	75	-59
Lab D	295	169	53	222	73	57	38	17	2	16	100	-27	30	43	50	23	75	-2
Rol A	115	67	0	67	48	37	28	6	3	11	100	-52	30	18	50	-2	75	-27
Rol B	131	120	0	120	11	25	17	6	2	-14	100	-89	30	-19	50	-39	75	-64
Rol C	162	112	0	112	50	48	34	11	3	2	100	-50	30	20	50	0	75	-25
Sif A	38	1	11	12	26	13	8	3	2	13	100	-74	30	-4	50	-24	75	-49
Sif B	43	2	10	12	31	18	13	3	2	13	100	-69	30	1	50	-19	75	-44
Sif C	56	6	10	16	40	15	10	3	2	25	100	-60	30	10	50	-10	75	-35
Sif D	47	13	16	29	18	16	7	7	2	2	100	-82	30	-12	50	-32	75	-57
RM																		
Hanover	148	49	39	88	60	31	21	8	2	29	100	-40	30	30	50	10	75	-15
La Broquerie	130	28	48	76	54	32	19	11	2	22	100	-46	30	24	50	4	75	-21
Roland	104	68	1	69	35	35	28	5	2	0	100	-65	30	5	50	-15	75	-40
Sifton	22	8	17	25	-3	14	7	6	1	-17	100	-103	30	-33	50	-53	75	-78
							# of farms in non-compliance			11		1		9		5		2

Average Calc Losses for Farms 37

* A positive residual value indicates a nutrient surplus.

Table 5.18 Summary of phosphorus budgets for cooperating producers. Dutch standard P losses have been included to identify the number of producers in non-compliance with the Dutch system. Three Manitoba standard P losses have also been included to identify producers in non-compliance. (all values in kg/ha)

						Dutch P		Hypothetical Manitoba P Losses and Corresponding Residuals					
	Inputs	Outputs	I - O	Calc Loss	Residual*	Loss Standard	Residual*	P	Residual*	P	Residual*	P	Residual*
Han A	39	16	23	1	22	20	3	5	18	10	13	15	8
Han B	25	10	15	1	14	20	-5	5	10	10	5	15	0
Han C	28	9	19	1	18	20	-1	5	14	10	9	15	4
Han D	21	11	10	1	9	20	-10	5	5	10	0	15	-5
Lab A	15	7	8	1	7	20	-12	5	3	10	-2	15	-7
Lab B	19	6	13	1	12	20	-7	5	8	10	3	15	-2
Lab C	10	15	-5	1	-6	20	-25	5	-10	10	-15	15	-20
Lab D	69	33	36	1	35	20	16	5	31	10	26	15	21
Rol A	8	12	-4	1	-5	20	-24	5	-9	10	-14	15	-19
Rol B	14	16	-2	1	-3	20	-22	5	-7	10	-12	15	-17
Rol C	29	15	14	1	13	20	-6	5	9	10	4	15	-1
Sif A	1	0	1	1	0	20	-19	5	-4	10	-9	15	-14
Sif B	3	0.5	2.5	1	1.5	20	-17.5	5	-2.5	10	-7.5	15	-12.5
Sif C	4	1	3	1	2	20	-17	5	-2	10	-7	15	-12
Sif D	2	2	0	1	-1	20	-20	5	-5	10	-10	15	-15
RM													
Hanover	21	10	11	1	10	20	-9	5	6	10	1	15	-4
La Broquerie	15	6	9	1	8	20	-11	5	4	10	-1	15	-6
Roland	15	13	2	1	1	20	-18	5	-3	10	-8	15	-13
Sifton	2	2	0	1	-1	20	-20	5	-5	10	-10	15	-15
			# of farms in non-compliance		10		2		8		6		3

Average Calc Losses for Farms 1

* A positive residual value indicates a nutrient surplus.

6.0 CONCLUSIONS

The goal of sustainable agricultural land management is to limit the transfer of nutrients into surface and groundwater resources to levels that will not degrade or impair the use of these water resources. The two primary strategies that will achieve this goal are limiting the concentration of nutrients in the soil and reducing runoff and leaching losses to surface and groundwater.

It is not necessary to eliminate nutrient losses – a certain level of nutrient loss is natural and inevitable. Nutrient loss from the soil pool has naturally occurred for thousands of years on native grassed and treed soils. This is part of the normal nutrient cycling that occurs in the ecosystem. Rather, the objective must be to limit any accumulation in the soil pool to levels that minimize risks to water resources. Unfortunately, these critical levels have not been well-defined for the various soil types and topographies in Manitoba.

The study found that in areas such as Hanover and La Broquerie, which have a significant intensive livestock industry, the import of large quantities of livestock feed is contributing to a build-up of nutrients in the soil, which increases the risks of nutrient losses to water resources. Manure, however, is not the only source of nutrients that must be considered. The farm case studies confirmed previous studies indicating a build-up of excess nutrients in soils from the over-application of chemical fertilizers. Although there has been an apparent increase in soil nutrients in Hanover and La Broquerie, the loss of nutrients to surface waters may not be greater than the other municipalities studied. The literature review found that the loss of nutrients from fields receiving inorganic fertilizer can be greater than those that were manured.

Better farm management practices need to be implemented to help delineate the build-up of available nutrients in soils. Regulations to prevent the accumulation of nutrients in soils should be consistent for all nutrient sources, both manure and commercial fertilizers. All producers should practice annual soil testing of all their fields. It is by soil testing that any build-up of nutrients can be detected. Currently, approximately 10 percent of producers soil test annually and approximately one-quarter of fields managed by these producers are sampled in any year.

In areas with a high density of intensive livestock operations, there appears to be excessive use of chemical fertilizers. The reduction in chemical fertilizer use is paramount to improving environmental sustainability in these areas. Nutrient management will need to address more than just fertilizer nutrients to successfully address nutrient imbalances for many livestock operations. More precise feed formulations would help decrease inputs of feed for livestock and increased usage of phytase would help reduce outputs of P in manure.

The losses of N and P to the environment comprise a significant component of the nutrient cycle. Nitrogen losses were equivalent to 35 to 79 percent of outputs, and P losses were between two and 16 percent of outputs. Further research is necessary to quantify the various losses and to understand the impacts of these losses on the ecosystem. A clearer understanding of losses will permit more accurate models of nutrient budgets, which are necessary to develop improved land management recommendations and government regulations.

Traditional "conservation" farming practices such as grassed waterways, vegetative filter strips and riparian areas, etc. need to be encouraged to a greater extent, as these practices minimize nutrient losses from agricultural lands.

On a farm-scale, this study revealed that detailed record keeping by producers would be required to accurately estimate nutrient flows. Inadequate record keeping and/or inaccurate nutrient concentrations of farm materials result in inaccurate accounting of significant nutrient flows. Sources of nutrient inputs are clearly defined on a farm-scale, however improved record keeping of these inputs would provide information for better management strategies for reducing excess nutrients inputs and options for increasing nutrient outputs. Precise estimates of yields and the monitoring of fertilizer and manure application rates would increase the understanding of nutrient flow on crop and livestock farms. Because it was a one-year study, factors such a bad crop yield could greatly affect the N and P status of a farm. A five-year study would provide a more accurate estimate of increases or decreases in the amount of nutrients in the available and organic soil pools.

Tools need to be provided to producers that will enable them to better monitor the flow of nutrients and complete proper budgets. In the Netherlands, all livestock producers need to submit yearly nutrient budgets. Producers are required to indicate the available land base available for spreading and all inputs and outputs of N and P. Nutrient inputs include manure applied to fields, other organic amendments, chemical fertilizers, purchased feed, manure in storage, and inventories of grazing and confined livestock. Outputs include crops, manure, animals, and animal products. Standard losses of N and P are dependent of soil texture and land use (grassland, cropland, natural pasture).

Animal manure is utilized on approximately five percent of Manitoba's agricultural land. The study verified the beneficial impact of manure in increasing soil organic matter, which improves soil structure, water infiltration and water storage capacity. Organic matter was shown to be decreasing in the R.M. of Roland, which has a limited livestock industry. Strategies or programs to encourage the distribution and/or application of manure on a greater land base would benefit most soils.

Regulating only nitrogen encourages N volatilization losses from manure. As these losses increase, manure application rates must also increase to meet crop N requirements. This normally results in an over-application of P, however, which accumulates in the soil. Technologies that reduce N volatilization, such as storage covers and manure injection, can significantly reduce the buildup of P in soils.

Finally, in order to protect the agricultural (livestock and crops) industry and the environment, Manitoba has to conduct research to develop a comprehensive "P Index" that can be used for thresholds and management strategies on a site-specific basis considering both source and transport factors. The RM of La Broquerie would provide an excellent model to conduct site-specific research for better estimating losses of N and P, and strategies for decreasing these losses. More research is needed to better estimate losses as the combination of these losses account for a large percentage of the total outputs.

Nutrients entering the environment from municipal and industrial sewage lagoons can be significant, especially in heavily populated municipalities such as Hanover. The analysis of the N and P content of this effluent should be enforced to help maintain water quality, especially for lagoons that discharge directly into watercourses. Although point sources generally contribute a small percentage of nutrients when compared to agricultural sources, direct discharge of these sources into watercourses would have a greater environmental impact.

The selection of the municipalities used for this study did represent a wide variety of intensive cropped and livestock areas, reflected by the nutrient balance performed on each municipality.

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Appendix A:

Farm Nutrient Budgets

RM of Hanover

Han A

Nutrient		**kg/year N**	**kg/year P**	**kg/ha**	**kg/ha**
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		430	80	1	0.3
30t. Transfer by net uptake from soils		39,995	7,215	134	24
31. Input by uptake from atmosphere					
	TOTAL	**40,426**	**7,294**	**135**	**24**
REMOVALS					
3. Transfer by consumption of harvested crops		9,152	1,775	31	6
18. Output by primary products		17,562	3,557	59	12
26. Transfer by plant production remaining on field		13,281	1,882	44	6
	TOTAL	**39,995**	**7,215**	**134**	**24**
	SUPPLIES-REMOVALS	**430**	**80**	**1**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		26,027	8,163	87	27
3. Transfer by consumption of harvested crops		9,152	1,775	31	6
	TOTAL	**35,179**	**9,939**	**118**	**33**
REMOVALS					
5. Output by animal products		6,597	1,292	22	4
6. Output by losses from manure to air before application		5,923		20	
8. Transfer by application of manure and/or waste		10,964	4,995	37	17
9. Transfer by droppings on grazed areas					
	TOTAL	**23,485**	**6,287**	**79**	**21**
	SUPPLIES-REMOVALS	**11,695**	**3,652**	**39**	**12**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		10,964	4,995	37	17
11. Input by fertilizers		25,034	3,323	84	11
12. Input by N fixation		306		1	
15. Input by dry and wet deposition		1,528	37	5	0.1
26. Transfer by plant products remaining on field		13,281	1,882	44	6
	TOTAL	**51,113**	**10,238**	**171**	**34**
REMOVALS					
19. Output by denitrification		7,984		27	
20. Output by volatilization of ammonia		1,096		4	
21. Output by leaching		1,727		6	
22. Output by run-off of available nutrients		345	170	1	1
28. Output by organic matter, removed by run-off		343	170	1	1
30. Transfer by net uptake from soil by plant		39,995	7,215	134	24
	TOTAL	**51,491**	**7,554**	**172**	**25**
	SUPPLIES-REMOVALS	**(378)**	**2,683**	**-1**	**9**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		8,662	2,497	29	8
11. Input by fertilizers		25,034	3,323	84	11
12. Input by N-fixation		306	-	1	
15. Input by dry and wet deposition		1,528	37	5	0.1
17. Transfer by mineralization of soil organic fraction		25,495	3,056	85	10
	TOTAL	**61,025**	**8,914**	**204**	**30**
REMOVALS					
19. Output by denitrification		7,984		27	
20. Output by volatilization of ammonia		1,096		4	
21. Output by leaching		1,727	-	6	
22. Output by run-off of available nutrients		345	170	1	1
24. Transfer by fixation in soil mineral fraction			1,748		6
25. Transfer by immobilization in soil organic fraction		8,370	1,007	28	3
30t. Transfer by net uptake by the plant		39,995	7,215	134	24
	TOTAL	**59,519**	**10,140**	**199**	**34**
SUPPLIES-REMOVALS		**1506**	**-1226**	**5**	**-4**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		2,303	2,497	8	8
25. Transfer by immobilization in soil organic fraction		8,370	1,007	28	3
26b. Transfer by plant products remaining of field		13,281	1,882	44	6
	TOTAL	**23,954**	**5,386**	**80**	**18**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		25,495	3,056	85	10
28. Output by organic matter, removed by run-off		343	170	1	1
	TOTAL	**25,838**	**3,226**	**86**	**11**
SUPPLIES-REMOVALS		**(1,884)**	**2,161**	**-6**	**7**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	25,034	3,323	Crops	17,562	3,557
Feed	26,027	8,163	Animal & animal products	6,597	1,292
Fixation/Deposition	1,834	37		**24,159**	**4,849**
TOTAL	**52,895**	**11,524**		**81**	**16**
kg/ha	**177**	**39**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	28,736	6,675	96	22
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	17,419	340	58	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	11,317	6,335	38	21

RM of Hanover

Han B

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		230	52	0.2	0.1
30t. Transfer by net uptake from soils		164,574	21,734	162	21
	TOTAL	**164,805**	**21,786**	**163**	**21**
REMOVALS					
3. Transfer by consumption of harvested crops		56,019	6,708	55	7
18. Output by primary products		42,083	7,851	42	8
26. Transfer by plant production remaining on field		66,486	7,176	66	7
27. Transfer by seed for sowing		1,083	200	1	0.2
	TOTAL	**165,670**	**21,936**	**163**	**22**
	SUPPLIES-REMOVALS	**(866)**	**(150)**	**-1**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		13,494	5,212	13	5
3. Transfer by consumption of harvested crops		56,019	6,708	55	7
	TOTAL	**69,513**	**11,920**	**69**	**12**
REMOVALS					
5. Output by animal products		8,509	1,750	8	2
6. Output by losses from manure to air before application		6,202		6	
8. Transfer by application of manure and/or waste		24,809	6,391	24	6
	TOTAL	**39,520**	**8,141**	**39**	**8**
	SUPPLIES-REMOVALS	**29,993**	**3,779**	**30**	**4**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		24,809	6,391	24	6
10. Input by application of manure		27,719	11,526	27	11
11. Input by fertilizers		45,525	8,858	45	9
12. Input by N fixation		60,481		60	
15. Input by dry and wet deposition		5,183	127	5	0.1
26. Transfer by plant products remaining on field		66,486	7,176	66	7
27. Transfer by seed for sowing		1,083	200	1	0.2
	TOTAL	**231,285**	**34,279**	**228**	**34**
REMOVALS					
19. Output by denitrification		52,316		52	
20. Output by volatilization of ammonia		4,549		4	
21. Output by leaching		10,325		10	
22. Output by run-off of available nutrients		1,152	528	1	0.5
28. Output by organic matter, removed by run-off		1,608	528	2	0.5
30. Transfer by net uptake from soil by plant		164,574	21,734	162	21
	TOTAL	**234,524**	**22,790**	**231**	**22**
	SUPPLIES-REMOVALS	**(3,239)**	**11,489**	**-3**	**11**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		16,560	3,196	16	3
10a. Input by application of manure		22,592	5,763	22	6
11. Input by fertilizers		45,525	8,858	45	9
12. Input by N-fixation		60,481		60	
15. Input by dry and wet deposition		5,183	127	5	0.1
17. Transfer by mineralization of soil organic fraction		130,057	16,257	128	16
27. Transfer by seed for sowing		1,083	200	1	0.2
	TOTAL	**281,480**	**34,401**	**278**	**34**
REMOVALS					
19. Output by denitrification		52,316		52	
20. Output by volatilization of ammonia		4,549	-	4	
21. Output by leaching		10,325		10	
22. Output by run-off of available nutrients		1,152	528	1	0.5
24. Transfer by fixation in soil mineral fraction			2,557		3
25. Transfer by immobilization in soil organic fraction		68,886	6,558	68	6
30t. Transfer by net uptake by the plant		164,574	21,734	162	21
	TOTAL	**301,802**	**31,376**	**298**	**31**
SUPPLIES-REMOVALS		**(20,322)**	**3,025**	**-20**	**3**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		8,249	3,196	8	3
10b. Input by application of manure		5,127	5,763	5	6
25. Transfer by immobilization in soil organic fraction		68,886	6,558	68	6
26b. Transfer by plant products remaining of field		66,486	7,176	66	7
	TOTAL	**148,748**	**22,693**	**147**	**22**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		130,057	16,257	128	16
28. Output by organic matter, removed by run-off		1,608	528	2	1
	TOTAL	**131,665**	**16,785**	**130**	**17**
SUPPLIES-REMOVALS		**17,083**	**5,907**	**17**	**6**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	45,525	8,858	Crops	42,083	7,851
Feed	13,494	5,212	Animal & animal products	8,509	1,750
Fixation/Deposition	65,664	127		**50,592**	**9,601**
Manure	27,719	11,526			
TOTAL	**152,402**	**25,723**		**50**	**9**
kg/ha	**150**	**25**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	101,811	16,122	100	16
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	76,152	1,056	75	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	25,659	15,066	25	15

RM of Hanover

Han C

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		953	173	2	0.3
30t. Transfer by net uptake from soils		47,863	8,176	84	14
	TOTAL	**48,816**	**8,350**	**86**	**15**
REMOVALS					
3. Transfer by consumption of harvested crops		11,488	2,313	20	4
18. Output by primary products		18,718	3,526	33	6
26. Transfer by plant production remaining on field		17,661	2,338	31	4
	TOTAL	**47,867**	**8,177**	**84**	**14**
	SUPPLIES-REMOVALS	**949**	**173**	**2**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		24,454	2,361	43	4
3. Transfer by consumption of harvested crops		11,488	2,313	20	4
	TOTAL	**35,942**	**4,674**	**63**	**8**
REMOVALS					
5. Output by animal products		6,775	1,330	12	2
6. Output by losses from manure to air before application		5,091		9	0
8. Transfer by application of manure and/or waste		7,418	3,467	13	6
9. Transfer by droppings on grazed areas					
	TOTAL	**19,284**	**4,797**	**34**	**8**
	SUPPLIES-REMOVALS	**16,657**	**(123)**	**29**	**0**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		6,568	3,467	12	6
10. Input by application of manure		8,705	4,069	15	7
11. Input by fertilizers		49,659	9,478	88	17
12. Input by N fixation		3,498		6	
15. Input by dry and wet deposition		2,900	71	5	0.1
26. Transfer by plant products remaining on field		17,661	2,338	31	4
	TOTAL	**88,992**	**19,423**	**157**	**34**
REMOVALS					
19. Output by denitrification		38,502		68	
20. Output by volatilization of ammonia		1,019		2	
21. Output by leaching		6,230		11	
22. Output by run-off of available nutrients		645	314	1	1
28. Output by organic matter, removed by run-off		945	314	2	1
30. Transfer by net uptake from soil by plant		47,863	8,176	84	14
	TOTAL	**95,203**	**8,804**	**168**	**16**
	SUPPLIES-REMOVALS	**(6,211)**	**10,619**	**-11**	**19**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		5,860	1,734	10	3
10a. Input by application of manure		6,877	2,034	12	4
11. Input by fertilizers		49,659	9,478	88	17
12. Input by N-fixation		3,498		6	0
15. Input by dry and wet deposition		2,900	71	5	0
17. Transfer by mineralization of soil organic fraction		50,816	6,352	90	11
	TOTAL	**119,611**	**19,669**	**211**	**35**
REMOVALS					
19. Output by denitrification		38,502		68	
20. Output by volatilization of ammonia		1,019	-	2	
21. Output by leaching		6,230		11	
22. Output by run-off of available nutrients		645	314	1	1
24. Transfer by fixation in soil mineral fraction			1,387		2
25. Transfer by immobilization in soil organic fraction		19,943	2,261	35	4
30t. Transfer by net uptake by the plant		47,863	8,176	84	14
	TOTAL	**114,201**	**12,138**	**201**	**21**
SUPPLIES-REMOVALS		**5,410**	**7,531**	**10**	**13**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		1,558	1,734	3	3
10b. Input by application of manure		1,828	2,034	3	4
25. Transfer by immobilization in soil organic fraction		19,943	2,261	35	4
26b. Transfer by plant products remaining of field		17,661	2,338	31	4
	TOTAL	**40,990**	**8,367**	**72**	**15**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		50,816	6,352	90	11
28. Output by organic matter, removed by run-off		945	314	2	1
	TOTAL	**51,761**	**6,666**	**91**	**12**
SUPPLIES-REMOVALS		**(10,771)**	**1,702**	**-19**	**3**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	49,659	9,478	Crops	18,718	3,526
Feed	24,454	2,361	Animal & animal products	6,775	1,330
Fixation/Deposition	6,399	71		**25,493**	**4,855**
Manure	8,705	4,069			
TOTAL	**89,216**	**15,978**		**45**	**9**
kg/ha	**157**	**28**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	63,723	11,123	112	20
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	52,431	627	92	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	11,292	10,496	20	19

RM of Hanover

Han D

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		627	124	1	0.3
30t. Transfer by net uptake from soils		94,680	11,758	214	27
	TOTAL	**95,307**	**11,882**	**215**	**27**
REMOVALS					
3. Transfer by consumption of harvested crops		34,567	4,041	78	9
18. Output by primary products		21,604	3,770	49	9
26. Transfer by plant production remaining on field		38,509	3,946	87	9
	TOTAL	**94,680**	**11,758**	**214**	**27**
	SUPPLIES-REMOVALS	**627**	**124**	**1**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		7,651	3,813	17	9
3. Transfer by consumption of harvested crops		34,567	4,041	78	9
	TOTAL	**42,218**	**7,854**	**95**	**18**
REMOVALS					
5. Output by animal products		5,052	1,047	11	2
6. Output by losses from manure to air before application		6,375		14	
8. Transfer by application of manure and/or waste		9,563	3,522	22	8
	TOTAL	**20,991**	**4,569**	**47**	**10**
	SUPPLIES-REMOVALS	**21,227**	**3,285**	**48**	**7**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		9,563	3,522	22	8
11. Input by fertilizers		10,212	5,433	23	12
12. Input by N fixation		45,330		102	
15. Input by dry and wet deposition		2,264	55	5	0
26. Transfer by plant products remaining on field		38,509	3,946	87	9
	TOTAL	**105,879**	**12,956**	**239**	**29**
REMOVALS					
19. Output by denitrification		9,282		21	
20. Output by volatilization of ammonia		956		2	
21. Output by leaching		3,432		8	
22. Output by run-off of available nutrients		503	212	1	0.5
28. Output by organic matter, removed by run-off		655	212	1	0.5
30. Transfer by net uptake from soil by plant		94,680	11,758	214	27
	TOTAL	**109,508**	**12,181**	**247**	**28**
	SUPPLIES-REMOVALS	**(3,629)**	**775**	**-8**	**2**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		7,555	1,761	17	4
11. Input by fertilizers		10,212	5,433	23	12
12. Input by N-fixation		45,330	-	102	
15. Input by dry and wet deposition		2,264	55	5	0.1
17. Transfer by mineralization of soil organic fraction		69,784	8,723	158	20
	TOTAL	**135,146**	**15,972**	**305**	**36**
REMOVALS					
19. Output by denitrification		9,282	-	21	
20. Output by volatilization of ammonia		956	-	2	
21. Output by leaching		3,432	-	8	
22. Output by run-off of available nutrients		503	212	1	0.5
24. Transfer by fixation in soil mineral fraction			1,057		2.4
25. Transfer by immobilization in soil organic fraction		39,625	4,828	89	11
30t. Transfer by net uptake by the plant		94,680	11,758	214	27
	TOTAL	**148,478**	**17,854**	**335**	**40**
SUPPLIES-REMOVALS		**(13,332)**	**(1,882)**	**-30**	**-4**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		2,008	1,761	5	4
25. Transfer by immobilization in soil organic fraction		39,625	4,828	89	10.9
26b. Transfer by plant products remaining of field		38,509	3,946	87	9
	TOTAL	**80,143**	**10,535**	**181**	**24**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		69,784	8,723	158	20
28. Output by organic matter, removed by run-off		655	212	1	0.5
	TOTAL	**70,439**	**8,935**	**159**	**20**
SUPPLIES-REMOVALS		**9,704**	**1,601**	**22**	**4**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	10,212	5,433	Crops	21,604	3,770
Feed	7,651	3,813	Animal & animal products	5,052	1,047
Fixation/Deposition	47,594	55		**26,656**	**4,818**
TOTAL	**65,458**	**9,301**		**60**	**11**
kg/ha	**148**	**21**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	38,802	4,484	**88**	**10**
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	21,203	423	**48**	**1**
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	17,598	4,061	40	9

RM of La Broquerie — Lab A

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		410	76	1	0.2
30t. Transfer by net uptake from soils		37,644	6,301	74	12
	TOTAL	**38,054**	**6,377**	**75**	**13**
REMOVALS					
3. Transfer by consumption of harvested crops		6,711	1,057	13	2
18. Output by primary products		17,022	3,404	34	7
26. Transfer by plant production remaining on field		13,902	1,838	27	4
	TOTAL	**37,635**	**6,300**	**74**	**12**
	SUPPLIES-REMOVALS	**419**	**78**	**1**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		6,711	1,057	13	2
	TOTAL	**6,711**	**1,057**	**13**	**2**
REMOVALS					
5. Output by animal products		229	62	0.5	0.1
6. Output by losses from manure to air before application		2,800		6	
8. Transfer by application of manure and/or waste		4,200	1,872	8	4
	TOTAL	**7,229**	**1,935**	**14**	**4**
	SUPPLIES-REMOVALS	**(518)**	**(877)**	**-1**	**-2**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		4,200	1,872	8	4
11. Input by fertilizers		16,910	7,425	33	15
12. Input by N fixation		7,298		14	
15. Input by dry and wet deposition		2,596	63	5	0.1
26. Transfer by plant products remaining on field		13,902	1,838	27	4
	TOTAL	**44,906**	**11,199**	**88**	**22**
REMOVALS					
19. Output by denitrification		10,555			
20. Output by volatilization of ammonia		210			
21. Output by leaching		6,475			
22. Output by run-off of available nutrients		577	245	1	0.5
28. Output by organic matter, removed by run-off		756	245	1	0.5
30. Transfer by net uptake from soil by plant		37,644	6,301	74	12
	TOTAL	**56,217**	**6,791**	**111**	**13**
	SUPPLIES-REMOVALS	**(11,311)**	**4,408**	**-22**	**9**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		2,534	936	5	2
11. Input by fertilizers		16,910	7,425	33	15
12. Input by N-fixation		7,298		14	
15. Input by dry and wet deposition		2,596	63	5	0.1
17. Transfer by mineralization of soil organic fraction		47,618	5,952	94	12
	TOTAL	**76,956**	**14,377**	**152**	**28**
REMOVALS					
19. Output by denitrification		10,555		21	
20. Output by volatilization of ammonia		210	-	0.4	
21. Output by leaching		6,475		13	
22. Output by run-off of available nutrients		577	245	1	0.5
24. Transfer by fixation in soil mineral fraction			562	0	1
25. Transfer by immobilization in soil organic fraction		6,011	1,890	12	4
30t. Transfer by net uptake by the plant		37,644	6,301	74	12
	TOTAL	**61,472**	**8,998**	**121**	**18**
SUPPLIES-REMOVALS		**15,485**	**5,379**	**31**	**11**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		1,666	936	3	2
25. Transfer by immobilization in soil organic fraction		6,011	1,890	12	4
26b. Transfer by plant products remaining of field		13,902	1,838	27	4
	TOTAL	**21,579**	**4,665**	**43**	**9**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		47,618	5,952	94	12
28. Output by organic matter, removed by run-off		756	245	1	0
	TOTAL	**48,375**	**6,197**	**95**	**12**
SUPPLIES-REMOVALS		**(26,795)**	**(1,533)**	**-53**	**-3**

Total Inputs	**N**	**P**	**Total Outputs**	**N**	**P**
Fertilizer	16,910	7,425	Crops	17,022	3,404
Feed	-	-	Animal & animal products	229	62
Fixaiton/Deposition	9,894	63	**TOTAL**	**17,251**	**3,466**
TOTAL	**26,804**	**7,488**	**kg/ha**	**34**	**7**
kg/ha	**53**	**15**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	9,553	4,022	19	8
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	21,373	490	42	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	(11,820)	3,532	(23)	7

RM of La Broquerie

Lab B

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		119,012	15,269	207	27
	TOTAL	**119,012**	**15,269**	**207**	**27**
REMOVALS					
3. Transfer by consumption of harvested crops		67,782	9,712	118	17
18. Output by primary products					
26. Transfer by plant production remaining on field		51,230	5,557	89	10
	TOTAL	**119,012**	**15,269**	**207**	**27**
	SUPPLIES-REMOVALS	**-**	**-**		
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock			4,505		8
3. Transfer by consumption of harvested crops		67,782	9,712	118	17
	TOTAL	**67,782**	**14,218**	**118**	**25**
REMOVALS					
5. Output by animal products		18,142	3,689	32	6
6. Output by losses from manure to air before application		15,860		28	
8. Transfer by application of manure and/or waste		23,790	8,185	41	14
	TOTAL	**57,792**	**11,874**	**101**	**21**
	SUPPLIES-REMOVALS	**9,990**	**2,344**	**17**	**4**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		23,790	8,185	41	14
11. Input by fertilizers		19,585	6,554	34	11
12. Input by N fixation		28,781		50	
15. Input by dry and wet deposition		2,938	72	5	0
26. Transfer by plant products remaining on field		51,230	5,557	89	10
	TOTAL	**126,324**	**20,368**	**220**	**35**
REMOVALS					
19. Output by denitrification		11,223		20	
20. Output by volatilization of ammonia		1,190		2	
21. Output by leaching		7,900		14	
22. Output by run-off of available nutrients		653	289	1	0.5
28. Output by organic matter, removed by run-off		653	289	1	0.50
30. Transfer by net uptake from soil by plant		119,012	15,269	207	27
	TOTAL	**140,630**	**15,846**	**245**	**28**
	SUPPLIES-REMOVALS	**(14,306)**	**4,522**	**-25**	**8**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		18,794	4,093	33	7
11. Input by fertilizers		19,585	6,554	34	11
12. Input by N-fixation		28,781		50	
15. Input by dry and wet deposition		2,938	72	5	0.1
17. Transfer by mineralization of soil organic fraction		87,718	10,965	153	19
	TOTAL	**157,816**	**21,684**	**275**	**38**
REMOVALS					
19. Output by denitrification		11,223		20	
20. Output by volatilization of ammonia		1,190	-	2	
21. Output by leaching		7,900		14	
22. Output by run-off of available nutrients		653	289	1	0.5
24. Transfer by fixation in soil mineral fraction			2,456	0	4
25. Transfer by immobilization in soil organic fraction		41,845	6,442	73	11
30t. Transfer by net uptake by the plant		119,012	15,269	207	27
	TOTAL	**181,822**	**24,455**	**316**	**43**
SUPPLIES-REMOVALS		**(24,006)**	**(2,771)**	**-42**	**-5**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		4,996	4,093	9	7
25. Transfer by immobilization in soil organic fraction		41,845	6,442	73	11
26b. Transfer by plant products remaining of field		51,230	5,557	89	10
	TOTAL	**98,071**	**16,091**	**171**	**28**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		87,718	10,965	153	19
28. Output by organic matter, removed by run-off		653	289	1	1
	TOTAL	**88,371**	**11,253**	**154**	**20**
SUPPLIES-REMOVALS		**9,700**	**4,838**	**17**	**8**

Total Inputs

	N	P
Fertilizer	19,585	6,554
Feed	-	4,505
Fixation/Deposition	31,719	72
TOTAL	**51,304**	**11,132**
kg/ha	**89**	**19**

Total Outputs

	N	P
Crops	-	-
Animal & animal products	18,142	3,689
TOTAL	**18,142**	**3,689**
kg/ha	**32**	**6**

	N	**P**	**kg N/ha**	**kg P/ha**
Input-Output	33,162	7,443	58	13
Calculated losses	37,478	577	65	1
Difference	(4,316)	6,866	(8)	12

RM of La Broquerie

Lab C

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		252,205	27,385	247	27
	TOTAL	**252,205**	**27,385**	**247**	**27**
REMOVALS					
3. Transfer by consumption of harvested crops		141,464	16,802	139	16
18. Output by primary products					
26. Transfer by plant production remaining on field		110,741	10,583	109	10
	TOTAL	**252,205**	**27,385**	**247**	**27**
	SUPPLIES-REMOVALS	**0**	**0**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		65,078	10,152	64	10
3. Transfer by consumption of harvested crops		141,464	16,802	139	16
	TOTAL	**206,542**	**26,955**	**202**	**26**
REMOVALS					
5. Output by animal products		33,190	7,818	33	8
6. Output by losses from manure to air before application		43,404		43	0
7. Output by manure		40,600	7,565	40	7
8. Transfer by application of manure and/or waste		99,129	19,043	97	19
	TOTAL	**216,323**	**34,427**	**212**	**34**
	SUPPLIES-REMOVALS	**(9,781)**	**(7,472)**	**-10**	**-7**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		55,724	19,043	55	19
11. Input by fertilizers					
12. Input by N fixation		71,753		70	
15. Input by dry and wet deposition		3,764	92	4	0.1
26. Transfer by plant products remaining on field		110,741	10,583	109	10
	TOTAL	**241,982**	**29,718**	**237**	**29**
REMOVALS					
19. Output by denitrification		28,227		28	
20. Output by volatilization of ammonia		9,240		9	
21. Output by leaching		5,795		6	
22. Output by run-off of available nutrients		1,159	348	1	0.3
28. Output by organic matter, removed by run-off		1,159	348	1	0.3
30. Transfer by net uptake from soil by plant		252,205	27,385	247	27
	TOTAL	**297,785**	**28,081**	**292**	**28**
	SUPPLIES-REMOVALS	**(55,804)**	**1,638**	**-55**	**2**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		46,677	9,522	46	9
11. Input by fertilizers		-	-		
12. Input by N-fixation		71,753		70	
15. Input by dry and wet deposition		3,764	92	4	0.1
17. Transfer by mineralization of soil organic fraction		138,568	17,321	136	17
26a. Transfer by plant production remaining on field					
	TOTAL	**260,761**	**26,935**	**256**	**26**
REMOVALS					
19. Output by denitrification		28,227		28	
20. Output by volatilization of ammonia		9,240	-	9	
21. Output by leaching		5,795		6	
22. Output by run-off of available nutrients		1,159	348	1	0.3
24. Transfer by fixation in soil mineral fraction			5,713		5.6
25. Transfer by immobilization in soil organic fraction		128,523	16,065	126	16
30t. Transfer by net uptake by the plant		252,205	27,385	247	27
	TOTAL	**425,149**	**49,511**	**417**	**49**
SUPPLIES-REMOVALS		**(164,388)**	**(22,577)**	**-161**	**-22**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		9,047	9,522	9	9
25. Transfer by immobilization in soil organic fraction		128,523	16,065	126	16
26b. Transfer by plant products remaining of field		110,741	-	109	
	TOTAL	**248,311**	**25,587**	**243**	**25**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		138,568	17,321	136	17
28. Output by organic matter, removed by run-off		1,159	348	1	0.3
	TOTAL	**139,727**	**17,669**	**137**	**17**
SUPPLIES-REMOVALS		**108,584**	**7,918**	**106**	**8**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	-	-	Crops	-	-
Feed	65,078	10,152	Animal & animal products	33,190	7,818
Fixation/Deposition	75,516	92	Manure	40,600	7,565
TOTAL	**140,594**	**10,244**		**73,790**	**15,383**
kg/ha	**138**	**10**		**72**	**15**

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	66,804	(5,139)	**65**	**-5**
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	88,985	695	**87**	**1**
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	(22,181)	(5,835)	(22)	(6)

RM of La Broquerie **Lab D**

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		318	59	1	0.3
30t. Transfer by net uptake from soils		28,370	5,102	126	23
	TOTAL	**28,688**	**5,161**	**127**	**23**
REMOVALS					
3. Transfer by consumption of harvested crops					
18. Output by primary products		18,462	3,703	82	16
26. Transfer by plant production remaining on field		9,908	1,399	44	6
	TOTAL	**28,370**	**5,102**	**126**	**23**
	SUPPLIES-REMOVALS	**318**	**59**	**1**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		53,797	11,326	238	50
3. Transfer by consumption of harvested crops		-	-		
	TOTAL	**53,797**	**11,326**	**238**	**50**
REMOVALS					
5. Output by animal products		19,698	3,857	87	17
6. Output by losses from manure to air before application		11,455		51	0
8. Transfer by application of manure and/or waste		20,364	8,925	90	39
	TOTAL	**51,516**	**12,783**	**228**	**57**
	SUPPLIES-REMOVALS	**2,281**	**(1,457)**	**10**	**-6**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		20,364	8,925	90	39
11. Input by fertilizers		11,577	4,135	51	18
12. Input by N fixation		231		1	
15. Input by dry and wet deposition		1,156	28	5	0.1
26. Transfer by plant products remaining on field		9,908	1,399	44	6
	TOTAL	**43,236**	**14,487**	**191**	**64**
REMOVALS					
19. Output by denitrification		8,545		38	
20. Output by volatilization of ammonia		403		2	
21. Output by leaching		3,852		17	
22. Output by run-off of available nutrients		257	128	1	1
28. Output by organic matter, removed by run-off		257	128	1	1
30. Transfer by net uptake from soil by plant		28,370	5,102	126	23
	TOTAL	**41,684**	**5,359**	**184**	**24**
	SUPPLIES-REMOVALS	**1,552**	**9,129**	**7**	**40**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		16,087	4,463	71	20
11. Input by fertilizers		11,577	4,135	51	18
12. Input by N-fixation		231			
15. Input by dry and wet deposition		1,156	28	5	0.1
17. Transfer by mineralization of soil organic fraction		19,261	2,311	85	10
	TOTAL	**48,313**	**10,938**	**214**	**48**
REMOVALS					
19. Output by denitrification		8,545			
20. Output by volatilization of ammonia		403	-		
21. Output by leaching		3,852			
22. Output by run-off of available nutrients		257	128	1	1
24. Transfer by fixation in soil mineral fraction			2,678		12
25. Transfer by immobilization in soil organic fraction		6,420	770	28	3
30t. Transfer by net uptake by the plant		28,370	5,102	126	23
	TOTAL	**47,848**	**8,678**	**212**	**38**
SUPPLIES-REMOVALS		**465**	**2,259**	**2**	**10**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		4,276	4,463	19	20
25. Transfer by immobilization in soil organic fraction		6,420	770	28	3
26b. Transfer by plant products remaining of field		9,908	1,399	44	6
	TOTAL	**20,605**	**6,632**	**91**	**29**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		19,261	2,311	85	10
28. Output by organic matter, removed by run-off		257	128	1	1
	TOTAL	**19,518**	**2,440**	**86**	**11**
SUPPLIES-REMOVALS		**1,087**	**4,192**	**5**	**19**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	11,577	4,135	Crops	18,462	3,703
Feed	53,797	11,326	Animal & animal products	19,698	3,857
Fixation/Deposition	1,387	28	**TOTAL**	**38,160**	**7,561**
TOTAL	**66,761**	**15,489**	**kg/ha**	**169**	**33**
kg/ha	**295**	**69**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	28,601	7,929	127	35
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	24,769	257	110	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	3,832	7,672	17	34

RM of Roland

Rol A

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		1,077	405	2	1
30t. Transfer by net uptake from soils		65,510	10,908	98	16
	TOTAL	**66,588**	**11,313**	**100**	**17**
REMOVALS					
3. Transfer by consumption of harvested crops					
18. Output by primary products		44,950	8,042	67	12
26. Transfer by plant production remaining on field		20,557	2,865	31	4
	TOTAL	**65,506**	**10,907**	**98**	**16**
	SUPPLIES-REMOVALS	**1,081**	**406**	**2**	**1**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		0	0		
	TOTAL	**0**	**0**		
REMOVALS					
5. Output by animal products					
6. Output by losses from manure to air before application					
8. Transfer by application of manure and/or waste					
	TOTAL	**0**	**0**		
	SUPPLIES-REMOVALS	**0**	**0**		
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		-	-		
11. Input by fertilizers		72,536	5,433	109	8
12. Input by N fixation		683		1	
15. Input by dry and wet deposition		3,416	84	5	0.1
26. Transfer by plant products remaining on field		20,557	1,302	31	2
	TOTAL	**97,192**	**6,818**	**145**	**10**
REMOVALS					
19. Output by denitrification		18,977		28	
20. Output by volatilization of ammonia					
21. Output by leaching		3,795		6	
22. Output by run-off of available nutrients		759	380	1	1
28. Output by organic matter, removed by run-off		1,139	380	2	1
30. Transfer by net uptake from soil by plant		65,510	10,908	98	16
	TOTAL	**90,181**	**11,667**	**135**	**17**
	SUPPLIES-REMOVALS	**7,011**	**(4,849)**	**10**	**-7**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste					
11. Input by fertilizers		72,536	5,433	109	8
12. Input by N-fixation		683		1	
15. Input by dry and wet deposition		3,416	84	5	0.1
17. Transfer by mineralization of soil organic fraction		56,932	6,832	85	10
	TOTAL	**133,567**	**12,348**	**200**	**18**
REMOVALS					
19. Output by denitrification		18,977		28	
20. Output by volatilization of ammonia		-	-		
21. Output by leaching		3,795		6	
22. Output by run-off of available nutrients		759	380	1	1
24. Transfer by fixation in soil mineral fraction					
25. Transfer by immobilization in soil organic fraction		18,977	2,277	28	3
30t. Transfer by net uptake by the plant		65,510	10,908	98	16
	TOTAL	**108,019**	**13,565**	**162**	**20**
SUPPLIES-REMOVALS		**25,548**	**(1,217)**	**38**	**-2**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste					
25. Transfer by immobilization in soil organic fraction		18,977	2,277	28	3
26b. Transfer by plant products remaining of field		20,557	1,302	31	2
	TOTAL	**39,534**	**3,580**	**59**	**5**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		56,932	6,832	85	10
28. Output by organic matter, removed by run-off		1,139	380	2	1
	TOTAL	**58,070**	**7,211**	**87**	**11**
SUPPLIES-REMOVALS		**(18,536)**	**(3,632)**	**-28**	**-5**

Total Inputs

	N	P
Fertilizer	72,536	5,433
Feed	-	-
Fixation/Deposition	4,099	84
TOTAL	**76,635**	**5,516**
kg/ha	**115**	**8**

Total Outputs

	N	P
Crops	44,950	8,042
Animal & animal products	-	-
TOTAL	**44,950**	**8,042**
kg/ha	**67**	**12**

	N	P	kg N/ha	kg P/ha
Input-Output	31,686	(2,526)	47	-4
Calculated losses	24,670	759	37	1
Difference	7,015	(3,285)	11	-5

RM of Roland

Rol B

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		523	155	4	1
30t. Transfer by net uptake from soils		21,085	2,642	170	21
	TOTAL	**21,608**	**2,797**	**174**	**23**
REMOVALS					
3. Transfer by consumption of harvested crops					
18. Output by primary products		14,736	2,023	119	16
26. Transfer by plant production remaining on field		6,349	620	51	5
	TOTAL	**21,085**	**2,642**	**170**	**21**
	SUPPLIES-REMOVALS	**523**	**154**	**4**	**1**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		0	0		
	TOTAL	**0**	**0**		
REMOVALS					
5. Output by animal products					
6. Output by losses from manure to air before application					
7. Output by manure					
8. Transfer by application of manure and/or waste					
9. Transfer by droppings on grazed areas					
	TOTAL	**0**	**0**		
	SUPPLIES-REMOVALS	**0**	**0**		
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		-	-		
9. Transfer by droppings on grazed areas		-	-		
11. Input by fertilizers		10,084	1,734	81	14
12. Input by N fixation		5,582		45	
15. Input by dry and wet deposition		634	16	5	0.1
26. Transfer by plant products remaining on field		6,349	620	51	5
	TOTAL	**22,649**	**2,369**	**183**	**19**
REMOVALS					
19. Output by denitrification		2,114		17	
20. Output by volatilization of ammonia					
21. Output by leaching		705		6	
22. Output by run-off of available nutrients		141	141	1	1
28. Output by organic matter, removed by run-off		141	141	1	1
30. Transfer by net uptake from soil by plant		21,085	2,642	170	21
	TOTAL	**24,185**	**2,924**	**195**	**24**
	SUPPLIES-REMOVALS	**(1,536)**	**(555)**	**-12**	**-4**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste					
11. Input by fertilizers		10,084	1,734	81	14
12. Input by N-fixation		5,582		45	
15. Input by dry and wet deposition		634	16	5	0
17. Transfer by mineralization of soil organic fraction		10,568	1,321	85	11
	TOTAL	**26,868**	**3,071**	**217**	**25**
REMOVALS					
19. Output by denitrification		2,114		17	
20. Output by volatilization of ammonia		-	-		
21. Output by leaching		705	-	6	
22. Output by run-off of available nutrients		141	141	1	1
24. Transfer by fixation in soil mineral fraction					
25. Transfer by immobilization in soil organic fraction		3,523	440	28	4
30t. Transfer by net uptake by the plant		21,085	2,642	170	21
	TOTAL	**27,567**	**3,223**	**222**	**26**
SUPPLIES-REMOVALS		**(699)**	**(153)**	**-6**	**-1**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste					
25. Transfer by immobilization in soil organic fraction		3,523	440	28	4
26b. Transfer by plant products remaining of field		6,349	620	51	5
	TOTAL	**9,872**	**1,060**	**80**	**9**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		10,568	1,321	85	11
28. Output by organic matter, removed by run-off		141	141	1	1
	TOTAL	**10,709**	**1,462**	**86**	**12**
SUPPLIES-REMOVALS		**(837)**	**(402)**	**-7**	**-3**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	10,084	1,734	Crops	14,736	2,023
Feed	-	-	Animal & animal products	-	-
Fixation/Deposition	6,216	16	**TOTAL**	**14,736**	**2,023**
TOTAL	**16,300**	**1,749**	**kg/ha**	**119**	**16**
kg/ha	**131**	**14**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	1,564	(273)	**13**	**-2**
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	3,100	282	**25**	**2**
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	(1,536)	(555)	-12	-4

RM of Roland

Rol C

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		280	49	2	0.3
30t. Transfer by net uptake from soils		29,610	3,978	174	23
	TOTAL	**29,889**	**4,026**	**176**	**24**
REMOVALS					
3. Transfer by consumption of harvested crops					
18. Output by primary products		19,101	2,603	112	15
26. Transfer by plant production remaining on field		10,509	1,374	62	8
	TOTAL	**29,610**	**3,978**	**174**	**23**
	SUPPLIES-REMOVALS	**280**	**49**	**2**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		0	0		
	TOTAL	**0**	**0**		
REMOVALS					
5. Output by animal products					
6. Output by losses from manure to air before application					
8. Transfer by application of manure and/or waste					
	TOTAL	**0**	**0**		
	SUPPLIES-REMOVALS	**0**	**0**		
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		-	-		
11. Input by fertilizers		26,481	4,918	156	29
12. Input by N fixation		174		1	
15. Input by dry and wet deposition		869	21	5	0
26. Transfer by plant products remaining on field		10,509	1,374	62	8
	TOTAL	**38,033**	**6,314**	**224**	**37**
REMOVALS					
19. Output by denitrification		5,795		34	
20. Output by volatilization of ammonia					
21. Output by leaching		1,932		11	
22. Output by run-off of available nutrients		193	97	1	0.6
28. Output by organic matter, removed by run-off		290	97	2	0.6
30. Transfer by net uptake from soil by plant		29,610	3,978	174	23
	TOTAL	**37,820**	**4,171**	**222**	**25**
	SUPPLIES-REMOVALS	**212**	**2,143**	**1**	**13**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste					
11. Input by fertilizers		26,481	4,918	156	29
12. Input by N-fixation		174		1	
15. Input by dry and wet deposition		869	21	5	0.1
17. Transfer by mineralization of soil organic fraction		14,489	1,739	85	10
	TOTAL	**42,013**	**6,678**	**247**	**39**
REMOVALS					
19. Output by denitrification		5,795		34	
20. Output by volatilization of ammonia		-	-		
21. Output by leaching		1,932		11	
22. Output by run-off of available nutrients		193	97	1	1
24. Transfer by fixation in soil mineral fraction					
25. Transfer by immobilization in soil organic fraction		4,830	580	28	3
30t. Transfer by net uptake by the plant		29,610	3,978	174	23
	TOTAL	**42,360**	**4,654**	**249**	**27**
SUPPLIES-REMOVALS		**(347)**	**2,024**	**-2**	**12**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste					
25. Transfer by immobilization in soil organic fraction		4,830	580	28	3
26b. Transfer by plant products remaining of field		10,509	1,374	62	8
	TOTAL	**15,338**	**1,954**	**90**	**11**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		14,489	1,739	85	10
28. Output by organic matter, removed by run-off		290	97	2	0.6
	TOTAL	**14,778**	**1,835**	**87**	**11**
SUPPLIES-REMOVALS		**560**	**119**	**3**	**1**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	26,481	4,918	Crops	19,101	2,603
Feed	-	-	Animal & animal products	-	-
Fixation/Deposition	1,043	21	**TOTAL**	**19,101**	**2,603**
TOTAL	**27,524**	**4,939**	**kg/ha**	**112**	**15**
kg/ha	**162**	**29**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	8,423	2,336	50	14
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	8,210	193	48	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	212	2,143	1	13

RM of Sifton

Sif A

Nutrient		kg/year N	kg/year P	kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		135	25	0.1	0.03
30t. Transfer by net uptake from soils		53,875	5,889	57	6
	TOTAL	**54,011**	**5,914**	**58**	**6**
REMOVALS					
3. Transfer by consumption of harvested crops		29,983	3,708	32	4
18. Output by primary products					0
26. Transfer by plant production remaining on field		23,892	2,180	25	2
	TOTAL	**53,875**	**5,889**	**57**	**6**
	SUPPLIES-REMOVALS	**135**	**25**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		591	108	0.6	0.12
3. Transfer by consumption of harvested crops		29,983	3,708	32	4
	TOTAL	**30,574**	**3,816**	**33**	**4**
REMOVALS					
5. Output by animal products		550	149	0.6	0.2
6. Output by losses from manure to air before application		7,020		7	
8. Transfer by application of manure and/or waste		9,306	4,367	10	5
	TOTAL	**16,875**	**4,516**	**18**	**5**
	SUPPLIES-REMOVALS	**13,699**	**(700)**	**15**	**-1**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		9,306	4,367	10	5
11. Input by fertilizers		6,136	1,112	7	1
12. Input by N fixation		24,604		26	
15. Input by dry and wet deposition		4,803	117	5	
26. Transfer by plant products remaining on field		23,892	2,180	25	2
	TOTAL	**68,741**	**7,777**	**73**	**8**
REMOVALS					
19. Output by denitrification		7,919		8	
20. Output by volatilization of ammonia		2,792		3	
21. Output by leaching		3,087		3	
22. Output by run-off of available nutrients		1,067	344	1	0.4
28. Output by organic matter, removed by run-off		1,067	344	1	0.4
30. Transfer by net uptake from soil by plant		53,875	5,889	57	6
	TOTAL	**69,808**	**6,577**	**74**	**7**
	SUPPLIES-REMOVALS	**(1,067)**	**1,200**	**-1**	**1**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		5,763	2,184	6	2
11. Input by fertilizers		6,136	1,112	7	1
12. Input by N-fixation		24,604		26	
15. Input by dry and wet deposition		4,803	117	5	0.1
17. Transfer by mineralization of soil organic fraction		86,682	10,835	92	12
	TOTAL	**127,988**	**14,248**	**136**	**15**
REMOVALS					
19. Output by denitrification		7,919		8	
20. Output by volatilization of ammonia		2,792	-	3	
21. Output by leaching		3,087		3	
22. Output by run-off of available nutrients		1,067	344	1	0.4
24. Transfer by fixation in soil mineral fraction			1,310		1
25. Transfer by immobilization in soil organic fraction		35,000	4,350	37	5
30t. Transfer by net uptake by the plant		53,875	5,889	57	6
	TOTAL	**103,741**	**11,892**	**110**	**13**
SUPPLIES-REMOVALS		**24,247**	**2,356**	**26**	**3**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		3,543	2,184	4	2
25. Transfer by immobilization in soil organic fraction		35,000	4,350	37	5
26b. Transfer by plant products remaining of field		23,892	2,180	25	2
	TOTAL	**62,435**	**8,714**	**66**	**9**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		86,682	10,835	92	12
28. Output by organic matter, removed by run-off		1,067	344	1	0.4
	TOTAL	**87,749**	**11,179**	**93**	**12**
SUPPLIES-REMOVALS		**(25,314)**	**(2,466)**	**-27**	**-3**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	6,136	1,112	Crops	-	-
Feed	591	108	Animal & animal products	550	149
Fixation/Deposition	29,407	117	**TOTAL**	**550**	**149**
TOTAL	**36,134**	**1,337**	**kg/ha**	**1**	**0**
kg/ha	**38**	**1**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	35,584	1,188	38	1
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	22,953	688	24	0.7
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	12,632	500	13	1

RM of Sifton

Sif B

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		126	24	0.1	0.02
30t. Transfer by net uptake from soils		62,884	6,706	63	7
	TOTAL	**63,010**	**6,730**	**63**	**7**
REMOVALS					
3. Transfer by consumption of harvested crops		36,247	4,403	36	4
18. Output by primary products					
26. Transfer by plant production remaining on field		27,265	2,332	27	2
27. Transfer by seed for sowing					
	TOTAL	**63,512**	**6,735**	**64**	**7**
	SUPPLIES-REMOVALS	**(502)**	**(5)**	**-1**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		374	71	0.4	0.07
3. Transfer by consumption of harvested crops		36,247	4,403	36	4
	TOTAL	**36,621**	**4,474**	**37**	**4**
REMOVALS					
5. Output by animal products		1,691	457	2	0.5
6. Output by losses from manure to air before application		7,383		7	
8. Transfer by application of manure and/or waste		9,787	4,593	10	5
	TOTAL	**18,861**	**5,051**	**19**	**5**
	SUPPLIES-REMOVALS	**17,760**	**(576)**	**19**	**5**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		9,787	4,593	10	4.6
11. Input by fertilizers		6,391	2,506	6	2.5
12. Input by N fixation		31,520		32	
15. Input by dry and wet deposition		5,110	125	5	0.1
26. Transfer by plant products remaining on field		27,265	2,332	27	2.3
	TOTAL	**80,073**	**9,556**	**80**	**10**
REMOVALS					
19. Output by denitrification		12,636		13	
20. Output by volatilization of ammonia		2,936		3	
21. Output by leaching		3,769		4	
22. Output by run-off of available nutrients		1,135	378	1	0.4
28. Output by organic matter, removed by run-off		1,229	378	1	0.4
30. Transfer by net uptake from soil by plant		62,884	6,706	63	7
	TOTAL	**84,590**	**7,463**	**85**	**7**
	SUPPLIES-REMOVALS	**(4,517)**	**2,094**	**-5**	**2**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		6,061	2,297	6	2
11. Input by fertilizers		6,391	2,506	6	3
12. Input by N-fixation		31,520		32	
15. Input by dry and wet deposition		5,110	125	5	0.1
17. Transfer by mineralization of soil organic fraction		106,636	13,330	107	13
	TOTAL	**155,718**	**18,257**	**156**	**18**
REMOVALS					
19. Output by denitrification		12,636		13	
20. Output by volatilization of ammonia		2,936	-	3	
21. Output by leaching		3,769		4	
22. Output by run-off of available nutrients		1,135	378	1	0.4
24. Transfer by fixation in soil mineral fraction			1,378		1.4
25. Transfer by immobilization in soil organic fraction		52,273	6,547	52	7
30t. Transfer by net uptake by the plant		62,884	6,706	63	7
	TOTAL	**135,633**	**15,010**	**136**	**15**
SUPPLIES-REMOVALS		**20,084**	**3,247**	**20**	**3**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		3,726	2,297	4	2
25. Transfer by immobilization in soil organic fraction		52,273	6,547	52	7
26b. Transfer by plant products remaining of field		27,265	2,332	27	2
	TOTAL	**83,264**	**11,176**	**83**	**11**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		106,636	13,330	107	13
28. Output by organic matter, removed by run-off		1,229	378	1	0.4
	TOTAL	**107,865**	**13,708**	**108**	**14**
SUPPLIES-REMOVALS		**(24,602)**	**(2,532)**	**-25**	**-3**

Total Inputs

	N	P
Fertilizer	6,391	2,506
Feed	374	71
Fixation/Deposition	36,629	125
TOTAL	**43,394**	**2,702**
kg/ha	**43**	**3**

Total Outputs

	N	P
Crops	-	-
Animal & animal products	1,691	457
TOTAL	**1,691**	**457**
kg/ha	**2**	**0.5**

	N	P	kg N/ha	kg P/ha
Input-Output	41,703	2,245	**42**	**2**
Calculated losses	29,089	756	**29**	**1**
Difference	12,614	1,488	13	1

RM of Sifton

Sif C

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
<u>Changes in amount of plant component</u>					
SUPPLIES					
29. Input by seeds or seedlings		378	71	0.4	0.1
30t. Transfer by net uptake from soils		89,567	10,519	88	10
	TOTAL	**89,945**	**10,590**	**88**	**10**
REMOVALS					
3. Transfer by consumption of harvested crops		46,764	5,687	46	6
18. Output by primary products		5,236	999	5	1
26. Transfer by plant production remaining on field		37,567	3,675	37	4
	TOTAL	**89,567**	**10,361**	**88**	**10**
	SUPPLIES-REMOVALS	**378**	**229**	**0.4**	**0.2**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		46,764	5,687	46	6
	TOTAL	**46,764**	**5,687**	**46**	**6**
REMOVALS					
5. Output by animal products		550	149	1	0.1
6. Output by losses from manure to air before application		6,819		7	
8. Transfer by application of manure and/or waste		9,040	4,243	9	4
	TOTAL	**16,409**	**4,391**	**16**	**4**
	SUPPLIES-REMOVALS	**30,355**	**1,296**	**30**	**1**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		9,040	4,243	9	4
11. Input by fertilizers		11,350	3,531	11	3
12. Input by N fixation		40,880		40	
15. Input by dry and wet deposition		5,220	128	5	0.1
26. Transfer by plant products remaining on field		37,567	3,675	37	4
	TOTAL	**104,057**	**11,575**	**102**	**11**
REMOVALS					
19. Output by denitrification		11,675		11	
20. Output by volatilization of ammonia		2,712		3	
21. Output by leaching		2,900		3	
22. Output by run-off of available nutrients		1,160	387	1	0.4
28. Output by organic matter, removed by run-off		1,257	387	1	0.4
30. Transfer by net uptake from soil by plant		89,567	10,519	88	10.3
	TOTAL	**109,270**	**11,292**	**107**	**11**
	SUPPLIES-REMOVALS	**(5,213)**	**283**	**-5**	**0.3**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		5,598	2,121	5	2
11. Input by fertilizers		11,350	3,531	11	3
12. Input by N-fixation		40,880		40	
15. Input by dry and wet deposition		5,220	128	5	0.1
17. Transfer by mineralization of soil organic fraction		119,545	14,943	117	15
	TOTAL	**182,594**	**20,723**	**179**	**20**
REMOVALS					
19. Output by denitrification		11,675		11	
20. Output by volatilization of ammonia		2,712	-	3	
21. Output by leaching		2,900		3	
22. Output by run-off of available nutrients		1,160	387	1	0.4
24. Transfer by fixation in soil mineral fraction			1,273	0	1
25. Transfer by immobilization in soil organic fraction		79,341	9,918	78	10
30t. Transfer by net uptake by the plant		89,567	10,519	88	10
	TOTAL	**187,354**	**22,096**	**184**	**22**
SUPPLIES-REMOVALS		**(4,760)**	**(1,373)**	**-5**	**-1**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		3,441	2,121	3	2
25. Transfer by immobilization in soil organic fraction		79,341	9,918	78	10
26b. Transfer by plant products remaining of field		37,567	3,675	37	4
	TOTAL	**120,350**	**15,714**	**118**	**15**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		119,545	14,943	117	15
28. Output by organic matter, removed by run-off		1,257	387	1	0
	TOTAL	**120,802**	**15,330**	**118**	**15**
SUPPLIES-REMOVALS		**(453)**	**384**	**-0.4**	**0.4**

Total Inputs	**N**	**P**	**Total Outputs**	**N**	**P**
Fertilizer	11,350	3,531	Crops	5,236	999
Feed	-	-	Animal & animal products	550	149
Fixation/Deposition	46,100	128	**TOTAL**	**5,786**	**1,148**
TOTAL	**57,450**	**3,658**	**kg/ha**	**6**	**1**
kg/ha	**56**	**4**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	51,664	2,510	51	2
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	26,522	773	26	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	25,142	1,737	25	2

RM of Sifton

Sif D

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
Changes in amount of plant component					
SUPPLIES					
29. Input by seeds or seedlings		21	5	0.03	0.01
30t. Transfer by net uptake from soils		54,553	6,282	72	8
	TOTAL	**54,574**	**6,287**	**72**	**8**
REMOVALS					
3. Transfer by consumption of harvested crops		22,092	2,473	29	3
18. Output by primary products		8,995	1,640	12	2
26. Transfer by plant production remaining on field		23,151	2,096	31	3
27. Transfer by seed for sowing		374	71	0.5	0.1
	TOTAL	**54,612**	**6,281**	**73**	**8**
	SUPPLIES-REMOVALS	**(38)**	**5**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock					
3. Transfer by consumption of harvested crops		22,092	2,473	29	3.3
	TOTAL	**22,092**	**2,473**	**29**	**3**
REMOVALS					
5. Output by animal products		1,164	315	2	0.4
6. Output by losses from manure to air before application		8,921		12	
8. Transfer by application of manure and/or waste		11,826	5,550	16	7
	TOTAL	**21,910**	**5,865**	**29**	**8**
	SUPPLIES-REMOVALS	**182**	**(3,392)**	**0**	**-5**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		11,826	5,550	16	7
11. Input by fertilizers		8,136	1,729	11	2
12. Input by N fixation		23,368		31	
15. Input by dry and wet deposition		3,850	94	5	0.1
26. Transfer by plant products remaining on field		23,151	2,096	31	3
27. Transfer by seed for sowing		374	71	0	0
	TOTAL	**70,704**	**9,541**	**94**	**13**
REMOVALS					
19. Output by denitrification		5,077		7	
20. Output by volatilization of ammonia		3,548		5	
21. Output by leaching		5,152		7	
22. Output by run-off of available nutrients		855	292	1	0.4
28. Output by organic matter, removed by run-off		855	292	1	0.4
30. Transfer by net uptake from soil by plant		54,553	6,282	72	8
	TOTAL	**70,040**	**6,865**	**93**	**9**
	SUPPLIES-REMOVALS	**664**	**2,676**	**1**	**4**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		7,324	2,775	10	4
11. Input by fertilizers		8,136	1,729	11	2
12. Input by N-fixation		23,368		31	
15. Input by dry and wet deposition		3,850	94	5	0.1
17. Transfer by mineralization of soil organic fraction		80,195	10,024	107	13
	TOTAL	**122,873**	**14,623**	**163**	**19**
REMOVALS					
19. Output by denitrification		5,077		7	
20. Output by volatilization of ammonia		3,548	-	5	
21. Output by leaching		5,152		7	
22. Output by run-off of available nutrients		855	292	1	0.4
24. Transfer by fixation in soil mineral fraction			2,220		3
25. Transfer by immobilization in soil organic fraction		45,720	4,833	61	6
30t. Transfer by net uptake by the plant		54,553	6,282	72	8
	TOTAL	**114,905**	**13,626**	**153**	**18**
SUPPLIES-REMOVALS		**7,967**	**997**	**11**	**1**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		4,502	2,775	6	4
25. Transfer by immobilization in soil organic fraction		45,720	4,833	61	6
26b. Transfer by plant products remaining of field		23,151	2,096	31	3
	TOTAL	**73,373**	**9,704**	**97**	**13**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		80,195	10,024	107	13
28. Output by organic matter, removed by run-off		855	292	1	0.4
	TOTAL	**81,051**	**10,316**	**108**	**14**
SUPPLIES-REMOVALS		**(7,678)**	**(612)**	**-10**	**-1**

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	8,136	1,729	Crops	8,995	1,640
Feed	-	-	Animal & animal products	1,164	315
Fixation/Deposition	27,217	94	**TOTAL**	**10,159**	**1,955**
TOTAL	**35,354**	**1,823**	**kg/ha**	**13**	**3**
kg/ha	**47**	**2**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	25,195	(132)	33	0
Calculated losses	**N**	**P**	**kg N/ha**	**kg P/ha**
	24,409	583	32	1
Difference	**N**	**P**	**kg N/ha**	**kg P/ha**
	787	(715)	1	-1

Appendix B:

Municipal Nutrient Budgets

RM of Hanover
Municipal Nutrient Balance

Cropland (excluding christmas trees)	45,197	hectares
Summerfallow land	3,223	hectares
Tame or Seeded pasture	4,299	hectares
Natural land for pasture	13,695	hectares
All other land (including Christmas trees)	6,875	hectares
	66,414	**52,719**
		(excludes other land)

Livestock

Total cattle and calf inventory

	Number	fraction removed/year	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Bulls	323	0.3	97	900	0.027	0.0073	2,355	637
Dairy cow	5,632	0.3	1690	600	0.027	0.0073	27,372	7,400
Beef cow	5,264	0.17	895	550	0.027	0.0073	13,289	3,593
Dairy heifer	2,629	0	0	385	0.024	0.0065	-	-
Beef heifer	1,209	0.8	967	360	0.024	0.0065	8,357	2,263
Slaughter heifer	4,161	1	4161	410	0.024	0.0065	40,944	11,089
Steer	2,675	0	0	360	0.024	0.0065	-	-
Calves	7,638	0.6	4583	135	0.024	0.0065	14,848	4,021
	29,531						**107,164**	**29,004**

	Milk producing cows	litres Milk produced (rate 8160 litres/cow)	Density of milk 1031kg/1000L	Fraction N	Fraction P	kg N
Milk production	4,787	39,063,552	40,274,522	0.005	0.001	**201,373**

Total pig inventory

	Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Boars	***726***	0.55	399	160	0.023	0.0047	1,469	300
Sows	***48,528***							
Gestating sows	38,337	0.45	17,252	150	0.023	0.0047	59,518	12,162
Nursing sows	7,279	0.45	3,276	160	0.023	0.0047	12,054.4	2,463
Gilts	2,912			125	0.024	0.0047	-	-
Market hogs	***352,318***							
Weanling	117,439	2	234,879	14	0.025	0.0056	82,208	18,414
Grower	117,439	2	234,879	35	0.025	0.0056	205,519	46,036
Finisher	117,440	2	234,880	75	0.025	0.0056	440,400	98,650
	401,572						**801,169**	**178,026**

Total chicken and hens

	Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Broilers,roasters,cornish	1,605,921	7.5	12,044,408	2.3	0.028	0.0058	775,660	160,672
Pullets	263,473	2	526,946	1.4	0.028	0.0058	20,656	4,279
Laying hens	333,420	1	333,420	1.8	0.028	0.0058	16,804	3,481
	Eggs produced per layer	5.6	1,867,152	0.06	0.0167	0.002	1,871	224
	2,202,814						**814,991**	**168,656**

Total turkeys

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
100,385	2	200,770	5.5	0.028	0.0058	30,919	6,405

Total kg N
1,955,615

Commercial Fertilizers

(from Stats Canada)

Total kg N	Total kg P2O5	Total kg P	Fertilized hectares
2,788,000	1,007,000	437,826	31,493
Average kg N/ha	**Average kg P2O5/ha**	**Average kg P/ha**	
89	32	14	

(from Crop Insurance)

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
92	35	15

Manure as Fertilizer

Manured Ha	Ha Applied with solid spreader	Applied with liquid spreader on surface
15,994	5,170	6083

Ha Applied using irrigation system	Applied with liquid spreader injected
206	4,535

Manure Production

Cattle	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P2O5/day/animal**	**Annual N production**
Bulls	323	900	0.306	0.188	36,076
Dairy cow	5,632	600	0.270	0.128	555,034
Beef cow	5,264	550	0.187	0.115	359,294
Dairy heifer	2,629	385	0.173	0.082	166,008
Beef heifer	1,209	360	0.122	0.075	53,837
Slaughter heifer	4,161	410	0.137	0.085	208,071
Steer	2,675	360	0.130	0.080	126,929
Calves	7,638	135	0.046	0.028	128,242
	29,531				**1,633,490**

Assumption: Storage lossses are 40%	0.6		**N production - storage losses**	**980,094**
Assumption: Application losses are 20%	0.8		***Volatilization losses (storage)***	653,396
(manure applied with solid spreader)			**N production - application losses**	**784,075**
			Volatilization losses (application)	196,019
Assume total yearly production (lbs) is	**251,306,206**	kg		
based on 6.5 kg N/tonne manure (or 0.65%)	0.0065			
Assume 2.1 kg available N/tonne manure	**527,743**	kg		
based on Alberta guidelines (0.21%)	0.0021			
Kg of N not available to crops in 1st year	**452,351**	kg		
(kg N available from storage - kg available N)				

Hog	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P2O5/day/animal**	**Annual N production**	**Annual P2O5 p**
Boars	*726*	160	0.035	0.027	9,275	
Sows	*48,528*					
Gestating sows	38,337	150	0.033	0.026	461,771	
Nursing sows	7,279	160	0.035	0.027	92,992	
Gilts	2,912	125	0.028	0.021	10,191	
Market hogs	*352,318*					
Weanling	117,439	14	0.006	0.004	257,192	
Grower	117,439	35	0.015	0.011	642,980	
Finisher	117,440	75	0.033	0.023	1,414,565	
Total	**401,572**				**2,888,965**	

			N production - storage losses	**1,733,379**
Assumption: Storage losses are 40%	0.6		***Volatilization losses (storage)***	1,155,586
Assumption: Application losses are 10%	0.9		**N production - application losses**	**1,560,041**
			Volatilization losses (application)	173,338
Assume storage yearly production (litres) is	**577,793,042**	litres		
based on 3.0 kg N/1000 litres manure (or 0.3%)	0.003			
Assume organic N content is	**520,014**	kg		
based on 0.9 kg N/1000 litres (or 0.09%)	0.0009			
Assume inorganic N content is	**1,213,365**	kg		
based on 2.1 kg N/1000 litres (0.21%)	0.0021			

Chickens	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P/day/animal**	**Annual N production**	**Annual P pr**
Broilers,roasters,cornish	1,605,921	2.5	0.0015	0.00042	855,956	
Pullets	263,473	1.5	0.0007	0.00016	63,234	
Laying hens	333,420	1.8	0.002	0.00047	243,397	
	2,202,814				**1,162,586**	

				Laying hens	**Broilers,Pullet**
Assumption: Storage losses are 20%	0.8	**N production - storage losses**	**930,069**	**194,717**	**735,352**
Assumption: Application losses are 10%	0.9	***Volatilization losses (storage)***	232,517		
		N production - application losses	**837,062**		
		Volatilization losses (application)	93,007		

Assumption: Use liquid N manure values for laying hens		**Assumption: Use solid manure N values for broilers and pullets**	
Assume storage yearly production (litres) is	**36,739,109**	**Assume storage yearly production (kg) is**	**43,255,972**
based on 5.3 kg N/1000 litres manure (or 0.53%)	0.0053	based on 17 kg N/tonne manure (or 1.7%)	0.017
Assume kg organic N content is	**18,370**	**Assume kg organic N content is**	**692,096**
based on 0.5 lbs N/1000 litres manure (or 0.05%)	0.0005	based on 16 kg N/tonne manure (or 1.6%)	0.016
Assume kg inorganic N content is	**176,348**	**Assume kg inorganic N content is**	**43,256**
based on 4.8 kg/1000 litres (0.48%)	0.0048	based on 1 kg N/tonne (0.1%)	0.001

Turkeys

Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
100,385	5.5	0.0021	0.00064	76,945	23,450
			N production - storage losses	**61,556**	
Assumption: Storage losses are 20%		0.8	***Volatilization losses (storage)***	15,389	
Assumption: Application losses are 10%		0.9	**N production - application losses**	**55,400**	
Assumption: Use solid manure N values			***Volatilization losses (application)***	6,156	
Assume storage yearly production (kg) is		**3,620,946** kg			
based on 17 kg N/tonne manure (or 1.7%)		0.017			
Assume organic N content is		**57,935** kg			
based on 16 kg N/tonne manure (or 1.6%)		0.016			
Assume inorganic N content is		**3,621** kg			
based on 1 kg N/tonne (0.1%)		0.001			
Total Annual N production		**5,761,987**	**Total Annual P production**	**1,643,979**	
Storage N volatilization losses		**2,056,888**			
Nitrogen available after losses		**3,705,098**			
Application N volatilization losses		**468,519**			
kg of inorganic N		**1,964,333**	**kg of available N**	**2,486,563**	***(inorganic-N+30% organic-N)***
kg of organic N		**1,740,765**	**kg of remaining N**	**1,218,536**	

Crops

Stats Canada

Type	hectares	tonnes	kg	yield kg/ha	acres	pounds	lbs/bu	bushels
durum wheat	-	-	-		-	-	60	-
spring wheat	8,600	21,700	21,700,000	2523	21,500	47,740,000	60	795,667
winter wheat	400	1,700	1,700,000	4250	1,000	3,740,000	60	62,333
oats	3,800	11,300	11,300,000	2974	9,500	24,860,000	32	776,875
barley	9,600	32,000	32,000,000	3333	24,000	70,400,000	48	1,466,667
mixed grain	100	400	400,000	4000	250	880,000	52	16,923
grain corn	1,400	7,700	7,700,000	5500	3,500	16,940,000	56	302,500
buckwheat	100	100	100,000	1000	250	220,000	48	4,583
rye	-	-	-		-	-	56	-
alfalfa	1,400	4,820		3	3,500	10,604,000		5,302
grass pasture	5,600	19,280		3	14,000	42,416,000		21,208
canola	6,700	11,600	11,600,000	1731	16,750	25,520,000	50	510,400
flax	500	700	700,000	1400	1,250	1,540,000	56	27,500
sunflower	100	300	300,000	3000	250	660,000	28	23,571
field peas	100	100	100,000	1000	250	220,000	60	3,667
lentils	-	-	-		-	-	60	-
coloured beans	100	100	100,000	1000	250	220,000	60	3,667
white beans	-	-	-		-	-	60	-
canary seed	100	100	100,000	1000	250	220,000	60	3,667
	38,600				**96,500**			

Nutrient uptake

Stats Canada

Type	bushels or tons	lbs N/ha	lbs P2O5/ha	kg N	kg P2O5
durum wheat	-	2.13	0.80	-	-
spring wheat	795,667	2.13	0.80	1,694,770	636,533
winter wheat	62,333	1.36	0.62	84,773	38,647
oats	776,875	1.07	0.41	831,256	318,519
barley	1,466,667	1.39	0.56	2,038,667	821,333
mixed grain	16,923	1.53	0.59	25,892	9,985
grain corn	302,500	1.53	0.63	462,825	190,575
buckwheat	4,583	1.39	0.56	6,371	2,567
rye	-	1.67	0.84	-	-
alfalfa	5,302	105.00	21.00	556,710	111,342
grass pasture	21,208	60.00	17.00	1,272,480	360,536
canola	510,400	3.20	1.49	1,633,280	760,496
flax	27,500	2.88	0.83	79,200	22,825
sunflower	23,571	1.50	0.52	35,357	12,257
field peas	3,667	3.06	0.84	11,220	3,080
lentils	-	3.07	0.83	-	-
coloured beans	3,667	5.72	0.98	20,973	3,593
white beans	-	5.72	0.98	-	-

canary seed	3,667				-	-	lbs P
				Total	**8,753,775**	**3,292,288**	**1,431,429**
				Total Kg	***3,978,989***	***1,496,494***	***650,650***

Nutrient Removal

Stats Canada

Type	**bushels or tons**	**lbs N/bushels**	**lbs PO5/bu**		**lbs N**	**lbs P2O5**	
durum wheat	-	1.5	0.6		-	-	
spring wheat	795,667	1.5	0.6		1,193,500	477,400	
winter wheat	62,333	1.04	0.52		64,827	32,413	
oats	776,875	0.62	0.26		481,663	201,988	
barley	1,466,667	0.98	0.43		1,437,333	630,667	
mixed grain	16,923	1.03	0.43		17,431	7,277	
grain corn	302,500	0.94	0.44		284,350	133,100	
buckwheat	4,583	0.98	0.43		4,492	1,971	
rye	-	1.07	0.45		-	-	
alfalfa	5,302	58	14		307,516	74,228	
grass pasture	21,208	34	10		721,072	212,080	
canola	510,400	1.94	1.06		990,176	541,024	
flax	27,500	2.13	0.67		58,575	18,425	
sunflower	23,571	1.08	0.32		25,457	7,543	
field peas	3,667	2.34	0.7		8,580	2,567	
lentils	-	2.03	0.63		-	-	
coloured beans	3,667	3.42	1.22		12,540	4,473	
white beans	-	3.42	1.22		-	-	
canary seed	3,667				-	-	lbs P
				Total	**5,607,511**	**2,345,155**	**1,019,633**
				Total Kg	***2,548,869***	***1,065,980***	***463,469***
				Nutrient remaining in soil (lbs)	**3,146,264**		**411,797**
				Nutrient remaining in soil (kg)	***1,430,120***		***187,180***

Feed

Type	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**
wheat	83,600	183,920,000	60			3,065,333	1.5	0.6	4,598,000	1,839,200
barley	68,800	151,360,000	48			3,153,333	0.98	0.43	3,090,267	1,355,933
oats	4,100	9,020,000	32			281,875	0.62	0.26	174,763	73,288
corn	29,300	64,460,000	56			1,151,071	0.94	0.44	1,082,007	506,471
mixed grain	-	-	52			-			-	
							Fraction N	**Fraction P**		
protein meal	47,300	104,060,000					0.03	0.01	3,121,800	1,040,600
								Total	**12,066,836**	**4,815,492**
								Total kg	***5,484,926***	***2,188,860***

Transfer Feed

Type	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**
barley	28,700	63,140,000	48			1,315,417	0.98	0.43	1,289,108	565,629
corn	7,700	16,940,000	56			302,500	0.94	0.44	284,350	133,100
alfalfa hay	4,820	10,604,000		5,302	tons		58	14	307,516	74,228
grass hay	19,280	42,416,000		21,208	tons		34	10	721,072	212,080
mixed grain	400	880,000	52			16,923	1.03	0.43	17,431	7,277
wheat	2,900	6,380,000	60			106,333	1.5	0.6	159,500	63,800
								Total	**2,778,977**	**1,056,114**
								Total kg	***1,263,171***	***480,052***

Crop Output

Crop	**tonnes**	**lbs**	**lbs/bu**	**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**
wheat	18,800	41,360,000	60	689,333	1.5	0.6	1,034,000	413,600
winter wheat	1,700	3,740,000	60	62,333	1.04	0.52	64,827	32,413
barley	3,300	7,260,000	48	151,250	0.98	0.43	148,225	65,038
buckwheat	100	220,000	48	4,583	0.98	0.43	4,492	1,971
oats	11,300	24,860,000	32	776,875	0.62	0.26	481,663	201,988
rye	-	-	56	-	1.07	0.45	-	-
canola	11,600	25,520,000	50	510,400	1.94	1.06	990,176	541,024
flax	700	1,540,000	56	27,500	2.13	0.67	58,575	18,425
sunflower	-			23,571	1.08	0.32	25,457	7,543
field peas	-			3,667	2.34	0.7	8,580	2,567
lentils	#REF!			-	2.03	0.63	-	-
coloured beans				3,667	3.42	1.22	12,540	4,473
white beans				-	3.42	1.22	-	-
						Total	**2,828,534**	**1,289,041**

Input by seeds

Crop	tonnes	pounds	lbs/bu	bushels	lbs N/bu	lbs PO5/bu	lbs N	lbs P2O5
						Total kg	***1,285,697***	***585,928***
wheat (-durum)	900	1,980,000	60	33,000	1.5	0.6	49,500	19,800
durum	0	-	60	-	1.5	0.6	-	-
barley	900	1,980,000	48	41,250	0.98	0.43	40,425	17,738
oats	400	880,000	32	27,500	0.62	0.26	17,050	7,150
corn	0	-	56	-	0.94	0.44	-	-
rye	0	-	56	-	1.07	0.45	-	-
flaxseed	0	-	56	-	2.13	0.67	-	-
canola	100	220,000	50	4,400	1.94	1.06	8,536	4,664

N fixation	**kg/ha**		**ha**	**kg N fixed**
non-symbiotic (cropland)	1		45,197	45,197
summerfallow	1		3,223	3,223
symbiotic alfalfa	220		860	189,156
grass seeded	1		3,439	3,439
(pasture)	1		13,695	13,695
		TOTAL	66,414	**254,710**

Denitrification

	kg/ha		**ha**	**kg N denitrified**			
manure	40		15,994	639,760	Fertilizer N	89	15% available N denitrified
cropland	20		27,483	549,668	Manure N	155	
alfalfa	5		860	4,299			
1 year after alfalfa	30		860	25,794			
4 years after alfalfa	25		860	21,495			
seeded pasture	5		3,439	17,196			
natural pasture	5		13,695	68,475			
summerfallow	30		3,223	96,690			
		TOTAL	66,414	**1,423,377**			

Ammonia volatilization

Output by leaching

	kg/ha	**ha**	**Total**
cropland	10	45,197	451,970
summerfallow	20	3,223	64,460
seeded pasture	2	4,299	8,598
natural pasture	2	13,695	27,390
		TOTAL	**552,418**

Output by run-off of available nutrient

	N			**P**	
	kg/ha	**ha**	**Total**	**kg/ha**	
cropland	1	45,197	45,197	0.5	22,599
summerfallow	2	3,223	6,446	0.5	1,612
seeded pasture	1	4,299	4,299	0.3	1,075
natural pasture	1	13,695	13,695	0.3	3,424
		TOTAL	**69,637**	**TOTAL**	**28,709**

Output by organic matter, removed by run-off

	N			**P**	
	kg/ha	**ha**	**Total**	**kg/ha**	
cropland	1.2	45,197	54,236	0.5	22,599
summerfallow	1.5	3,223	4,835	0.5	1,612
seeded pasture	1.2	4,299	5,159	0.3	1,075
natural pasture	1.2	13,695	16,434	0.3	3,424
		TOTAL	**80,664**	**TOTAL**	**28,709**

Transfer by mineralization in soil organic fraction

	N			P		
	kg/ha	ha	kg N	kg/ha	ha	kg P
cropland	75	36,599	2,744,925	9	36,599	343,116
summerfallow	80	3,223	257,840	10	3,223	32,230
alfalfa-current	120	860	103,176	15	860	12,897
1 year after alfalfa	165	860	141,867	21	860	17,733
4 years after alfalfa	100	860	85,980	13	860	10,748
seeded pasture	75	3,439	257,940	9	3,439	32,243
1 year after pasture	100	3,439	343,920	13	3,439	42,990
4 years after pasture	85	3,439	292,332	11	3,439	36,542
natural pasture	75	13,695	1,027,125	9	13,695	128,391
		Total	**5,255,105**			**656,888**

Transfer by immobilization in soil organic fraction

N				P		
	kg/ha	ha	Total	kg/ha	ha	kg P
cropland	25	45,197	1,129,925	3	45,197	141,241
summerfallow	5	3,223	16,115	1	3,223	2,014
alfalfa	165	860	141,867	21	860	17,733
seeded pasture	90	3,439	309,528	11	3,439	38,691
natural pasture	75	13,695	1,027,125	9	13,695	128,391
		TOTAL	**2,624,560**			**328,070**
			1,597,435			**199,679**

Wet and Dry Deposition

N	(excludes other land)			P		
kg/ha	ha		Total	kg/ha	ha	Total
5		66,414	**332,070**	0.11	66,414	**7,306**

RM of Hanover

Nutrient		kg/year N	kg/year P	Includes Native pasture kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
30t. Transfer by net uptake from soils		3,978,989	650,650	60	10
	TOTAL	**3,978,989**	**650,650**	**60**	**10**
REMOVALS					
3. Transfer by consumption of harvested crops		1,263,171	208,718	19	3
18. Output by primary products		1,285,697	254,751	19	4
26. Transfer by plant production remaining on field		1,430,120	187,180	22	3
	TOTAL	**3,978,989**	**650,650**	**60**	**10**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		5,484,926	951,678	83	14
3. Transfer by consumption of harvested crops		1,263,171	208,718	19	3
	TOTAL	**6,748,097**	**1,160,397**	**102**	**17**
REMOVALS					
5. Output by animal products		1,955,615	422,365	29	6
6. Output by losses from manure to air before application		2,056,888		31	
8. Transfer by application of manure and/or waste		3,705,098	1,643,979	56	25
	TOTAL	**7,717,602**	**2,066,344**	**116**	**31**
	SUPPLIES-REMOVALS	**(969,505)**	**(905,948)**	**-15**	**-14**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		3,705,098	1,643,979	56	25
10. Input by application of manure					
11. Input by fertilizers		2,788,000	437,826	42	7
12. Input by N fixation		254,710		4	
15. Input by dry and wet deposition		332,070	7,306	5	0.1
26. Transfer by plant products remaining on field		1,430,120	187,180	22	3
	TOTAL	**8,509,998**	**2,276,291**	**128**	**34**
REMOVALS					
19. Output by denitrification		1,423,377		21	
20. Output by volatilization of ammonia		468,519		7	
21. Output by leaching		552,418		8	
22. Output by run-off of available nutrients		69,637	28,709	1	0.4
28. Output by organic matter, removed by run-off		80,664	28,709	1	0.4
30. Transfer by net uptake from soil by plant		3,978,989	650,650	60	10
	TOTAL	**6,573,604**	**708,067**	**99**	**11**
	SUPPLIES-REMOVALS	**1,936,395**	**1,568,224**	**29**	**24**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		2,486,563	821,989	37	12
11. Input by fertilizers		2,788,000	437,826	42	7
12. Input by N-fixation		254,710		4	
15. Input by dry and wet deposition		332,070	7,306	5	0.1
17. Transfer by mineralization of soil organic fraction		5,255,105	656,888	79	10
	TOTAL	**11,116,448**	**1,924,009**	**167**	**29**
REMOVALS					
19. Output by denitrification		1,423,377		21	
20. Output by volatilization of ammonia		468,519	-	7	
21. Output by leaching		552,418		8	
22. Output by run-off of available nutrients		69,637	28,709	1	0.4
24. Transfer by fixation in soil mineral fraction			657,592		10
25. Transfer by immobilization in soil organic fraction		2,624,560	328,070	40	5
30t. Transfer by net uptake by the plant		3,978,989	650,650	60	10
	TOTAL	**9,117,500**	**1,665,020**	**137**	**25**
	SUPPLIES-REMOVALS	**1,998,948**	**258,989**	**30**	**4**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		1,218,536	821,989	18	12
25. Transfer by immobilization in soil organic fraction		2,624,560	328,070	40	5
26b. Transfer by plant products remaining of field		1,430,120	187,180	22	3
	TOTAL	**5,273,216**	**1,337,240**	**79**	**20**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		5,255,105	656,888	79	10
28. Output by organic matter, removed by run-off		80,664	28,709	1	0.4
	TOTAL	**5,335,769**	**685,597**	**80**	**10**
SUPPLIES-REMOVALS		**(62,553)**	**651,643**	**-1**	**10**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	2,788,000	437,826	Crops	1,285,697	254,751
Feed	5,484,926	951,678	Animal & animal products	1,955,615	422,365
Fixation/Deposition	586,780	7,306		**3,241,313**	**677,116**
TOTAL	**8,859,706**	**1,396,810**		**49**	**10**
kg/ha	**133**	**21**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	5,618,393	719,693	85	11
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	4,651,503	57,417	70	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	966,890	662,276	15	10

RM of Hanover

Nutrient		kg/year N	kg/year P	Modified feed input kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		3,978,989	650,650	60	10
	TOTAL	**3,978,989**	**650,650**	**60**	**10**
REMOVALS					
3. Transfer by consumption of harvested crops		1,263,171	208,718	19	3
18. Output by primary products		1,285,697	254,751	19	4
26. Transfer by plant production remaining on field		1,430,120	187,180	22	3
	TOTAL	**3,978,989**	**650,650**	**60**	**10**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		6,454,431	1,857,626	97	28
3. Transfer by consumption of harvested crops		1,263,171	208,718	19	3
	TOTAL	**7,717,602**	**2,066,344**	**116**	**31**
REMOVALS					
5. Output by animal products		1,955,615	422,365	29	6
6. Output by losses from manure to air before application		2,056,888		31	0
8. Transfer by application of manure and/or waste		3,705,098	1,643,979	56	25
	TOTAL	**7,717,602**	**2,066,344**	**116**	**31**
	SUPPLIES-REMOVALS	**0**	**0**	**0**	**0**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		3,705,098	1,643,979	56	25
10. Input by application of manure				0	0
11. Input by fertilizers		2,788,000	437,826	42	7
12. Input by N fixation		254,710		4	0
15. Input by dry and wet deposition		332,070	7,306	5	0
26. Transfer by plant products remaining on field		1,430,120	187,180	22	3
	TOTAL	**8,509,998**	**2,276,291**	**128**	**34**
REMOVALS					
19. Output by denitrification		1,423,377		21	
20. Output by volatilization of ammonia		468,519		7	
21. Output by leaching		552,418		8	
22. Output by run-off of available nutrients		69,637	28,709	1	0.4
28. Output by organic matter, removed by run-off		80,664	28,709	1	0.4
30. Transfer by net uptake from soil by plant		3,978,989	650,650	60	10
	TOTAL	**6,573,604**	**708,067**	**99**	**11**
	SUPPLIES-REMOVALS	**1,936,395**	**1,568,224**	**29**	**24**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		2,486,563	821,989	37	12
11. Input by fertilizers		2,788,000	437,826	42	7
12. Input by N-fixation		254,710		4	0
15. Input by dry and wet deposition		332,070	7,306	5	0
17. Transfer by mineralization of soil organic fraction		5,255,105	656,888	79	10
	TOTAL	**11,116,448**	**1,924,009**	**167**	**29**
REMOVALS					
19. Output by denitrification		1,423,377		21	
20. Output by volatilization of ammonia		468,519	-	7	
21. Output by leaching		552,418		8	
22. Output by run-off of available nutrients		69,637	28,709	1	0.4
24. Transfer by fixation in soil mineral fraction			657,592	0	10
25. Transfer by immobilization in soil organic fraction		2,624,560	328,070	40	5
30t. Transfer by net uptake by the plant		3,978,989	650,650	60	10
	TOTAL	**9,117,500**	**1,665,020**	**137**	**25**
	SUPPLIES-REMOVALS	**1,998,948**	**258,989**	**30**	**4**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		1,218,536	821,989	18	12
25. Transfer by immobilization in soil organic fraction		2,624,560	328,070	40	5
26b. Transfer by plant products remaining of field		1,430,120	187,180	22	3
	TOTAL	**5,273,216**	**1,337,240**	**79**	**20**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		5,255,105	656,888	79	10
28. Output by organic matter, removed by run-off		80,664	28,709	1	0
	TOTAL	**5,335,769**	**685,597**	**80**	**10**
SUPPLIES-REMOVALS		**(62,553)**	**651,643**	**-1**	**10**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	2,788,000	437,826	Crops	1,285,697	254,751
Feed	6,454,431	1,857,626	Animal & animal products	1,955,615	422,365
Fixation/Deposition	586,780	7,306		**3,241,313**	**677,116**
TOTAL	**9,829,211**	**2,302,758**		**49**	**10**
kg/ha	**148**	**35**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	6,587,899	1,625,641	99	24
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	4,651,503	57,417	70	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	1,936,395	1,568,224	29	24

RM of La Broquerie
Municipal Nutrient Balance

Cropland (excluding christmas trees)	12,217	hectares	
Summerfallow land	1,594	hectares	
Tame or Seeded pasture	2,775	hectares	
Natural land for pasture	8,276	hectares	
All other land (including Christmas trees)	5,485	hectares	
	24,862		**16,586**

Livestock (excludes other land)

Total cattle and calf inventory

	Number	fraction removed/year	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Bulls	152	0.3	46	900	0.027	0.0073	1,108	300
Dairy cow	1,865	0.3	560	600	0.027	0.0073	9,064	2,451
Beef cow	3,369	0.17	573	550	0.027	0.0073	8,505	2,300
Dairy heifer	967	0	0	385	0.024	0.0065	-	-
Beef heifer	641	0.8	513	360	0.024	0.0065	4,431	1,200
Slaughter heifer	210	1	210	410	0.024	0.0065	2,066	560
Steer	219	1	219	360	0.024	0.0065	1,892	512
Calves	3,940	0.6	2364	135	0.024	0.0065	7,659	2,074
	11,363						**34,726**	**9,396**

	Milk producing cows	litres Milk produced (rate 8160 litres/cow)	Density of milk 1031kg/1000L	Fraction N	Fraction P	kg N	kg P
Milk production	1,585	12,935,640	13,336,645	0.005	0.001	**66,683**	**13,337**

Total pig inventory

	Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Boars	***343***	0.55	189	160	0.023	0.0047	694	142
Sows	***31,461***							
Gestating sows	24,854	0.45	11,184	150	0.023	0.0047	38,586	7,885
Nursing sows	4,719	0.45	2,124	160	0.023	0.0047	7,814.9	1,597
Gilts	1,888			125	0.024	0.0047	-	-
Market hogs	***237,365***							
Weanling	79,122	2	158,243	14	0.025	0.0056	55,385	12,406
Grower	79,122	2	158,243	35	0.025	0.0056	138,463	31,016
Finisher	79,121	2	158,242	75	0.025	0.0056	296,704	66,462
	269,169						**537,647**	**119,507**

Total chicken and hens

	Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
All chickens	75,405	3	226,215	1.6	0.028	0.0058	10,134	2,099

Total turkeys

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
41	2	82	5.5	0.028	0.0058	13	3

Total kg N	Total kg P
649,203	**144,342**

Commercial Fertilizers

(from Stats Canada)

Total kg N	Total kg P2O5	Total kg P	Fertilized hectares
526,000	190,000	82,609	7,145

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
74	27	12

(from Crop Insurance)

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
70	31	13

Manure as Fertilizer

Manured Ha	Ha Applied with solid spreader	Applied with liquid spreader on surface
5,908	2,089	3174

Ha Applied using irrigation system	Applied with liquid spreader injected
-	645

Manure Production

Cattle	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P2O5/day/animal**	**Annual N production**	**Annual P2O!**
Bulls	152	900	0.306	0.188	16,977	
Dairy cow	1,865	600	0.270	0.128	183,796	
Beef cow	3,369	550	0.187	0.115	229,951	
Dairy heifer	967	385	0.173	0.082	61,061	
Beef heifer	641	360	0.122	0.075	28,544	
Slaughter heifer	210	410	0.137	0.085	10,501	
Steer	219	360	0.130	0.080	10,392	
Calves	3,940	135	0.046	0.028	66,153	
	11,363				**607,374**	

Assumption: Storage lossses are 40%	0.6	**N production - storage losses**	**364,424**	**Annual P**
Assumption: Application losses are 20%	0.8	***Volatilization losses (storage)***	242,950	
(manure applied with solid spreader)		**N production - application losses**	**291,539**	
		Volatilization losses (application)	72,885	

Assume total yearly production (kg) is	**83,201,900**	kg
based on 7.3 kg N/tonne manure (or 0.73%)	0.0073	
Assume 2.2 kg available N/tonne manure	**183,044**	kg
based on Alberta guidelines (0.22%)	0.0022	
Kg of N not available to crops in 1st year	**181,380**	kg
(kg N available from storage - kg available N)		

Hog	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P2O5/day/animal**	**Annual N production**	**Annual P2O5 production**
Boars	*343*	160	0.035	0.027	4,382	3,380
Sows	*31,461*					-
Gestating sows	24,854	150	0.033	0.026	299,369	235,866
Nursing sows	4,719	160	0.035	0.027	60,287	46,507
Gilts	1,888	125	0.028	0.021	6,607	14,469
Market hogs	*237,365*					-
Weanling	79,122	14	0.006	0.004	173,276	115,518
Grower	79,122	35	0.015	0.011	433,191	317,673
Finisher	79,121	75	0.033	0.023	953,012	664,221
					1,930,125	**1,397,635**

		N production - storage losses	**1,158,075**
Assumption: Storage losses are 40%	0.6	***Volatilization losses (storage)***	772,050
Assumption: Application losses are 10%	0.9	**N production - application losses**	**1,042,267**
		Volatilization losses (application)	115,807

Assume storage yearly production (litres) is	**386,024,903**	litres
based on 3.0 kg N/1000 litres manure (or 0.3%)	0.003	
Assume organic N content is	**347,422**	kg
based on 0.9 kg N/1000 litres (or 0.09%)	0.0009	
Assume inorganic N content is	**810,652**	kg
based on 2.1 kg N/1000 litres (0.21%)	0.0021	

Chickens	**Number**	**Average Weight (kg)**	**kg N/day/animal**	**kg P/day/animal**		**Annual N production**	**Annual P production**
All chickens	75,405	2.5	0.0015	0.00042		40,191	11,499
Assumption: Storage losses are 20%		0.8		**N production - storage losses**	**32,153**	**20,095**	(50% of total N)
Assumption: Application losses are 10%		0.9		***Volatilization losses (storage)***	8,038		
				N production - application losses	**28,937**		
				Volatilization losses (application)	3,215		

Assume: 50% of chickens are layers, se liquid N manure values		**50% or chickens are boiler, use solid manure N values**	
Assume storage yearly production (litres) is	**3,791,591**	**Assume storage yearly production (kg) is**	**1,182,084**
based on 5.3 kg N/1000 litres manure (or 0.53%)	0.0053	based on 17 kg N/tonne manure (or 1.7%)	0.017
Assume kg organic N content is	**1,896**	**Assume lbs organic N content is**	**18,913**
based on 0.5 lbs N/1000 litres manure (or 0.05%)	0.0005	based on 16 kg N/tonne manure (or 1.6%)	0.016
Assume kg inorganic N content is	**18,200**	**Assume lbs inorganic N content is**	**1,182**
based on 4.8 kg/1000 litres (0.48%)	0.0048	based on 1 kg N/tonne (0.1%)	0.001

Turkeys

Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
41	5.5	0.0021	0.00064	31	10

			N production - storage losses	**25**
Assumption: Storage losses are 20%	0.8		***Volatilization losses (storage)***	6
Assumption: Application losses are 10%	0.9		**N production - application losses**	**23**
Assumption: Use solid manure N values			***Volatilization losses (application)***	3
Assume storage yearly production (litres) is	**1,479**	litres		
based on 17 kg N/tonne manure (or 1.7%)	0.017			
Assume organic N content is	**24**	kg		
based on 16 kg N/tonne manure (or 1.6%)	0.016			
Assume inorganic N content is	**1**	kg		
based on 1 kg N/tonne (0.1%)	0.001			
Total Annual N production	**2,577,721**		**Total Annual P production**	**766,412**
Storage N volatilization losses	**1,023,044**			
Nitrogen available after losses	**1,554,677**			
Application N volatilization losses	**191,910**			
kg of inorganic N	**1,013,080**	**kg of available N**	**1,177,970**	***(inorganic-N+30% organic-N)***
kg of organic N	**549,635**	**kg of remaining N**	**384,745**	

Crops

Stats Canada

Type	hectares	tonnes	kg	yield kg/ha	acres	pounds	lbs/bu	bushels	yield bu/ac
durum wheat	-	-	-		-	-	60	-	
spring wheat	500	1,200	1,200,000	2400	1,250	2,640,000	60	44,000	35
winter wheat	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
oats	800	2,300	2,300,000	2875	2,000	5,060,000	32	158,125	79
barley	1,700	5,800	5,800,000	3412	4,250	12,760,000	48	265,833	63
mixed grain	200	600	600,000	3000	500	1,320,000	52	25,385	51
grain corn	200	1,200	1,200,000	6000	500	2,640,000	56	47,143	94
buckwheat	100	100	100,000	1000	250	220,000	48	4,583	18
rye	-	-	-		-	-	56	-	
alfalfa	1,720	5,920		3	4,300	13,024,000		6,512	2
grass pasture	6,880	23,680		3	17,200	52,096,000		26,048	2
canola	300	500	500,000	1667	750	1,100,000	50	22,000	29
flax	100	100	100,000	1000	250	220,000	56	3,929	16
sunflower	-	-	-	#DIV/0!	-	-	28	-	#DIV/0!
field peas	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
lentils	-	-	-		-	-	60	-	
coloured beans	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
white beans	-	-	-		-	-	60	-	
canary seed	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
	12,500				**31,250**				

Nutrient uptake

Stats Canada

Type	bushels or tons	lbs N/ha	lbs P2O5/ha	kg N	kg P2O5
durum wheat	-	2.13	0.80	-	-
spring wheat	44,000	2.13	0.80	93,720	35,200
winter wheat	-	1.36	0.62	-	-
oats	158,125	1.07	0.41	169,194	64,831
barley	265,833	1.39	0.56	369,508	148,867
mixed grain	25,385	1.53	0.59	38,838	14,977
grain corn	47,143	1.53	0.63	72,129	29,700
buckwheat	4,583	1.39	0.56	6,371	2,567
rye	-	1.67	0.84	-	-
alfalfa	6,512	105.00	21.00	683,760	136,752
grass pasture	26,048	60.00	17.00	1,562,880	442,816
canola	22,000	3.20	1.49	70,400	32,780
flax	3,929	2.88	0.83	11,314	3,261

sunflower	-	1.50	0.52		-	-				
field peas	-	3.06	0.84		-	-				
lentils	-	3.07	0.83		-	-				
coloured beans	-	5.72	0.98		-	-				
white beans	-	5.72	0.98		-	-				
canary seed	-				-	-	**lbs P**			
				Total	**3,078,114**	**911,750**	**396,413**			
Nutrient Removal				**Total Kg**	***1,399,143***	***414,432***	***180,188***			
Stats Canada										
Type	**bushels or tons**	**lbs N/bushels**	**lbs PO5/bu**		**lbs N**	**lbs P2O5**				
durum wheat	-	1.5	0.6		-	-				
spring wheat	44,000	1.5	0.6		66,000	26,400				
winter wheat	-	1.04	0.52		-	-				
oats	158,125	0.62	0.26		98,038	41,113				
barley	265,833	0.98	0.43		260,517	114,308				
mixed grain	25,385	1.03	0.43		26,146	10,915				
grain corn	47,143	0.94	0.44		44,314	20,743				
buckwheat	4,583	0.98	0.43		4,492	1,971				
rye	-	1.07	0.45		-	-				
alfalfa	6,512	58	14		377,696	91,168				
grass pasture	26,048	34	10		885,632	260,480				
canola	22,000	1.94	1.06		42,680	23,320				
flax	3,929	2.13	0.67		8,368	2,632				
sunflower	-	1.08	0.32		-	-				
field peas	-	2.34	0.7		-	-				
lentils	-	2.03	0.63		-	-				
coloured beans	-	3.42	1.22		-	-				
white beans	-	3.42	1.22		-	-				
canary seed	-				-	-	**lbs P**			
				Total	**1,813,882**	**593,050**	**257,848**			
				Total Kg	***824,492***	***269,568***	***117,204***			
			Nutrient remaining in soil (lbs)		**1,264,232**		**138,565**			
			Nutrient remaining in soil (kg)		***574,651***		***62,984***			
Feed										
Type	**tonnes**	**lbs**	**lbs/bu**		**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	23,600	51,920,000	60		865,333	1.5	0.6	1,298,000	519,200	225,739
barley	25,900	56,980,000	48		1,187,083	0.98	0.43	1,163,342	510,446	221,933
oats	-	-	32		-	0.62	0.26	-	-	-
corn	9,900	21,780,000	56		388,929	0.94	0.44	365,593	171,129	74,404
mixed grain	-	-	52		-			-		
						Fraction N	**Fraction P**			
protein meal	14,200	31,240,000				0.04	0.01	1,249,600	312,400	
							Total	**4,076,535**	**1,513,174**	**657,902**
Transfer Feed							***Total kg***	***1,852,970***	***687,807***	***299,046***
Type	**tonnes**	**lbs**	**lbs/bu**		**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
barley	5,800	12,760,000	48		265,833	0.98	0.43	260,517	114,308	49,699
corn	1,200	2,640,000	56		47,143	0.94	0.44	44,314	20,743	9,019
alfalfa hay	5,920	13,024,000		6,512 tons		58	14	377,696	91,168	39,638
grass hay	23,680	52,096,000		26,048 tons		34	10	885,632	260,480	113,252
mixed grain	600	1,320,000	52		25,385	1.03	0.43	26,146	10,915	4,746
oats	1,200	2,640,000	32		82,500	0.62	0.26	51,150	21,450	9,326
wheat	1,200	2,640,000	60		44,000	1.5	0.6	66,000	26,400	11,478
							Total	**1,711,455**	**545,465**	**237,159**
Crop Output							***Total kg***	***777,934***	***247,938***	***107,799***
Crop	**tonnes**	**lbs**	**lbs/bu**		**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	-	-	60		-	1.5	0.6	-	-	-
winter wheat	-	-	60		-	1.04	0.52	-	-	-
barley	-	-	48		-	0.98	0.43	-	-	-

buckwheat	100	220,000	48	4,583	0.98	0.43	4,492	1,971	
oats	1,100	2,420,000	32	75,625	0.62	0.26	46,888	19,663	8,549
rye	-	-	56	-	1.07	0.45	-	-	-
canola	500	1,100,000	50	22,000	1.94	1.06	42,680	23,320	10,139
flax	100	220,000	56	3,929	2.13	0.67	8,368	2,632	1,144
sunflower	-			-	1.08	0.32	-	-	-
field peas	-			-	2.34	0.7	-	-	-
lentils				-	2.03	0.63	-	-	-
coloured beans				-	3.42	1.22	-	-	-
white beans				-	3.42	1.22	-	-	-
						Total	**102,427**	**47,585**	**20,689**
						Total kg	***46,558***	***21,630***	***9,404***

<u>Input by seeds</u>

Crop	**tonnes**	**pounds**	**lbs/bu**	**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat (-durum)	900	1,980,000	60	33,000	1.5	0.6	49,500	19,800	8,609
durum	0	-	60	-	1.5	0.6	-	-	-
barley	900	1,980,000	48	41,250	0.98	0.43	40,425	17,738	7,712
oats	400	880,000	32	27,500	0.62	0.26	17,050	7,150	3,109
corn	0	-	56	-	0.94	0.44	-	-	-
rye	0	-	56	-	1.07	0.45	-	-	-
flaxseed	0	-	56	-	2.13	0.67	-	-	-
canola	100	220,000	50	4,400	1.94	1.06	8,536	4,664	2,028
							115,511		**21,457**
						Total kg	***52,505***		***9,753***

N fixation	**kg/ha**		**ha**	**kg N fixed**
non-symbiotic (cropland)	1		12,217	12,217
summerfallow	1		1,594	1,594
symbiotic alfalfa	220		555	122,100
grass seeded	1		2,220	2,220
(pasture)	1		8,276	8,276
		TOTAL	24,862	**146,407**

Denitrification

	kg/ha		**ha**	**kg N denitrified**
manure	40		5,908	236,320
cropland	20		5,199	103,980
alfalfa	5		555	2,775
1 year after alfalfa	30		555	16,650
4 years after alfalfa	25		555	13,875
seeded pasture	5		2,220	11,100
natural pasture	5		8,276	41,380
summerfallow	25		1,594	39,850
		TOTAL	24,862	**465,930**

Fertilizer N	74	15% available N denitrified
Manure N	199	

Ammonia volatilization

Output by leaching

	kg/ha	**ha**	**Total**
cropland	15	12,217	183,255
summerfallow	25	1,594	39,850
seeded pasture	5	2,775	13,875
natural pasture	5	8,276	41,380
		TOTAL	**278,360**

Output by run-off of available nutrient

	N			**P**	
	kg/ha	**ha**	**Total**	**kg/ha**	
cropland	1	12,217	12,217	0.5	6,109
summerfallow	2	1,594	3,188	0.5	797
seeded pasture	1	2,775	2,775	0.3	694
natural pasture	1	8,276	8,276	0.3	2,069
		TOTAL	**26,456**	**TOTAL**	**9,668**

Output by organic matter, removed by run-off

	N kg/ha	ha	Total	P kg/ha	
cropland	1.2	12,217	14,660	0.5	6,109
summerfallow	1.5	1,594	2,391	0.5	797
seeded pasture	1.2	2,775	3,330	0.3	694
natural pasture	1.2	8,276	9,931	0.3	2,069
		TOTAL	**30,313**	**TOTAL**	**9,668**

Transfer by mineralization in soil organic fraction

	N kg/ha	ha	kg N	P kg/ha	ha	kg P
cropland	75	6,667	500,025	9	6,667	62,503
summerfallow	80	1,594	127,520	10	1,594	15,940
alfalfa-current	120	555	66,600	15	555	8,325
1 year after alfalfa	165	555	91,575	21	555	11,447
4 years after alfalfa	100	555	55,500	13	555	6,938
seeded pasture	75	2,220	166,500	9	2,220	20,813
1 year after pasture	100	2,220	222,000	13	2,220	27,750
4 years after pasture	85	2,220	188,700	11	2,220	23,588
natural pasture	75	8,276	620,700	9	8,276	77,588
		Total	**2,039,120**			**254,890**

Transfer by immobilization in soil organic fraction

N	kg/ha	ha	Total	P kg/ha	ha	kg P
cropland	25	12,217	305,425	3	12,217	38,178
summerfallow	5	1,594	7,970	1	1,594	996
alfalfa	165	555	91,575	21	555	11,447
seeded pasture	90	2,220	199,800	11	2,220	24,975
natural pasture	75	8,276	620,700	9	8,276	77,588
		TOTAL	**1,225,470**			**153,184**

Wet and Dry Deposition

N kg/ha	(excludes other land) ha		Total	P kg/ha	ha		Total
5		24,307	**121,535**	0.11		24,307	**2,674**

RM of La Broquerie

Nutrient		kg/year N	kg/year P	kg/ha	kg/ha
				Includes Natural pasture	
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		1,399,143	180,188	56	7
	TOTAL	**1,399,143**	**180,188**	**56**	**7**
REMOVALS					
3. Transfer by consumption of harvested crops		777,934	107,799	31	4
18. Output by primary products		46,558	9,404	2	0.4
26. Transfer by plant production remaining on field		574,651	62,984	23	3
	TOTAL	**1,399,143**	**180,188**	**56**	**7**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		1,852,970	299,046	75	12
3. Transfer by consumption of harvested crops		777,934	107,799	31	4
	TOTAL	**2,630,904**	**406,846**	**106**	**16**
REMOVALS					
5. Output by animal products		649,203	144,342	26	6
6. Output by losses from manure to air before application		1,023,044		41	
7. Output by manure					
8. Transfer by application of manure and/or waste		1,554,677	766,412	63	31
	TOTAL	**3,226,924**	**910,754**	**130**	**37**
	SUPPLIES-REMOVALS	**(596,019)**	**(503,909)**	**-24**	**-20**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		1,554,677	766,412	63	31
11. Input by fertilizers		526,000	82,609	21	3
12. Input by N fixation		146,407		6	
13. Input by application of litter, sludge, and waste					
15. Input by dry and wet deposition		121,535	2,674	5	0.1
26. Transfer by plant products remaining on field		574,651	62,984	23	3
	TOTAL	**2,923,270**	**914,679**	**118**	**37**
REMOVALS					
19. Output by denitrification		465,930		19	
20. Output by volatilization of ammonia		191,910		8	
21. Output by leaching		278,360		11	
22. Output by run-off of available nutrients		26,456	9,668	1	0.4
28. Output by organic matter, removed by run-off		30,313	9,668	1	0.4
30. Transfer by net uptake from soil by plant		1,399,143	180,188	56	7
	TOTAL	**2,392,112**	**199,524**	**96**	**8**
	SUPPLIES-REMOVALS	**531,158**	**715,155**	**21**	**29**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		1,177,970	383,206	47	15
11. Input by fertilizers		526,000	82,609	21	3
12. Input by N-fixation		146,407		6	
13a. Input by application of litter, sludge and waste					
15. Input by dry and wet deposition		121,535	2,674	5	0.1
17. Transfer by mineralization of soil organic fraction		2,039,120	254,890	82	10
	TOTAL	**4,011,032**	**723,379**	**161**	**29**
REMOVALS					
19. Output by denitrification		465,930		19	
20. Output by volatilization of ammonia		191,910	-	8	
21. Output by leaching		278,360		11	
22. Output by run-off of available nutrients		26,456	9,668	1	0.4
24. Transfer by fixation in soil mineral fraction			229,924		9
25. Transfer by immobilization in soil organic fraction		1,225,470	153,184	49	6
30t. Transfer by net uptake by the plant		1,399,143	180,188	56	7
	TOTAL	**3,587,269**	**572,963**	**144**	**23**
SUPPLIES-REMOVALS		**423,763**	**150,415**	**17**	**6**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		384,745	383,206	15	15
25. Transfer by immobilization in soil organic fraction		1,225,470	153,184	49	6
26b. Transfer by plant products remaining of field		574,651	62,984	23	3
	TOTAL	**2,184,866**	**599,374**	**88**	**24**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		2,039,120	254,890	82	10
28. Output by organic matter, removed by run-off		30,313	9,668	1	0.4
	TOTAL	**2,069,433**	**264,558**	**83**	**11**
SUPPLIES-REMOVALS		**115,433**	**334,816**	**5**	**13**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	526,000	82,609	Crops	46,558	9,404
Feed	1,852,970	299,046	Animal & animal products	649,203	144,342
Fixation/Deposition	267,942	2,674		**695,761**	**153,746**
TOTAL	**2,646,912**	**384,329**		**28**	**6**
kg/ha	**106**	**15**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	1,951,152	230,582	78	9
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	2,016,013	19,337	81	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	(64,861)	211,246	-3	8

RM of La Broquerie

Nutrient		kg/year N	kg/year P	Modified feed input kg/year N	Modified feed input kg/year P
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		1,399,143	180,188	56	7
	TOTAL	**1,399,143**	**180,188**	**56**	**7**
REMOVALS					
3. Transfer by consumption of harvested crops		777,934	107,799	31	4
18. Output by primary products		46,558	9,404	2	0.4
26. Transfer by plant production remaining on field		574,651	62,984	23	3
	TOTAL	**1,399,143**	**180,188**	**56**	**7**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		2,448,989	802,955	99	32
3. Transfer by consumption of harvested crops		777,934	107,799	31	4
	TOTAL	**3,226,923**	**910,754**	**130**	**37**
REMOVALS					
5. Output by animal products		649,203	144,342	26	6
6. Output by losses from manure to air before application		1,023,044		41	
7. Output by manure					
8. Transfer by application of manure and/or waste		1,554,677	766,412	63	31
	TOTAL	**3,226,924**	**910,754**	**130**	**37**
	SUPPLIES-REMOVALS	**(0)**	**(0)**	**0**	**0**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		1,554,677	766,412	63	31
11. Input by fertilizers		526,000	82,609	21	3
12. Input by N fixation		146,407		6	
13. Input by application of litter, sludge, and waste					
15. Input by dry and wet deposition		121,535	2,674	5	0.1
26. Transfer by plant products remaining on field		574,651	62,984	23	3
	TOTAL	**2,923,270**	**914,679**	**118**	**37**
REMOVALS					
19. Output by denitrification		465,930		19	
20. Output by volatilization of ammonia		191,910		8	
21. Output by leaching		278,360		11	
22. Output by run-off of available nutrients		26,456	9,668	1	0.4
28. Output by organic matter, removed by run-off		30,313	9,668	1	0.4
30. Transfer by net uptake from soil by plant		1,399,143	180,188	56	7
	TOTAL	**2,392,112**	**199,524**	**96**	**8**
	SUPPLIES-REMOVALS	**531,158**	**715,155**	**21**	**29**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		1,177,970	383,206	47	15
11. Input by fertilizers		526,000	82,609	21	3
12. Input by N-fixation		146,407		6	
13a. Input by application of litter, sludge and waste					
15. Input by dry and wet deposition		121,535	2,674	5	0.1
17. Transfer by mineralization of soil organic fraction		2,039,120	254,890	82	10
	TOTAL	**4,011,032**	**723,379**	161	29
REMOVALS					
19. Output by denitrification		465,930		19	
20. Output by volatilization of ammonia		191,910	-	8	
21. Output by leaching		278,360		11	
22. Output by run-off of available nutrients		26,456	9,668	1	0.4
24. Transfer by fixation in soil mineral fraction			229,924		9
25. Transfer by immobilization in soil organic fraction		1,225,470	153,184	49	6
30t. Transfer by net uptake by the plant		1,399,143	180,188	56	7
	TOTAL	**3,587,269**	**572,963**	**144**	**23**
SUPPLIES-REMOVALS		**423,763**	**150,415**	**17**	**6**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		384,745	383,206	15	15
25. Transfer by immobilization in soil organic fraction		1,225,470	153,184	49	6
26b. Transfer by plant products remaining of field		574,651	62,984	23	3
	TOTAL	**2,184,866**	**599,374**	**88**	**24**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		2,039,120	254,890	82	10
28. Output by organic matter, removed by run-off		30,313	9,668	1	0.4
	TOTAL	**2,069,433**	**264,558**	**83**	**11**
SUPPLIES-REMOVALS		**115,433**	**334,816**	**5**	**13**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	526,000	82,609	Crops	46,558	9,404
Feed	2,448,989	802,955	Animal & animal products	649,203	144,342
Fixation/Deposition	267,942	2,674		**695,761**	**153,746**
TOTAL	**3,242,931**	**888,237**		**28**	**6**
kg/ha	**130**	**36**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	2,547,170	734,491	102	30
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	2,016,013	19,337	81	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	531,158	715,155	21	29

RM of Roland
Municipal Nutrient Balance

Cropland (excluding christmas trees)	42,036	hectares	
Summerfallow land	926	hectares	
Tame or Seeded pasture	297	hectares	
Natural land for pasture	62	hectares	
All other land (including Christmas trees)	906	hectares	
	43,321		**43,259**
Livestock	(excludes other land)		

Total cattle and calf inventory

	Number	fraction removed/year	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Bulls	38	0.3	11	900	0.027	0.0073	277	75
Dairy cow	-	0.3	0	600	0.027	0.0073	-	-
Beef cow	659	0.17	112	550	0.027	0.0073	1,664	450
Dairy heifer	-	0	0	385	0.024	0.0065	-	-
Beef heifer	-	0.8	0	360	0.024	0.0065	-	-
Slaughter heifer	62	1	62	410	0.024	0.0065	610	165
Steer	-	1	0	360	0.024	0.0065	-	-
Calves	561	0.6	337	135	0.024	0.0065	1,091	295
	1,320						**3,641**	**985**

	Milk producing cows	litres Milk produced (rate 8160 litres/cow)	Density of milk 1031kg/1000L	Fraction N	Fraction P	kg N	kg P
Milk production	-	-	-	0.005	0.001	-	-

Total pig inventory

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
5,895	2	11,790	45	0.023	0.0047	12,203	2,494

Total chicken and hens

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
7,342	3.5	25,697	1.6	0.028	0.0058	1,151	238

Total turkeys

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
-	2	-	5.5	0.028	0.0058	-	-

Total kg N	Total kg P
16,995	**3,717**

Commercial Fertilizers
(from Stats Canada)

Total kg N	Total kg P2O5	Total kg P	Fertilized hectares
3,582,000	1,294,000	562,609	37,498
Average kg N/ha	**Average kg P2O5/ha**	**Average kg P/ha**	
96	35	15	

(from Crop Insurance)

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
89	35	15

Manure as Fertilizer

Manured Ha	Ha Applied with solid spreader	Applied with liquid spreader on surface
1,286	293	348

Ha Applied using irrigation system	Applied with liquid spreader injected
-	645

Manure Production

Cattle	Number	Average Weight (kg)	kg N/day/animal	kg P2O5/day/animal	Annual N production	Annual P2O
Bulls	38	900	0.306	0.188	4,244	
Dairy cow	-	600	0.270	0.128	-	
Beef cow	659	550	0.187	0.115	44,980	
Dairy heifer	-	385	0.173	0.082	-	
Beef heifer	-	360	0.122	0.075	-	
Slaughter heifer	62	410	0.137	0.085	3,100	
Steer	-	360	0.130	0.080	-	
Calves	561	135	0.046	0.028	9,419	
	1,320				**61,744**	

Assumption: Storage lossses are 40%	0.6	**N production - storage losses**	**37,046**	**Annual P p**
Assumption: Application losses are 20%	0.8	***Volatilization losses (storage)***	24,698	
(manure applied with solid spreader)		**N production - application losses**	**29,637**	
		Volatilization losses (application)	7,409	

Assume total yearly production (kg) is	**8,458,050**	kg
based on 7.3 kg N/tonne manure (or 0.73%)	0.0073	
Assume 2.2 kg available N/tonne manure	**18,608**	kg
based on Alberta guidelines (0.22%)	0.0022	
Kg of N not available to crops in 1st year	**18,439**	kg
(kg N available from storage - kg available N)		

Hog

Number	Average Weight (kg)	kg N/day/animal	kg P2O5/day/animal	Annual N production	Annual P2O5 production	Annual P
5,895	45	0.035	0.027	75,309	58,095	25,259

		N production - storage losses	**45,185**
Assumption: Storage losses are 40%	0.6	***Volatilization losses (storage)***	30,123
Assumption: Application losses are 10%	0.9	**N production - application losses**	**40,667**
		Volatilization losses (application)	4,519

Assume storage yearly production (litres) is	**15,061,725**	litres
based on 3.0 kg N/1000 litres manure (or 0.3%)	0.003	
Assume organic N content is	**13,556**	kg
based on 0.9 kg N/1000 litres (or 0.09%)	0.0009	
Assume inorganic N content is	**31,630**	kg
based on 2.1 kg N/1000 litres (0.21%)	0.0021	

Chickens

Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
7,342	2.5	0.0015	0.00042	3,913	1,120

Assumption: Storage losses are 20%	0.8	**N production - storage losses**	**3,131**	**1,957**	(50% of total N)
Assumption: Application losses are 10%	0.9	***Volatilization losses (storage)***	783		
		N production - application losses	**2,818**		
		Volatilization losses (application)	313		

Assume: 50% of chickens are layers, se liquid N manure values		**50% or chickens are boiler, use solid manure N values**	
Assume storage yearly production (litres) is	**369,178**	**Assume storage yearly production (kg) is**	**115,097**
based on 5.3 kg N/1000 litres manure (or 0.53%)	0.0053	based on 17 kg N/tonne manure (or 1.7%)	0.017
Assume kg organic N content is	**185**	**Assume lbs organic N content is**	**1,842**
based on 0.5 lbs N/1000 litres manure (or 0.05%)	0.0005	based on 16 kg N/tonne manure (or 1.6%)	0.016
Assume kg inorganic N content is	**1,772**	**Assume lbs inorganic N content is**	**115**
based on 4.8 kg/1000 litres (0.48%)	0.0048	based on 1 kg N/tonne (0.1%)	0.001

Turkeys

Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
-	5.5	0.0021	0.00064	-	-

		N production - storage losses	**-**
Assumption: Storage losses are 20%	0.8	***Volatilization losses (storage)***	-
Assumption: Application losses are 10%	0.9	**N production - application losses**	**-**
Assumption: Use solid manure N values		***Volatilization losses (application)***	-

Assume storage yearly production (litres) is	**-**	litres
based on 17 kg N/tonne manure (or 1.7%)	0.017	
Assume organic N content is	**-**	kg
based on 16 kg N/tonne manure (or 1.6%)	0.016	
Assume inorganic N content is	**-**	kg
based on 1 kg N/tonne (0.1%)	0.001	

Total Annual N production	**140,966**	**Total Annual P production**	**42,868**	
Storage N volatilization losses	**55,604**			
Nitrogen available after losses	**85,362**			
Application N volatilization losses	**12,241**			
kg of inorganic N	**52,124**	**kg of available N**	**62,331**	***(inorganic-N+30% organic-N)***
kg of organic N	**34,020**	**kg of remaining N**	**23,814**	

Crops

Stats Canada

Type	hectares	tonnes	kg	yield kg/ha	acres	pounds	lbs/bu	bushels	yield bu/ac
durum wheat	200	500	1,100,000		500	1,100,000	60	18,333	
spring wheat	13,900	35,600	35,600,000	2561	34,750	78,320,000	60	1,305,333	38
winter wheat	200	900	900,000	4500	500	1,980,000	60	33,000	66
oats	2,000	6,300	6,300,000	3150	5,000	13,860,000	32	433,125	87
barley	3,300	11,400	11,400,000	3455	8,250	25,080,000	48	522,500	63
mixed grain	-	-	-	#DIV/0!	-	-	52	-	#DIV/0!
grain corn	2,800	15,200	15,200,000	5429	7,000	33,440,000	56	597,143	85
buckwheat	200	200	200,000	1000	500	440,000	48	9,167	18
rye	-	-	-		-	-	56	-	

alfalfa	100	400		4	250	880,000		440	2
grass pasture	100	400		4	250	880,000		440	2
canola	9,800	17,800	17,800,000	1816	24,500	39,160,000	50	783,200	32
flax	5,300	7,400	7,400,000	1396	13,250	16,280,000	56	290,714	22
sunflower	900	1,400	1,400,000	1556	2,250	3,080,000	28	110,000	49
field peas	500	900	900,000	1800	1,250	1,980,000	60	33,000	26
lentils	-	-	-		-	-	60	-	
coloured beans	1,700	2,800	2,800,000	1647	4,250	6,160,000	60	102,667	24
white beans	2,100	3,600	3,600,000		5,250	7,920,000	60	132,000	
canary seed	100	100	100,000	1000	250	220,000	60	3,667	15
	43,200				**108,000**				

Nutrient uptake

Stats Canada

Type	**bushels or tons**	**lbs N/ha**	**lbs P2O5/ha**	**kg N**	**kg P2O5**	
durum wheat	18,333	2.13	0.80	39,050	14,667	
spring wheat	1,305,333	2.13	0.80	2,780,360	1,044,267	
winter wheat	33,000	1.36	0.62	44,880	20,460	
oats	433,125	1.07	0.41	463,444	177,581	
barley	522,500	1.39	0.56	726,275	292,600	
mixed grain	-	1.53	0.59	-	-	
grain corn	597,143	1.53	0.63	913,629	376,200	
buckwheat	9,167	1.39	0.56	12,742	5,133	
rye	-	1.67	0.84	-	-	
alfalfa	440	105	21	46,200	9,240	
grass pasture	440	60	17	26,400	7,480	
canola	783,200	3.20	1.49	2,506,240	1,166,968	
flax	290,714	2.88	0.83	837,257	241,293	
sunflower	110,000	1.50	0.52	165,000	57,200	
field peas	33,000	3.06	0.84	100,980	27,720	
lentils	-	3.07	0.83	-	-	
coloured beans	102,667	5.72	0.98	587,253	100,613	
white beans	132,000	5.72	0.98	755,040	129,360	
canary seed	3,667			-	-	**lbs P**
			Total	**10,004,749**	**3,670,782**	**1,595,992**
			Total Kg	***4,547,613***	***1,668,537***	***725,451***

Nutrient Removal

Stats Canada

Type	**bushels or tons**	**lbs N/bushels**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	
durum wheat	18,333	1.5	0.6	27,500	11,000	
spring wheat	1,305,333	1.5	0.6	1,958,000	783,200	
winter wheat	33,000	1.04	0.52	34,320	17,160	
oats	433,125	0.62	0.26	268,538	112,613	
barley	522,500	0.98	0.43	512,050	224,675	
mixed grain	-	1.03	0.43	-	-	
grain corn	597,143	0.94	0.44	561,314	262,743	
buckwheat	9,167	0.98	0.43	8,983	3,942	
rye	-	1.07	0.45	-	-	
alfalfa	440	58	14	25,520	6,160	
grass pasture	440	34	10	14,960	4,400	
canola	783,200	1.94	1.06	1,519,408	830,192	
flax	290,714	2.13	0.67	619,221	194,779	
sunflower	110,000	1.08	0.32	118,800	35,200	
field peas	33,000	2.34	0.7	77,220	23,100	
lentils	-	2.03	0.63	-	-	
coloured beans	102,667	3.42	1.22	351,120	125,253	
white beans	132,000	3.42	1.22	451,440	161,040	
canary seed	3,667			-	-	**lbs P**
			Total	**6,548,395**	**2,795,456**	**1,215,416**
			Total Kg	***2,976,543***	***1,270,662***	***552,462***
			Nutrient remaining in soil (lbs)	**3,456,355**		**380,577**
			Nutrient remaining in soil (kg)	***1,571,070***		***172,989***

Feed

Type	**tonnes**	**lbs**	**lbs/bu**	**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	5,900	12,980,000	60	216,333	1.5	0.6	324,500	129,800	56,435
barley	7,100	15,620,000	48	325,417	0.98	0.43	318,908	139,929	60,839
oats	200	440,000	32	13,750	0.62	0.26	8,525	3,575	1,554

durum wheat	100	220,000	60			3,667	1.5	0.6	5,500	2,200	957
mixed grain	-	-	52			-			-		
							Fraction N	Fraction P			
protein meal	3,400	7,480,000					0.04	0.01	299,200	74,800	
								Total	**956,633**	**350,304**	**152,306**
Transfer Feed								***Total kg***	***434,833***	***159,229***	***69,230***
Type	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
barley	-	-	48			-	0.98	0.43	-	-	-
corn	2,600	5,720,000	56			102,143	0.94	0.44	96,014	44,943	19,540
alfalfa hay	400	880,000		440	tons		58	14	25,520	6,160	2,678
grass hay	400	880,000		440	tons		34	10	14,960	4,400	1,913
mixed grain	-	-	52			-	1.03	0.43	-	-	-
oats	-	-	32			-	0.62	0.26	-	-	-
durum wheat	100	220,000	60			3,667	1.5	0.6	5,500	2,200	957
								Total	**141,994**	**57,703**	**25,088**
Crop Output								***Total kg***	***64,543***	***26,229***	***11,404***
Crop	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	35,600	78,320,000	60			1,305,333	1.5	0.6	1,958,000	783,200	340,522
winter wheat	900	1,980,000	60			33,000	1.04	0.52	34,320	17,160	7,461
durum wheat	400	880,000	60			14,667	1.5	0.6	22,000	8,800	3,826
barley	11,400	25,080,000	48			522,500	0.98	0.43	512,050	224,675	97,685
buckwheat	200	440,000	48			9,167	0.98	0.43	8,983	3,942	
oats	6,300	13,860,000	32			433,125	0.62	0.26	268,538	112,613	48,962
rye	-	-	56			-	1.07	0.45	-	-	-
canola	17,800	39,160,000	50			783,200	1.94	1.06	1,519,408	830,192	360,953
corn	12,600	27,720,000	56			495,000	0.94	0.44	465,300	217,800	94,696
flax	7,400	16,280,000	56			290,714	2.13	0.67	619,221	194,779	84,686
sunflower	-					110,000	1.08	0.32	118,800	35,200	15,304
field peas	-					33,000	2.34	0.7	77,220	23,100	10,043
lentils						-	2.03	0.63	-	-	-
coloured beans						102,667	3.42	1.22	351,120	125,253	54,458
white beans						132,000	3.42	1.22	451,440	161,040	70,017
								Total	**6,406,400**	**2,737,753**	**1,190,327**
Input by seeds								***Total kg***	***2,912,000***	***1,244,433***	***541,058***
Crop	**tonnes**	**pounds**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat (-durum)	1600	3,520,000	60			58,667	1.5	0.6	88,000	35,200	15,304
durum	0	-	60			-	1.5	0.6	-	-	-
barley	300	660,000	48			13,750	0.98	0.43	13,475	5,913	2,571
oats	200	440,000	32			13,750	0.62	0.26	8,525	3,575	1,554
corn	0	-	56			-	0.94	0.44	-	-	-
rye	0	-	56			-	1.07	0.45	-	-	-
flaxseed	200	440,000	56			7,857	2.13	0.67	16,736	5,264	2,289
canola	100	220,000	50			4,400	1.94	1.06	8,536	4,664	2,028
									135,272		**23,746**
								Total kg	***61,487***		***10,794***
N fixation	**kg/ha**	**ha**	**kg N fixed**								
non-symbiotic (cropland)	1	37,736		37,736							
summerfallow	1	926		926							
symbiotic alfalfa	220	149		32,780							
grass seeded	1	148		148							
(pasture)	1	62		62							
pulse crops	125	4,300		537,500							
	TOTAL	43,321		**609,152**							
Denitrification											
	kg/ha	**ha**	**kg N denitrified**								
manure	40	1,286		51,440			Fertilizer N	96	15% available N denitrified		
cropland	30	36,152		1,084,560			Manure N	48			
alfalfa	5	149		745							
1 year after alfalfa	35	149		5,215							
4 years after alfalfa	40	149		5,960							
seeded pasture	5	148		740							
natural pasture	5	62		310							
summerfallow	25	926		23,150							
	TOTAL	**39,021**		**1,172,120**							

Ammonia volatilization

Output by leaching

	kg/ha		ha	Total
cropland	5		42,036	210,180
summerfallow	10		926	9,260
seeded pasture	2		297	594
natural pasture	2		62	124
		TOTAL	**43,321**	**220,158**

Output by run-off of available nutrient

	N kg/ha		ha	Total	P kg/ha	
cropland	1		42,036	42,036	0.5	21,018
summerfallow	2		926	1,852	0.5	463
seeded pasture	1		297	297	0.3	74
natural pasture	1		62	62	0.3	16
		TOTAL	**43,321**	**44,247**	**TOTAL**	**21,571**

Output by organic matter, removed by run-off

	N kg/ha		ha	Total	P kg/ha	
cropland	1		42,036	42,036	0.5	21,018
summerfallow	1.5		926	1,389	0.5	463
seeded pasture	1		297	297	0.3	74
natural pasture	1		62	62	0.3	16
			TOTAL	**43,784**	**TOTAL**	**21,571**

Transfer by mineralization in soil organic fraction

	N kg/ha		ha	kg N	P kg/ha	ha	kg P
cropland	75		41,442	3,108,150	9	41,442	388,519
summerfallow	80		926	74,080	10	926	9,260
alfalfa-current	120		149	17,880	15	149	2,235
1 year after alfalfa	165		149	24,585	21	149	3,073
4 years after alfalfa	100		149	14,900	13	149	1,863
seeded pasture	75		148	11,100	9	148	1,388
1 year after pasture	100		148	14,800	13	148	1,850
4 years after pasture	85		148	12,580	11	148	1,573
natural pasture	75		62	4,650	9	62	581
		Total	**43,321**	**3,282,725**			**410,341**

Transfer by immobilization in soil organic fraction

N	kg/ha		ha	Total	P kg/ha	ha	kg P
cropland	25		42,036	1,050,900	3	42,036	131,363
summerfallow	5		926	4,630	1	926	579
alfalfa	165		149	24,585	21	149	3,073
seeded pasture	90		148	13,320	11	148	1,665
natural pasture	75		62	4,650	9	62	581
		TOTAL	**43,321**	**1,098,085**			**137,261**

Wet and Dry Deposition

N kg/ha	(excludes other land) ha		Total		P kg/ha	ha	Total
5		39,021		**195,105**	0.11	39,021	**4,292**

RM of Roland

Nutrient		kg/year N	kg/year P	Including native pasture kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
30t. Transfer by net uptake from soils		4,547,613	725,451	105	17
	TOTAL	**4,547,613**	**725,451**	**105**	**17**
REMOVALS					
3. Transfer by consumption of harvested crops		64,543	11,404	1	0.3
18. Output by primary products		2,912,000	541,058	67	12
26. Transfer by plant production remaining on field		1,571,070	172,989	36	4
	TOTAL	**4,547,613**	**725,451**	105	17
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		434,833	69,230	10	2
3. Transfer by consumption of harvested crops		64,543	11,404	1	0.3
	TOTAL	**499,376**	**80,634**	**12**	**2**
REMOVALS					
5. Output by animal products		16,995	3,717	0.4	0.1
6. Output by losses from manure to air before application		55,604		1	
8. Transfer by application of manure and/or waste		85,362	42,868	2	1
	TOTAL	**157,961**	**46,585**	**4**	**1**
	SUPPLIES-REMOVALS	**341,415**	**34,048**	**8**	**1**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		85,362	42,868	2	1
11. Input by fertilizers		3,582,000	562,609	83	13
12. Input by N fixation		609,152		14	
15. Input by dry and wet deposition		195,105	4,292	5	0.1
26. Transfer by plant products remaining on field		1,571,070	172,989	36	4
	TOTAL	**6,042,689**	**782,758**	**139**	**18**
REMOVALS					
19. Output by denitrification		1,172,120		27	
20. Output by volatilization of ammonia		12,241		0.3	
21. Output by leaching		220,158		5	
22. Output by run-off of available nutrients		44,247	21,571	1	0.5
28. Output by organic matter, removed by run-off		43,784	21,571	1	0.5
30. Transfer by net uptake from soil by plant		4,547,613	725,451	105	17
	TOTAL	**6,040,163**	**768,593**	**139**	**18**
	SUPPLIES-REMOVALS	**2,526**	**14,166**	**0**	**0**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		62,331	21,434	1	0.5
11. Input by fertilizers		3,582,000	562,609	83	13
12. Input by N-fixation		609,152		14	
15. Input by dry and wet deposition		195,105	4,292	5	0.1
17. Transfer by mineralization of soil organic fraction		3,282,725	410,341	76	9
	TOTAL	**7,731,313**	**998,676**	**178**	**23**
REMOVALS					
19. Output by denitrification		1,172,120		27	
20. Output by volatilization of ammonia		12,241	-	0.3	
21. Output by leaching		220,158		5	
22. Output by run-off of available nutrients		44,247	21,571	1	0.5
24. Transfer by fixation in soil mineral fraction			17,147		0.4
25. Transfer by immobilization in soil organic fraction		1,098,085	137,261	25	3
30t. Transfer by net uptake by the plant		4,547,613	725,451	105	17
	TOTAL	**7,094,464**	**901,430**	**164**	**21**
SUPPLIES-REMOVALS		**636,848**	**97,246**	**15**	**2**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		23,814	21,434	1	0.5
25. Transfer by immobilization in soil organic fraction		1,098,085	137,261	25	3
26b. Transfer by plant products remaining of field		1,571,070	172,989	36	4
	TOTAL	**2,692,970**	**331,684**	**62**	**8**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		3,282,725	410,341	76	9
28. Output by organic matter, removed by run-off		43,784	21,571	1	0.5
	TOTAL	**3,326,509**	**431,911**	**77**	**10**
SUPPLIES-REMOVALS		**(633,539)**	**(100,227)**	**-15**	**-2**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	3,582,000	562,609	Crops	2,912,000	541,058
Feed	434,833	69,230	Animal & animal products	16,995	3,717
Fixation/Deposition	804,257	4,292		**2,928,995**	**544,775**
TOTAL	**4,821,090**	**636,131**		**68**	**13**
kg/ha	**111**	**15**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	1,892,095	**91,356**	**44**	**2**
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	1,548,153	43,142	**36**	**1**
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	343,942	48,214	**8**	**1**

RM of Roland

Nutrient		kg/year N	kg/year P	Modified feed input kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		4,547,613	725,451	105	17
	TOTAL	**4,547,613**	**725,451**	**105**	**17**
REMOVALS					
3. Transfer by consumption of harvested crops		64,543	11,404	1	0.3
18. Output by primary products		2,912,000	541,058	67	12
26. Transfer by plant production remaining on field		1,571,070	172,989	36	4
	TOTAL	**4,547,613**	**725,451**	**105**	**17**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		93,418	35,182	2	1
3. Transfer by consumption of harvested crops		64,543	11,404	1	0.3
	TOTAL	**157,961**	**46,586**	**4**	**1**
REMOVALS					
5. Output by animal products		16,995	3,717	0.4	0.1
6. Output by losses from manure to air before application		55,604		1	
8. Transfer by application of manure and/or waste		85,362	42,868	2	1
	TOTAL	**157,961**	**46,585**	**4**	**1**
	SUPPLIES-REMOVALS	**0**	**0**	**0**	**0**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		85,362	42,868	2	1
11. Input by fertilizers		3,582,000	562,609	83	13
12. Input by N fixation		609,152		14	
15. Input by dry and wet deposition		195,105	4,292	5	0.1
26. Transfer by plant products remaining on field		1,571,070	172,989	36	4
	TOTAL	**6,042,689**	**782,758**	**139**	**18**
REMOVALS					
19. Output by denitrification		1,172,120		27	
20. Output by volatilization of ammonia		12,241			
21. Output by leaching		220,158		5	
22. Output by run-off of available nutrients		44,247	21,571	1	0.5
28. Output by organic matter, removed by run-off		43,784	21,571	1	0.5
30. Transfer by net uptake from soil by plant		4,547,613	725,451	105	17
	TOTAL	**6,040,163**	**768,593**	**139**	**18**
	SUPPLIES-REMOVALS	**2,526**	**14,166**	**0**	**0**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		62,331	21,434	1	0.5
11. Input by fertilizers		3,582,000	562,609	83	13
12. Input by N-fixation		609,152		14	
15. Input by dry and wet deposition		195,105	4,292	5	0.1
17. Transfer by mineralization of soil organic fraction		3,282,725	410,341	76	9
	TOTAL	**7,731,313**	**998,676**	**178**	**23**
REMOVALS					
19. Output by denitrification		1,172,120		27	
20. Output by volatilization of ammonia		12,241	-	0	
21. Output by leaching		220,158		5	
22. Output by run-off of available nutrients		44,247	21,571	1	0.5
24. Transfer by fixation in soil mineral fraction			17,147		0.4
25. Transfer by immobilization in soil organic fraction		1,098,085	137,261	25	3
30t. Transfer by net uptake by the plant		4,547,613	725,451	105	17
	TOTAL	**7,094,464**	**901,430**	**164**	**21**
SUPPLIES-REMOVALS		**636,848**	**97,246**	**15**	**2**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		23,814	21,434	1	0.5
25. Transfer by immobilization in soil organic fraction		1,098,085	137,261	25	3
26b. Transfer by plant products remaining of field		1,571,070	172,989	36	4
	TOTAL	**2,692,970**	**331,684**	**62**	**8**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		3,282,725	410,341	76	9
28. Output by organic matter, removed by run-off		43,784	21,571	1	0.5
	TOTAL	**3,326,509**	**431,911**	**77**	**10**
SUPPLIES-REMOVALS		**(633,539)**	**(100,227)**	**-15**	**-2**

Including native pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	3,582,000	562,609	Crops	2,912,000	541,058
Feed	93,418	35,182	Animal & animal products	16,995	3,717
Fixation/Deposition	804,257	4,292		**2,928,995**	**544,775**
TOTAL	**4,479,675**	**602,083**		**68**	**13**
kg/ha	**103**	**14**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	1,550,680	**57,308**	**36**	**1**
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	1,548,153	43,142	**36**	**1**
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	2,526	14,166	**0**	**0**

RM of Sifton

Municipal Nutrient Balance

Cropland (excluding christmas trees)	27,636	hectares
Summerfallow land	1,759	hectares
Tame or Seeded pasture	6,721	hectares
Natural land for pasture	24,031	hectares
All other land (including Christmas trees)	6,314	hectares
	60,147	**36,116**
	(excludes other land)	

Livestock

Total cattle and calf inventory

	Number	fraction removed/year	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
Bulls	475	0.3	143	900	0.027	0.0073	3,463	936
Dairy cow	193	0.3	58	600	0.027	0.0073	938	254
Beef cow	9,487	0.17	1613	550	0.027	0.0073	23,950	6,475
Dairy heifer	61	0	0	385	0.024	0.0065	-	-
Beef heifer	1,746	0.8	1397	360	0.024	0.0065	12,068	3,269
Slaughter heifer	2,811	1	2811	410	0.024	0.0065	27,660	7,491
Steer	1,730	1	1730	360	0.024	0.0065	14,947	4,048
Calves	8,489	0.6	5093	135	0.024	0.0065	16,503	4,469
	24,992						**99,529**	**26,943**

	Milk producing cows	litres Milk produced (rate 8160 litres/cow)	Density of milk 1031kg/1000L	Fraction N	Fraction P	kg N	kg P
Milk production	164	1,338,648	1,380,146	0.005	0.001	**6,901**	**1,380**

Total pig inventory

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
43	2	86	45	0.023	0.0047	89	18

Total chicken and hens

	Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
All chickens	930	3.5	3,255	1.6	0.028	0.0058	146	30

Total turkeys

Number	Turnover rate	Yearly output	Average Weight (kg)	Fraction N	Fraction P	kg N	kg P
1,296	2	2,592	5.5	0.028	0.0058	399	83

Total kg N	Total kg P
107,064	**28,454**

Commercial Fertilizers

(from Stats Canada)

Total kg N	Total kg P2O5	Total kg P	Fertilized hectares
552,000	199,000	86,522	10,451

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
53	19	8

(from Crop Insurance)

Average kg N/ha	Average kg P2O5/ha	Average kg P/ha
60	29	13

Manure as Fertilizer

Manured Ha	Ha Applied with solid spreader	Applied with liquid spreader on surface
2,822	2,822	

Ha Applied using irrigation system	Applied with liquid spreader injected
-	

Manure Production

Cattle	Number	Average Weight (lbs)	kg N/day/animal	kg P2O5/day/animal	Annual N production	Annual P2O5 p
Bulls	475	900	0.306	0.188	53,053	
Dairy cow	193	600	0.270	0.128	19,020	
Beef cow	9,487	550	0.187	0.115	647,535	
Dairy heifer	61	385	0.173	0.082	3,852	
Beef heifer	1,746	360	0.122	0.075	77,749	
Slaughter heifer	2,811	410	0.137	0.085	140,564	
Steer	1,730	360	0.130	0.080	82,089	
Calves	8,489	135	0.046	0.028	142,530	
	24,992				**1,166,392**	

Assumption: Storage lossses are 40%	0.6	**N production - storage losses**	**699,835**	**Annual P prc**
Assumption: Application losses are 20%	0.8	***Volatilization losses (storage)***	466,557	
(manure applied with solid spreader)		**N production - application losses**	**559,868**	
		Volatilization losses (application)	139,967	

Assume total yearly production (kg) is	**159,779,750**	kg
based on 7.3 kg N/tonne manure (or 0.73%)	0.0073	
Assume 2.2 kg available N/tonne manure	**351,515**	kg
based on Alberta guidelines (0.22%)	0.0022	
Kg of N not available to crops in 1st year	**348,320**	kg
(kg N available from storage - kg available N)		

Hog

Number	Average Weight (kg)	kg N/day/animal	kg P2O5/day/animal	Annual N production	Annual P2O5 production	Annual P
43	45	0.035	0.027	549	424	184

		N production - storage losses	**330**
Assumption: Storage losses are 40%	0.6	***Volatilization losses (storage)***	220
Assumption: Application losses are 10%	0.9	**N production - application losses**	**297**
		Volatilization losses (application)	33

Assume storage yearly production (litres) is	**109,865**	litres
based on 3.0 kg N/1000 litres manure (or 0.3%)	0.003	
Assume organic N content is	**99**	kg
based on 0.9 kg N/1000 litres (or 0.09%)	0.0009	
Assume inorganic N content is	**231**	kg
based on 2.1 kg N/1000 litres (0.21%)	0.0021	

Chickens

	Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
All chickens	930	2.5	0.0015	0.00042	496	142

Assumption: Storage losses are 20%	0.8	**N production - storage losses**	**397**	**248**	(50% of total N)
Assumption: Application losses are 10%	0.9	***Volatilization losses (storage)***	99		
		N production - application losses	**357**		
		Volatilization losses (application)	40		

Assume: 50% of chickens are layers, se liquid N manure values		**50% or chickens are boiler, use solid manure N values**	
Assume storage yearly production (litres) is	**46,763**	**Assume storage yearly production (kg) is**	**14,579**
based on 5.3 kg N/1000 litres manure (or 0.53%)	0.0053	based on 17 kg N/tonne manure (or 1.7%)	0.017
Assume kg organic N content is	**23**	**Assume lbs organic N content is**	**233**
based on 0.5 lbs N/1000 litres manure (or 0.05%)	0.0005	based on 16 kg N/tonne manure (or 1.6%)	0.016
Assume kg inorganic N content is	**224**	**Assume lbs inorganic N content is**	**15**
based on 4.8 kg/1000 litres (0.48%)	0.0048	based on 1 kg N/tonne (0.1%)	0.001

Turkeys

Number	Average Weight (kg)	kg N/day/animal	kg P/day/animal	Annual N production	Annual P production
1,296	5.5	0.0021	0.00064	993	303

		N production - storage losses	**795**
Assumption: Storage losses are 20%	0.8	***Volatilization losses (storage)***	199
Assumption: Application losses are 10%	0.9	**N production - application losses**	**715**
Assumption: Use solid manure N values		***Volatilization losses (application)***	79

Assume storage yearly production (litres) is	**46,747**	litres
based on 17 kg N/tonne manure (or 1.7%)	0.017	
Assume organic N content is	**748**	kg
based on 16 kg N/tonne manure (or 1.6%)	0.016	
Assume inorganic N content is	**47**	kg
based on 1 kg N/tonne (0.1%)	0.001	

Total Annual N production	**1,168,431**	**Total Annual P production**	**311,036**	
Storage N volatilization losses	**467,074**			
Nitrogen available after losses	**701,356**			
Application N volatilization losses	**140,119**			
kg of inorganic N	**352,032**	**kg of available N**	**456,859**	***(inorganic-N+30% organic-N)***
kg of organic N	**349,423**	**kg of remaining N**	**244,596**	

Crops

Stats Canada

Type	hectares	tonnes	kg	yield kg/ha	acres	pounds	lbs/bu	bushels	yield bu/ac
durum wheat	200	500	1,100,000		500	1,100,000	60	18,333	
spring wheat	3,400	7,400	7,400,000	2176	8,500	16,280,000	60	271,333	32
winter wheat	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
oats	2,400	5,200	5,200,000	2167	6,000	11,440,000	32	357,500	60
barley	1,500	4,200	4,200,000	2800	3,750	9,240,000	48	192,500	51
mixed grain	100	400	400,000	4000	250	880,000	52	16,923	68
grain corn			-	#DIV/0!	-	-	56	-	#DIV/0!
buckwheat			-	#DIV/0!	-	-	48	-	#DIV/0!
rye	1,000	2,100	2,100,000	2100	2,500	4,620,000	56	82,500	
alfalfa	3,200	10,860		3	8,000	23,892,000		11,946	1

grass pasture	12,600	43,440		3	31,500	95,568,000		47,784	2
canola	1,500	2,200	2,200,000	1467	3,750	4,840,000	50	96,800	26
flax	800	100	100,000	125	2,000	220,000	56	3,929	2
sunflower	100	100	100,000	1000	250	220,000	28	7,857	31
field peas	100	200	200,000	2000	250	440,000	60	7,333	29
lentils	-	-	-		-	-	60	-	
coloured beans	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
white beans	-	-	-		-	-	60	-	
canary seed	-	-	-	#DIV/0!	-	-	60	-	#DIV/0!
	26,900				**67,250**				

Nutrient uptake

Stats Canada

Type	**bushels or tons**	**lbs N/ha**	**lbs P2O5/ha**	**kg N**	**kg P2O5**	
durum wheat	18,333	2.13	0.80	39,050	14,667	
spring wheat	271,333	2.13	0.80	577,940	217,067	
winter wheat	-	1.36	0.62	-	-	
oats	357,500	1.07	0.41	382,525	146,575	
barley	192,500	1.39	0.56	267,575	107,800	
mixed grain	16,923	1.53	0.59	25,892	9,985	
grain corn	-	1.53	0.63	-	-	
buckwheat	-	1.39	0.56	-	-	
rye	82,500	1.67	0.84	137,775	69,300	
alfalfa	11,946	105.00	21.00	1,254,330	250,866	
grass pasture	47,784	60.00	17.00	2,867,040	812,328	
canola	96,800	3.20	1.49	309,760	144,232	
flax	3,929	2.88	0.83	11,314	3,261	
sunflower	7,857	1.50	0.52	11,786	4,086	
field peas	7,333	3.06	0.84	22,440	6,160	
lentils	-	3.07	0.83	-	-	
coloured beans	-	5.72	0.98	-	-	
white beans	-	5.72	0.98	-	-	
canary seed	-			-	-	**lbs P**
			Total	**5,907,427**	**1,786,325**	**776,663**
			Total Kg	***2,685,194***	***811,966***	***353,029***

Nutrient Removal

Stats Canada

Type	**bushels or tons**	**lbs N/bushels**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	
durum wheat	18,333	1.5	0.6	27,500	11,000	
spring wheat	271,333	1.5	0.6	407,000	162,800	
winter wheat	-	1.04	0.52	-	-	
oats	357,500	0.62	0.26	221,650	92,950	
barley	192,500	0.98	0.43	188,650	82,775	
mixed grain	16,923	1.03	0.43	17,431	7,277	
grain corn	-	0.94	0.44	-	-	
buckwheat	-	0.98	0.43	-	-	
rye	82,500	1.07	0.45	88,275	37,125	
alfalfa	11,946	58	14	692,868	167,244	
grass pasture	47,784	34	10	1,624,656	477,840	
canola	96,800	1.94	1.06	187,792	102,608	
flax	3,929	2.13	0.67	8,368	2,632	
sunflower	7,857	1.08	0.32	8,486	2,514	
field peas	7,333	2.34	0.7	17,160	5,133	
lentils	-	2.03	0.63	-	-	
coloured beans	-	3.42	1.22	-	-	
white beans	-	3.42	1.22	-	-	
canary seed	-			-	-	**lbs P**
			Total	**3,489,835**	**1,151,899**	**500,826**
			Total Kg	***1,586,289***	***523,590***	***227,648***
			Nutrient remaining in soil (lbs)	**2,417,592**		**275,838**
			Nutrient remaining in soil (kg)	***1,098,905***		***125,381***

Feed

Type	**tonnes**	**lbs**	**lbs/bu**	**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	-	-	60	-	1.5	0.6	-	-	-
barley	4,500	9,900,000	48	206,250	0.98	0.43	202,125	88,688	38,560
oats	-	-	32	-	0.62	0.26	-	-	-
corn	100	220,000	56	3,929	0.94	0.44	3,693	1,729	752

mixed grain	-	-	52			-			-		
							Fraction N	Fraction P			
protein meal	300	660,000					0.04	0.01	26,400	6,600	
								Total	**232,218**	**97,016**	**42,181**
<u>**Transfer Feed**</u>								***Total kg***	***105,554***	***44,098***	***19,173***
Type	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
barley	4,200	9,240,000	48			192,500	0.98	0.43	188,650	82,775	35,989
corn	-	-	56			-	0.94	0.44	-	-	-
alfalfa hay	10,860	23,892,000		11,946	tons		58	14	692,868	167,244	72,715
grass hay	43,440	95,568,000		47,784	tons		34	10	1,624,656	477,840	207,757
mixed grain	400	880,000	52			16,923	1.03	0.43	17,431	7,277	3,164
oats	3,000	6,600,000	32			206,250	0.62	0.26	127,875	53,625	23,315
wheat	900	1,980,000	60			33,000	1.5	0.6	49,500	19,800	8,609
								Total	**2,700,980**	**808,561**	**351,548**
<u>**Crop Output**</u>								***Total kg***	***1,227,718***	***367,528***	***159,795***
Crop	**tonnes**	**lbs**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat	6,500	14,300,000	60			238,333	1.5	0.6	357,500	143,000	62,174
durum wheat	500	1,100,000	60			18,333	1.5	0.6	27,500	11,000	4,783
barley	-	-	48			-	0.98	0.43	-	-	-
buckwheat		-	48			-	0.98	0.43	-	-	
oats	2,200	4,840,000	32			151,250	0.62	0.26	93,775	39,325	17,098
rye	2,100	4,620,000	56			82,500	1.07	0.45	88,275	37,125	16,141
canola	2,200	4,840,000	50			96,800	1.94	1.06	187,792	102,608	44,612
flax	100	220,000	56			3,929	2.13	0.67	8,368	2,632	1,144
sunflower	-					7,857	1.08	0.32	8,486	2,514	1,093
field peas	-					7,333	2.34	0.7	17,160	5,133	2,232
lentils						-	2.03	0.63	-	-	-
coloured beans						-	3.42	1.22	-	-	-
white beans						-	3.42	1.22	-	-	-
								Total	**788,856**	**343,338**	**149,277**
<u>**Input by seeds**</u>								***Total kg***	***358,571***	***156,063***	***67,853***
Crop	**tonnes**	**pounds**	**lbs/bu**			**bushels**	**lbs N/bu**	**lbs PO5/bu**	**lbs N**	**lbs P2O5**	**lbs P**
wheat (-durum)	900	1,980,000	60			33,000	1.5	0.6	49,500	19,800	8,609
durum	0	-	60			-	1.5	0.6	-	-	-
barley	900	1,980,000	48			41,250	0.98	0.43	40,425	17,738	7,712
oats	400	880,000	32			27,500	0.62	0.26	17,050	7,150	3,109
corn	0	-	56			-	0.94	0.44	-	-	-
rye	0	-	56			-	1.07	0.45	-	-	-
flaxseed	0	-	56			-	2.13	0.67	-	-	-
canola	100	220,000	50			4,400	1.94	1.06	8,536	4,664	2,028
									115,511		**21,457**
								Total kg	***52,505***		***9,753***

N fixation	**kg/ha**		**ha**	**kg N fixed**
non-symbiotic (cropland)	1		27,636	27,636
summerfallow	1		1,759	1,759
symbiotic alfalfa	220		1,344	295,724
grass seeded	1		5,377	5,377
(pasture)	1		24,031	24,031
		TOTAL	**60,147**	**354,527**

Denitrification

	kg/ha		**ha**	**kg N denitrified**
manure	20		2,822	56,440
cropland	10		22,126	221,256
alfalfa	2		1,344	2,688
1 year after alfalfa	15		1,344	20,163
4 years after alfalfa	20		1,344	26,884
seeded pasture	2		5,377	10,754
natural pasture	2		24,031	48,062
summerfallow	10		1,759	17,590
		TOTAL	**60,147**	**403,837**

Fertilizer N	53	15% available N denitrified
Manure N	162	

Ammonia volatilization

Output by leaching

	kg/ha		ha	Total
cropland	10		27,636	276,360
summerfallow	20		1,759	35,180
seeded pasture	2		6,721	13,442
natural pasture	2		24,031	48,062
		TOTAL	**60,147**	**373,044**

Output by run-off of available nutrient

	N				P	
	kg/ha		**ha**	**Total**	**kg/ha**	
cropland	1		27,636	27,636	0.5	13,818
summerfallow	2		1,759	3,518	0.5	880
seeded pasture	1		6,721	6,721	0.3	1,680
natural pasture	1		24,031	24,031	0.3	6,008
		TOTAL	**60,147**	**61,906**	**TOTAL**	**22,386**

Output by organic matter, removed by run-off

	N			P	
	kg/ha	**ha**	**Total**	**kg/ha**	
cropland	1	27,636	27,636	0.5	13,818
summerfallow	1.5	1,759	2,639	0.5	880
seeded pasture	1	6,721	6,721	0.3	1,680
natural pasture	1	24,031	24,031	0.3	6,008
		TOTAL	**61,027**	**TOTAL**	**22,386**

Transfer by mineralization in soil organic fraction

	N				P		
	kg/ha		**ha**	**kg N**	**kg/ha**	**ha**	**kg P**
cropland	75		14,194	1,064,550	9	14,194	133,069
summerfallow	80		1,759	140,720	10	1,759	17,590
alfalfa-current	120		1,344	161,304	15	1,344	20,163
1 year after alfalfa	165		1,344	221,793	21	1,344	27,724
4 years after alfalfa	120		1,344	161,304	15	1,344	20,163
seeded pasture	75		5,377	403,260	9	5,377	50,408
1 year after pasture	100		5,377	537,680	13	5,377	67,210
4 years after pasture	90		5,377	483,912	11	5,377	60,489
natural pasture	75		24,031	1,802,325	9	24,031	225,291
		Total	**60,147**	**4,976,848**			**622,106**

Transfer by immobilization in soil organic fraction

N				P		
	kg/ha	**ha**	**Total**	**kg/ha**	**ha**	**kg P**
cropland	25	27,636	690,900	3	27,636	86,363
summerfallow	5	1,759	8,795	1	1,759	1,099
alfalfa	165	1,344	221,793	21	1,344	27,724
seeded pasture	90	5,377	483,912	11	5,377	60,489
natural pasture	75	24,031	1,802,325	9	24,031	225,291
		TOTAL	**3,207,725**			**400,966**

Wet and Dry Deposition

N	(excludes other land)		**P**		
kg/ha	**ha**	**Total**	**kg/ha**	**ha**	**Total**
5	60,147	**300,735**	0.11	60,147	**6,616**

RM of Sifton

Nutrient		kg/year N	kg/year P	Including native pasture kg/ha N	kg/ha P
<u>Changes in amount of plant component</u>					
SUPPLIES					
30t. Transfer by net uptake from soils		2,685,194	353,029	45	6
	TOTAL	**2,685,194**	**353,029**	**45**	**6**
REMOVALS					
3. Transfer by consumption of harvested crops		1,227,718	159,795	20	3
18. Output by primary products		358,571	67,853	6	1
26. Transfer by plant production remaining on field		1,098,905	125,381	18	2
27. Transfer by seed for sowing					
	TOTAL	**2,685,194**	**353,029**	**45**	**6**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
<u>Changes in amount of animal component</u>					
SUPPLIES					
1. Input by feed for livestock		105,554	19,173	2	0.3
3. Transfer by consumption of harvested crops		1,227,718	159,795	20	2.7
	TOTAL	**1,333,272**	**178,968**	**22**	**3**
REMOVALS					
5. Output by animal products		107,064	28,454	2	0.5
6. Output by losses from manure to air before application		467,074		8	
8. Transfer by application of manure and/or waste		701,356	311,036	12	5.2
	TOTAL	**1,275,494**	**339,489**	**21**	**6**
	SUPPLIES-REMOVALS	**57,777**	**(160,522)**	**1**	**-3**
<u>Changes in amount of total soil component</u>					
SUPPLIES					
8. Transfer by application of manure and/waste		701,356	311,036	12	5
11. Input by fertilizers		552,000	86,522	9	1
12. Input by N fixation		354,527		6	
15. Input by dry and wet deposition		300,735	6,616	5	0.1
26. Transfer by plant products remaining on field		1,098,905	125,381	18	2
27. Transfer by seed for sowing		-	-		
	TOTAL	**3,007,523**	**529,554**	**50**	**9**
REMOVALS					
19. Output by denitrification		403,837		7	
20. Output by volatilization of ammonia		467,074		8	
21. Output by leaching		373,044		6	
22. Output by run-off of available nutrients		61,906	22,386	1	0.4
28. Output by organic matter, removed by run-off		61,027	22,386	1	0.4
30. Transfer by net uptake from soil by plant		2,685,194	353,029	45	6
	TOTAL	**4,052,082**	**397,800**	**67**	**7**
	SUPPLIES-REMOVALS	**(1,044,559)**	**131,755**	**-17**	**2**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		456,859	155,518	8	3
11. Input by fertilizers		552,000	86,522	9	1
12. Input by N-fixation		354,527		6	
15. Input by dry and wet deposition		300,735	6,616	5	0.1
17. Transfer by mineralization of soil organic fraction		4,976,848	622,106	83	10
	TOTAL	**6,640,969**	**870,762**	**110**	**14**
REMOVALS					
19. Output by denitrification		403,837		7	
20. Output by volatilization of ammonia		467,074	-	8	
21. Output by leaching		373,044		6	
22. Output by run-off of available nutrients		61,906	22,386	1	0.4
24. Transfer by fixation in soil mineral fraction			93,311		2
25. Transfer by immobilization in soil organic fraction		3,207,725	400,966	53	7
30t. Transfer by net uptake by the plant		2,685,194	353,029	45	6
	TOTAL	**7,198,781**	**869,691**	**120**	**14**
SUPPLIES-REMOVALS		**(557,812)**	**1,071**	**-9**	**0**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		244,596	155,518	4	3
25. Transfer by immobilization in soil organic fraction		3,207,725	400,966	53	7
26b. Transfer by plant products remaining of field		1,098,905	125,381	18	2
	TOTAL	**4,551,227**	**681,864**	**76**	**11**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		4,976,848	622,106	83	10
28. Output by organic matter, removed by run-off		61,027	22,386	1	0.4
	TOTAL	**5,037,875**	**644,492**	**84**	**11**
SUPPLIES-REMOVALS		**(486,648)**	**37,373**	**-8**	**1**

Including natural pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	552,000	86,522	Crops	358,571	67,853
Feed	105,554	19,173	Animal & animal products	107,064	28,454
Fixation/Deposition	655,262	6,616		**465,635**	**96,307**
TOTAL	**1,312,815**	**112,311**		**8**	**2**
kg/ha	**22**	**2**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	847,181	16,004	14	0
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	1,833,962	44,771	30	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	(986,781)	(28,767)	-16	0

RM of Sifton

Nutrient		kg/year N	kg/year P	Modified feed input kg/ha N	kg/ha P
Changes in amount of plant component					
SUPPLIES					
30t. Transfer by net uptake from soils		2,685,194	353,029	45	6
	TOTAL	**2,685,194**	**353,029**	**45**	**6**
REMOVALS					
3. Transfer by consumption of harvested crops		1,227,718	159,795	20	3
18. Output by primary products		358,571	67,853	6	1
26. Transfer by plant production remaining on field		1,098,905	125,381	18	2
27. Transfer by seed for sowing					
	TOTAL	**2,685,194**	**353,029**	**45**	**6**
	SUPPLIES-REMOVALS	**-**	**-**	**0**	**0**
Changes in amount of animal component					
SUPPLIES					
1. Input by feed for livestock		47,776	179,695	1	3
3. Transfer by consumption of harvested crops		1,227,718	159,795	20	3
	TOTAL	**1,275,494**	**339,490**	**21**	**6**
REMOVALS					
5. Output by animal products		107,064	28,454	2	0.5
6. Output by losses from manure to air before application		467,074		8	
8. Transfer by application of manure and/or waste		701,356	311,036	12	5
	TOTAL	**1,275,494**	**339,489**	**21**	**6**
	SUPPLIES-REMOVALS	**0**	**0**	**0**	**0**
Changes in amount of total soil component					
SUPPLIES					
8. Transfer by application of manure and/waste		701,356	311,036	12	5
11. Input by fertilizers		552,000	86,522	9	1
12. Input by N fixation		354,527		6	
15. Input by dry and wet deposition		300,735	6,616	5	0.1
26. Transfer by plant products remaining on field		1,098,905	125,381	18	2
27. Transfer by seed for sowing		-	-		
	TOTAL	**3,007,523**	**529,554**	**50**	**9**
REMOVALS					
19. Output by denitrification		403,837		7	
20. Output by volatilization of ammonia		467,074		8	
21. Output by leaching		373,044		6	
22. Output by run-off of available nutrients		61,906	22,386	1	0.4
28. Output by organic matter, removed by run-off		61,027	22,386	1	0.4
30. Transfer by net uptake from soil by plant		2,685,194	353,029	45	6
	TOTAL	**4,052,082**	**397,800**	**67**	**7**
	SUPPLIES-REMOVALS	**(1,044,559)**	**131,755**	**-17**	**2**

Changes in amount of available soil nutrients

SUPPLIES					
8a. Transfer by application of manure and/or waste		456,859	155,518	8	3
11. Input by fertilizers		552,000	86,522	9	1
12. Input by N-fixation		354,527		6	
15. Input by dry and wet deposition		300,735	6,616	5	0.1
17. Transfer by mineralization of soil organic fraction		4,976,848	622,106	83	10
	TOTAL	**6,640,969**	**870,762**	**110**	**14**
REMOVALS					
19. Output by denitrification		403,837		7	
20. Output by volatilization of ammonia		467,074	-	8	
21. Output by leaching		373,044		6	
22. Output by run-off of available nutrients		61,906	22,386	1	0.4
24. Transfer by fixation in soil mineral fraction			93,311		2
25. Transfer by immobilization in soil organic fraction		3,207,725	400,966	53	7
30t. Transfer by net uptake by the plant		2,685,194	353,029	45	6
	TOTAL	**7,198,781**	**869,691**	**120**	**14**
SUPPLIES-REMOVALS		**(557,812)**	**1,071**	**-9**	**0**

Changes in amount of soil organic matter

SUPPLIES					
8b. Transfer by application and/or waste		244,596	155,518	4	3
25. Transfer by immobilization in soil organic fraction		3,207,725	400,966	53	7
26b. Transfer by plant products remaining of field		1,098,905	125,381	18	2
	TOTAL	**4,551,227**	**681,864**	**76**	**11**
REMOVALS					
17. Transfer by mineralization of soil organic fraction		4,976,848	622,106	83	10
28. Output by organic matter, removed by run-off		61,027	22,386	1	0.4
	TOTAL	**5,037,875**	**644,492**	**84**	**11**
SUPPLIES-REMOVALS		**(486,648)**	**37,373**	**-8**	**1**

Including natural pasture

Total Inputs			**Total Outputs**		
	N	**P**		**N**	**P**
Fertilizer	552,000	86,522	Crops	358,571	67,853
Feed	47,776	179,695	Animal & animal products	107,064	28,454
Fixation/Deposition	655,262	6,616		**465,635**	**96,307**
TOTAL	**1,255,038**	**272,833**		**8**	**2**
kg/ha	**21**	**5**			

Input-Output	**N**	**P**	**kg N/ha**	**kg P/ha**
	789,403	176,526	13	3
	N	**P**	**kg N/ha**	**kg P/ha**
Calculated losses	1,833,962	44,771	30	1
	N	**P**	**kg N/ha**	**kg P/ha**
Difference	(1,044,559)	131,755	-17	2

Appendix C:

Methodology for Estimating Nutrient Effluents from the Domestic Lagoons

Although information on licensed lagoons is available from Manitoba Conservation, the files on several of the lagoons we studied were unavailable at the Manitoba Conservation library. Much of the information in this report was received directly from the Rural Municipalities.

Wastewater treatment lagoons are licensed with Manitoba Conservation. Information available on licensed lagoons includes a basic description of the lagoons, including the size and location, the characters of the influent and effluent and annual treated waste volume.

Estimation of the nutrients in the effluent from the lagoons

- Wastewater volume

  If the lagoon size was unknown, the annual waste volumes from the lagoons were estimated on the basis of the lagoon size or the number of people and businesses the lagoon served. The only exception was the Blumenort lagoon. The quantity and quality of the annual wastewater was found in the Environment Act proposal for the lagoon expansion.

- Nutrient concentrations in the lagoon effluent

  The Total Kjeldahl Nitrogen (TKN) and Total Phosphorous (TP) concentrations in the effluents were investigated.

  The data from the lagoons in Mitchell, New Bothwell, Bothwell Cheese Co-Op, Blumenort, Steinbach and La Broquerie were adopted from "Seine River Diversion Water Quality Model" provided by Manitoba Water Resources Service Department. The nutrients in the remaining lagoons were estimated according to the data obtained from similar lagoons. The "Manual for Land Application of Treated Municipal Wastewater and Sludge" (Manual EPS 6-EP-84-1) was also used to estimate nutrient discharge.

- Annual nutrient discharge

  The annual nutrients discharged from a lagoon were estimated as the product of the estimated concentrations (or concentrations of the samples if the actual concentrations were available) of the nutrients multiplied by the estimated annual discharge volume.

Nutrients discharged from the lagoons in R.M. Hanover

	TKN	TP
annual discharge (kg)	43185	16128

Nine registered lagoons are located in the R.M. of Hanover. No information indicated the existence of any unregistered lagoons.
For the Mitchell, New Bothwell, Bothwell Cheese, Blumenort and Steinbach lagoons, the holding volumes and concentrations of TKN and TP were adopted from "Seine River Diversion Water Quality Model"

Concentration estimation:
- Fall discharge concentration: average of concentration in Sept and Oct
- Spring discharge concentration: concentration in May
- Annual average: the average concentration of spring discharge and fall discharge

For the Niverville, Grunthal, Kleefeld and Country Meat lagoons, the annual waste volume and nutrients contents in the effluents were estimated on the bases of similar size lagoons.

Mitchell Lagoon Effluent Estimation (1-7-5E) licence No. 1053

sampling date		TKN	TP	Volume: 30,000 m^3
09/14/00	fall discharge1 (mg/L)	2.5	2.5	This lagoon serves a town of 1100 people, including a
10/24/00	fall discharge2 (mg/L)	1.8	2.48	meat processing business.
05/16/01	spring discharge (mg/L)	15.7	4.5	
	annual average (mg/L)	8.9	3.5	Annual water quantity was estimated as 87,600 m^3.
	annual discharge (kg)	803	315	(200 L/person/day, 20 m^3/day from meat processing)

New Bothwell Community Lagoon Effluent Estimation (29-7-5E) Licence No. 1524

sampling date		TKN	TP	volume: 35,000 m^3
09/15/00	fall discharge1 (mg/L)	2.2	2.04	No population or flow rate information was available.
10/24/00	fall discharge2 (mg/L)	7.2	3.01	Annual water quantity is estimated as 26,250 m^3.
05/18/01	spring discharge (mg/L)	6.6	2.42	(75 percent of the volume discharged)
	annual average (mg/L)	5.7	2.5	
	annual discharge (kg)	148	65	

Bothwell Cheese COOP Lagoon Effluent Estimation (SE 30-7-5E) Licence No. 1015

sampling date		TKN	TP	volume: 15,600 m^3
09/15/00	fall discharge1 (mg/L)	10.4	12	This lagoon serves the cheese plant.
10/24/00	fall discharge2 (mg/L)	7.6	10.7	No flow rate information was available.

05/18/01	spring discharge (mg/L)	23.1	23.8	Annual water quantity is estimated at 11,700 m^3.
	annual average (mg/L)	16.1	17.6	(75 percent of the volume discharged)
	annual discharge (kg)	501	548	

Blumenort Lagoon Effluent Estimation

(33-7-6E) Licence No. 1065

sampling date		TKN	TP	volume: 140,000 m^3
09/14/00	fall discharge1 (mg/L)	15	14.4	This lagoon accepts wastewater
10/24/00	fall discharge2 (mg/L)	27.4	12.4	from Granny's Poultry, Steve's Livestock Transport, and
05/16/01	spring discharge (mg/L)	58.8	15.1	the community of Bluemnort.
	annual average (mg/L)	40.0	14.3	The annual water quantity is 718,685 m^3 (Environment Act proposal
	annual discharge (kg)	28747	10241	file No.1957.20).

Steinbach Lagoon Effluent Estimation

(8-7-6E) Licence No. 1105

sampling date		TKN	TP	volume: 1,226,471 m^3
09/14/00	fall discharge1 (mg/L)	2.8	2.5	This lagoon serves approximately 8500 people.
10/24/00	fall discharge2 (mg/L)	1.8	2.48	There is some industrial wastewater discharge.
05/16/01	spring discharge (mg/L)	15.7	4.5	The annual water quantity was estimated estimated at
	annual average (mg/L)	9.0	3.5	920,000 m^3 (75 percent of the lagoon volume)
	annual discharge (kg)	8280	3215	

Niverville Lagoon Effluent Estimation

(SW 30-7-4E) Licence No. 737

	TKN	TP	Volume: 138,000
nutrients estimation (mg/L)	8.9	3.5	This lagoon serves approximately 1600 people
annual discharge (kg)	921.15	362	There is very limited industrial discharge.

No nutrient information is available. N & P were estimated at 8.9 mg TKN/L, 3.5 mg TP/L (similar to Michell). Annual water quantity was estimated as 116,800 m^3. (75 percent of the lagoon volume)

Kleefeld Lagoon Effluent Estimation

(19-6-5E) Licence No. 1985

	TKN	TP	No volume information available.
nutrients estimation (mg/L)	8.9	3.5	This lagoon sereves approximately 450 people
annual discharge (kg)	292	115	There is very limited industrial discharge.

No nutrients information available. N & P are estimated as 8.9 mg/L and 3.5mg/L respectively. Annual water quantity was estimated as 32,850 m^3 (200 L/person/day).

Grunthal Lagoon Effluent Estimation

	TKN	TP
nutrients estimation (mg/L)	8.9	3.5
annual discharge (kg)	617	243

(20-5-5E) Licence No. 1940RR
No volume information is available.
This lagoon serves approximately 950 people and a cheese plant.
No nutrients information available. N & P are estimated at 15 mg/L and 5.2mg/L, respectively.
The flow rate is estimated at 550 L/person/day.

Country Meats & Sausage Lagoon Effluent Estimation

	TKN	TP
annual discharge (kg)	2875	1024

(35-7-6E)
No information available is about this lagoon, except the location.
Since the scale of Country Meats and Sausage is much smaller than Granny's Poultry, the annual nutrient discharge was estimated as ten percent of the Blumonort Lagoon.

Nutrients discharged from the lagoons in the R.M. of La Broquerie

La Broquerie Lagoon Effluent Estimation

	TKN	TP
Sept and Oct samples (mg/L)	3.1	2.14
represent fall discharge (mg/L)	2.6	1.82
spring discharge (mg/L)	7.9	2.27
annual average (mg/L)	5.4	2.1
annual discharge (kg)	1027	406

Licence No. 1198
volume: 95,500 m^3

This lagoon serves approximately 650 people.
No industrial discharge.
Annual water quantity was estimated as 71,625 m^3 (75 percent of the lagoon volume). TKN and TP data were adopted from "Seine River Diversion Water Quality Model".

Nutrients discharged from the lagoons in the R.M. of Roland

	TKN	TP
annual discharge (kg)	138	53

This municipal lagoon serves approximately 350 people
No nutrient information is available. N & P are estimated as 5.4 mg/L and 2.1mg/L respectively (similar to La Broquerie).
Annual water quantity was estimated as 27,010 m^3 (200 L/person/day).

Nutrients discharged from the lagoons in R.M. of Sifton

	TKN	TP	
annual discharge (kg)	146	57	This municipal lagoon serves approximately 370 people No nutrient information is available. N & P are estimated as 5.4 mg/L and 2.1mg/L respectively (similar to La Broquerie). Annual water quantity was estimated as 27,010 m^3 (200 L/person/day).

Appendix D:

Manure and the Environment
The Dutch approach to reduce mineral nutrient surplus and ammonia volatilization

Manure and the environment

The Dutch approach to reduce the mineral surplus and ammonia volatilisation

2nd edition
31-12-2001

Contents

Foreword

The Dutch environment is under considerable pressure from the high intensity of agricultural production here. Too much fertiliser, or more precisely too many minerals and ammonia, is being deposited into the environment. The eutrophication of surface water and the deteriorating quality of groundwater are caused largely by minerals leaching into the environment. Ammonia emissions from livestock manure are acidifying the soil and causing grass invasions in nature areas.

The Dutch government first introduced policy to combat the problem of minerals surpluses in the 1980s. The first measures were aimed at minimising the negative effects of minerals surpluses. Over the years, farmers have had to comply with progressively tighter and more comprehensive regulations and standards.
The Dutch government is serious about tackling the manure surplus, or more accurately the minerals surplus. Until now, our country produced far more manure than we had land on which to deposit it. But with the implementation of the new minerals policy, the Netherlands now complies with the objectives and obligations of the EU Nitrate Directive (EC/91/676).
Dutch minerals policy was tightened considerably in 1999. Priority is given to the realisation of environmental targets on farms. The full implementation of the Minerals accounting system (Minas) was completed well ahead of schedule. Now, livestock farms, arable farms and horticultural establishments are all required to submit a minerals return. Furthermore a system of manure transfer contracts will be introduced in 2002, where livestock farmers with manure surpluses will have to have contracts with farms with a manure shortage or with manure processors. Farmers who are unable to dispose of all of their surplus manure in this manner would be faced with the choice of cutting down on the number of livestock or selling up.
In this brochure, we first present the background to Dutch minerals policy and environmental targets. We then briefly review the various instruments used to tackle the minerals surplus: the Minerals accounting system (Minas), the system of manure transfer contracts, regulations on depositing manure and other organic fertiliser on land, and regulations to reduce ammonia emissions from manure.

We hope that this brochure will give you a better understanding of how the Netherlands aims to tackle the difficult problem of minerals surpluses.

The Department of Agriculture,
Ministry of Agriculture, Nature Management and Fisheries

Summary

Tackling surplus minerals and ammonia

Agricultural and horticultural production in the Netherlands are very advanced. We have a large livestock population and accordingly a high livestock density per hectare. The manure produced by livestock constitutes a major environmental problem. Or rather, the minerals nitrogen, phosphate and ammonia in livestock manure are the problem. Nitrogen and phosphate are also found in chemical fertiliser and other organic fertilisers such as compost and sludge.

Minerals are essential nutrients for plants and animals. But too many minerals are harmful for the environment. Through leaching and emission, mineral surpluses are deposited in surface water where they cause such an explosive growth of water plants and algae that they seriously unbalance the water ecosystem. Drinking water, too, can be negatively affected by the leaching of minerals in water catchment areas while ammonia emissions from manure are largely responsible for the ongoing acidification of the soil and eutrophication of nature areas. Manure has other harmful emissions, too, for example the greenhouse gases methane and nitrous oxide (laughing gas). Finally, fertiliser may also contain heavy metals and other contaminants.

Focusing on environmental targets
The Dutch government combats environmental pollution caused by manures and fertilisers through a policy of environmental targets. To realise these targets, significant reductions need to be realised in the leaching and emission of minerals and ammonia, and in the deposition of harmful substances such as heavy metals.

Minerals policy was first introduced in the 1980s and is being implemented in phases. The “second generation” in minerals policy was introduced in 1998. In 1999, Parliament passed new, stricter requirements for minerals policy, and agreed to accelerate the schedule for realising the environmental targets. This will require considerable effort and investment on the part of farmers and expectations are that several thousand farmers will be forced to sell up. Ancillary policy has been drawn up to soften to some extent the dramatic social impact of the new measures.

There is also new legislation to reduce ammonia emissions from livestock housing. Regulations to tackle the greenhouse gases methane and nitrous oxide are in the pipeline.

Minerals accounting system
The Minerals accounting system (Minas) forms the core of Dutch minerals policy. This unique system sets restrictively high levies on phosphate and nitrogen surpluses above a certain maximum allowed standards for nitrogen and phosphate per hectare (loss standard), effectively forcing farmers to take measures to minimise mineral losses to the environment. The system was first made compulsory for intensive livestock farms in 1998; it was extended to all farms in 2001. In 1999, the government decided to progressively reduce the maximum allowable standards to reach their final level in 2003. Dry sandy soils and loess soils are most vulnerable to nitrate leaching to groundwater. Stricter standards apply to these soil types, so that environmental targets may also be met there.

Restrictive levies
Minas is essentially a registration system where farmers keep a detailed record of nitrogen and phosphate inputs and outputs on their farm. The difference between inputs and outputs reflects the farm’s minerals surplus. Farmers are required by law to complete an annual minerals return form. Some mineral losses are allowed; these so-called loss standards are expressed in kilograms of mineral per hectare. A

levy is charged for losses which exceed the loss standards. The levies are very high in order to persuade farmers to take measures to reduce their losses. The Netherlands is confident that the reduction of nitrogen and phosphate losses that has been achieved meets environmental objectives, including those of the EU Nitrate Directive.

Added security through manure transfer contracts
The Dutch government also plans to introduce a Manure transfer contract system to complement Minas. Together, the two systems should ensure that the volume of manure deposited on land is always equal to what the land can take. Under the manure transfer contracts system, farmers must plan manure transfer before it is produced. Farmers can apply manure on their own land provided they do not exceed the Minas loss standards. Surplus manure can be delivered to arable farmers or livestock farmers with a manure shortage, or to manure processors. A farmer who is unable to contract sufficient buyers for his surplus manure will have to reduce the number of livestock on the farm. The manure transfer contracts system will be implemented in 2002. The system should result in a balance of supply and demand on the manure market.

Lower ammonia emissions
The Dutch livestock sector is a major contributor to acidification in the Netherlands. Over the years, several regulations have been implemented to limit ammonia emissions.

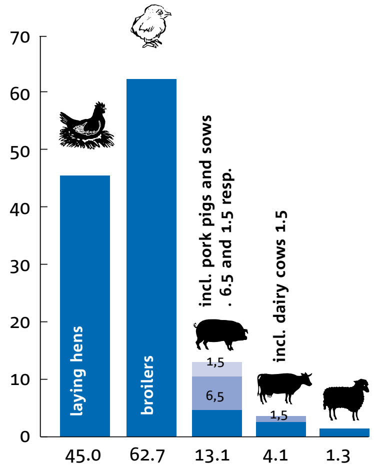
Most importantly, the regulations aim to prevent emissions in the first place. For example, farmers must inject manure into the soil and cover manure silos. Ammonia emissions can also be reduced with low-emission livestock housing. In 2002, new animal housing regulations laying down stricter emission standards will come into effect. Already, however, municipal building permits for new livestock housing often prescribe lower emission rates.

The government has strict regulations on the quality and use of products such as sewage sludge, compost and black soil to prevent contamination of the soil with heavy metals and arsenic.

The Dutch manure problem in brief

1

Number of livestock animals in 2000 (in millions)
Source: 2000 May count (CBS/LEI 2001)



The Netherlands is the most densely populated country in Europe, in terms of both human and livestock populations. The Dutch know how to make the most of a square metre. In the agricultural and horticultural sectors, the drive to optimise the use of space is further stimulated by rocketing land prices.

The Netherlands has a reputation to uphold in modern agriculture. Farmers and growers here use the latest methods and technology. Productivity is high, in part due to the intensive use of organic and chemical fertilisers. But these intensive methods have their drawbacks. Most importantly, the generous use of fertiliser places a heavy burden on the environment. A strict environmental policy coupled with ambitious targets should alleviate the negative environmental impact of intensive agricultural and horticultural production. The government recently accelerated the schedule for realising the environmental targets, which poses a major challenge to farmers in the next few years.

Intensive agricultural production
Dutch agricultural and horticultural production uses about 2 million hectares of land. Half of this is grassland for cattle. Fodder maize is grown on more than 0.2 million hectares, while other arable crops such as cereals, potatoes and sugar beets take up 0.7 million hectares.

Productivity is high. The average wheat yield, for example, is 8 to 9 tonnes per hectare. Dairy farmers usually get about five cuts of roughage from their pastures in a single growing season. In many other parts of Europe, yields such as these are the stuff of dreams.

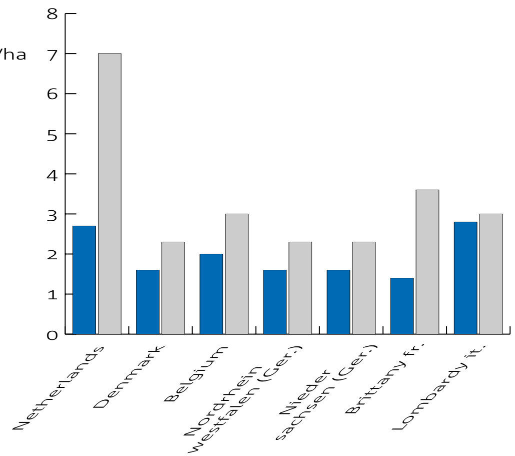
For a small country, the Netherlands has a lot of livestock: 4.1 million cattle, about 13 million pigs, 108 million poultry and 1.3 million sheep. Actual stocking densities of course differ per farm and per type of livestock. Poultry or pig production farms have a considerably higher livestock density than dairy farms. Livestock density is expressed as the number of livestock units per hectare of agricultural land (LU). A farm's total livestock density is the sum of all LU per type of animal. Although there are more and less intensively livestocked regions in Europe, the Netherlands leads with an average national livestock density of 3.9 LU.

The environmental cost of minerals and trace elements
Animal manure and chemical fertilisers contain minerals that are essential for plant growth, such as nitrogen, phosphate and potassium. Fertilisers also contain trace elements which are necessary for physiological processes in plant and animal organisms. Copper and zinc are essential trace elements; others such as cadmium are in fact harmful. Excessive concentrations of minerals and trace elements can cause damage to the environment. Nitrogen that converts into nitrate and leaches into groundwater directly threatens the quality of our drinking water. Nitrogen and phosphate also leach to surface waters, where they cause explosive growth of algae and make the water so turbid that plants and animals have difficulty surviving. Eutrophication is also a serious threat to the North Sea.

Ammonia emissions from manure cause both eutrophication and acidification. Acidification in particular has dramatic consequences for species diversity in nature areas.

Agriculture, or more accurately its dependence on manure and fertiliser, is responsible for over 40% of the domestic phosphate pollution of Dutch surface waters (RIVM, 2001). It accounts for almost 70% of the total nitrogen leached to Dutch surface waters. Ammonia emissions from agriculture are responsible for 42% of the acidification from domestic

Stocking density in Europe, in livestock units per hectare of farmland (LU)



Average stocking densities in a number of intensive livestock production regions in Europe.
** Mixed farms are usually intensive livestock production units (pigs, poultry or beef) with a small arable area under maize or another arable crop*
(Source: LEI, 1995 figures)

sources. Although there are strong regional differences, the mean nitrogen deposition for all of the Netherlands is almost 3000 mole per hectare. This is much higher than the amount that is considered safe as regards the quality of nature. In short, effective minerals policy is a must. The government has formulated a series of environmental targets to serve as a framework for such policy (see inset).

Environmental targets for phosphate and nitrogen

groundwater quality targets
nitrogen: 50 mg nitrate per litre (norm)
25 mg nitrate per litre (target)
phosphate: 0.15 mg P/l

surface water quality targets
nitrogen: 2.2 mg total N per litre for standing water susceptible to eutrophication (summer average)
phosphate: 0.15 mg total P per litre for all waters (year average)

emission reduction targets (North Sea)
nitrogen: 50% reduction compared to 1985
phosphate: 50% reduction compared to 1985

acidification by ammonia
emission target
no more than 100 kt ammonia emission in 2010, of which no more than 86 kt is produced by agriculture

N deposition
target for 2010*
Mean deposition of 1550 mole N/ha per year in ecosystems which make up about 30% of the total area of nature in the Netherlands

** Agriculture (ammonia) and traffic (NOx) are the main sources of nitrogen emissions.*

Source: VROM, 1998, 2001

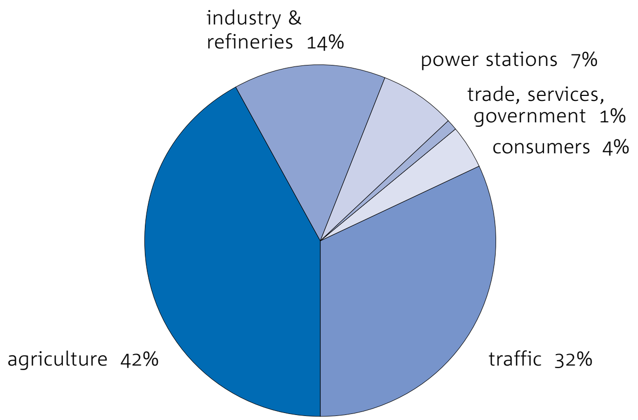
High nitrogen production per hectare

High livestock densities inevitably mean a high production of animal manure per hectare, too. On average, Dutch livestock produces about 270 kg nitrogen per hectare. That is a lot, but this figure has become a lot lower since the introduction of the new minerals policy. In the early 1990s, livestock farms were still producing 340 kg N per hectare. The intensive nature of production in the Netherlands in general also means that artificial chemical fertiliser use is also quite high. These high inputs are offset by a high output of nitrogen through agricultural products (crops, meat, milk). Nevertheless, a considerable quantity of nitrogen still leaches to the environment.

Heavy metals

Besides livestock manure, farmers also use other organic fertilisers, mostly household compost and sewage sludge. These fertilisers may contain heavy metals and arsenic which can contaminate the soil. The government has laid down heavy metal target thresholds based on the principle that the soil should retain its multifunctionality. In other words, the soil should be suitable for all types of use, including food production. Quality criteria have also been laid down for household compost and sludge.

Sources of acidification in the Netherlands, in 1999
Source: Milieucompendium RIVM/CBS, 2001

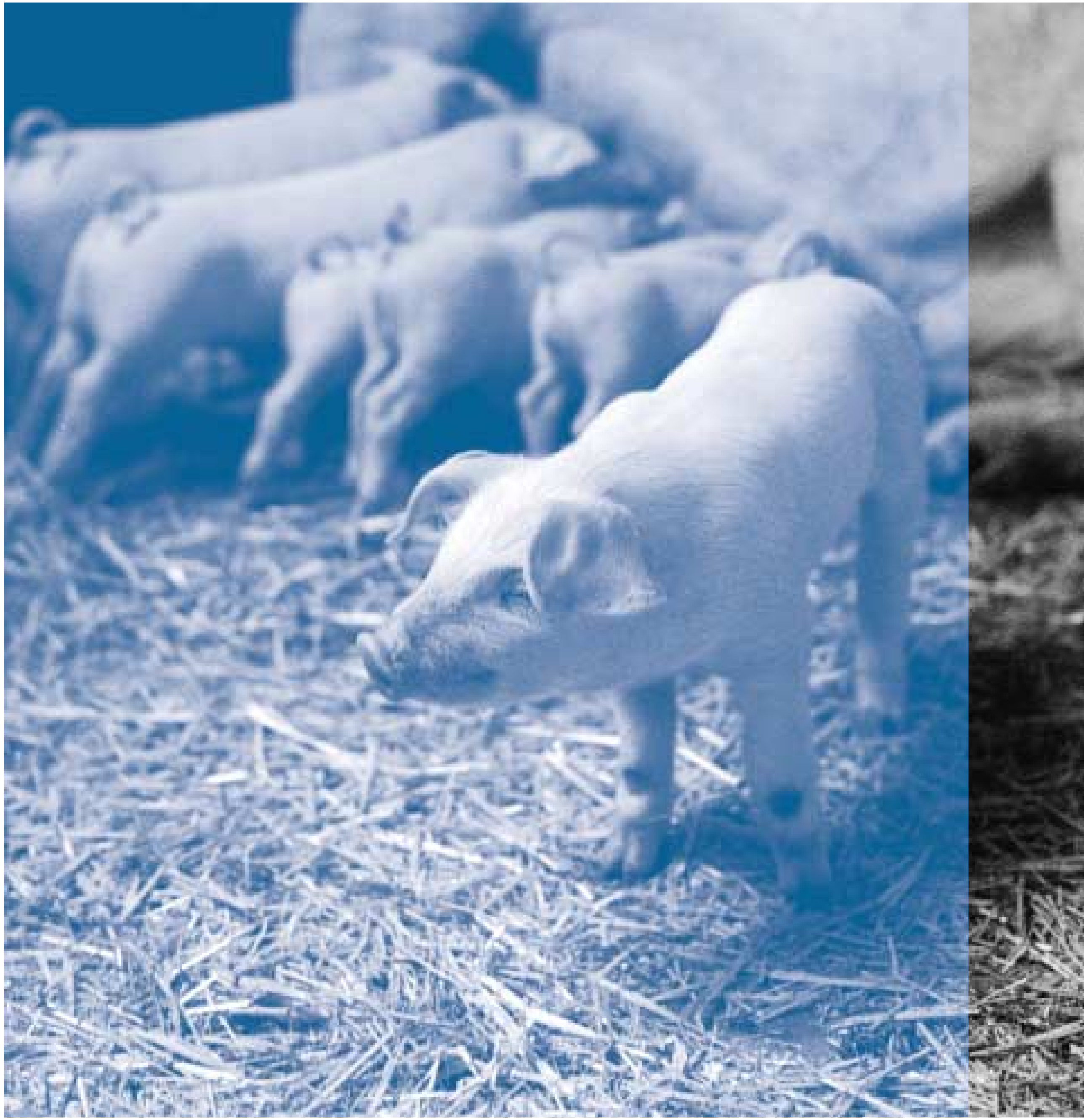


European Nitrate Directive

The Netherlands' environmental targets and policy do not stand on their own. The European Nitrate Directive has strongly influenced national minerals policy in our country and other Member States. The Directive dates from 1991, but most countries have started to implement the Directive only recently. The Netherlands has designated its entire territory as a vulnerable area and as such must meet the strictest standards in Nitrate Directive.

The European Union has recently introduced legislation to restrict ammonia emission and other forms of eutrophication, the so-called NEC Directive.

The Netherlands is also party to various binding international environmental agreements, such as the 1985 North Sea treaty which lays down a 50% reduction in nitrogen and phosphate leaching to the North Sea.



Dutch minerals policy

2

The Dutch government takes the minerals surplus problem seriously. Ambitious environmental targets have been set (see chapter 1) as part of policy to combat the negative effects of minerals on the quality of the soil, groundwater and surface water. The minerals surplus is to be reduced through a generic reduction of the livestock population and high levies for farmers who exceed the allowable loss standards. There are also specific measures concerning animal housing, manure storage and manure application on land, which all aim to reduce ammonia emissions. Policy to reduce greenhouse gases is in development.

The phases of Dutch mineral policy

The government is implementing its minerals policy in phases to enable farmers to adapt their management systems gradually to the new regulations. Recent events, however, have forced up the pace of implementation.

The first measures to reduce the negative impact of manure were introduced in the 1980s. In this first phase (1987 to 1990), efforts were focused on stopping the manure surplus from getting any bigger. In the second phase (1990 to 1998) the government aimed to significantly reduce the environmental burden of the manure surplus. The goal of the current third phase, which commenced on 1 January 1998, is to achieve a balance in the supply and demand of nitrogen and phosphate. A modest minerals surplus may still be produced. Allowable loss standards have been established that take into account the environment's bearing capacity.

In 2002, the system for manure transfer contracts will come into force. Farmers with a manure surplus will have to dispose of their surpluses by entering into contracts with farmers who have capacity and need for it.

Measures

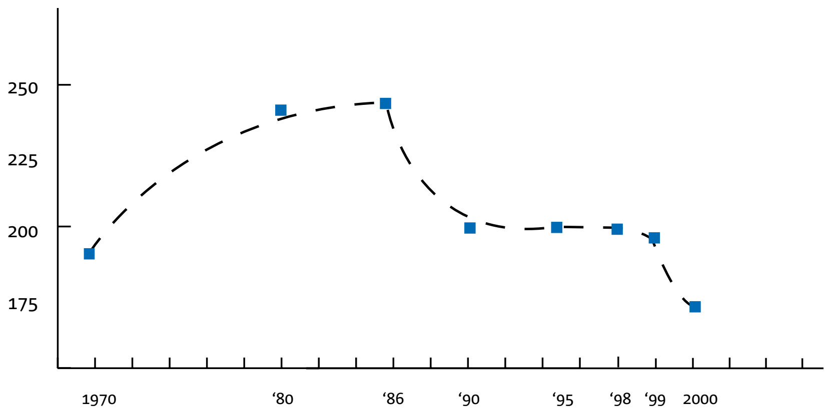
Below, we list the most important components of Dutch minerals policy:

- Severe restrictions to prevent the further expansion of the livestock population.
- A compulsory generic reduction of the pig population by 10%.
- Buying up and creaming off schemes for production rights to reduce manure production.
- Implementation of a Minerals accounting system, Minas. From 2001, all farms must submit a minerals return stating their annual mineral losses. Minas promotes measurement of real mineral losses as opposed to calculated estimates.
- Ban on applying animal manure and artificial chemical fertiliser on land in autumn and winter.
- Compulsory use of injection method for applying animal manure in order to minimise ammonia emissions.
- Compulsory covering of manure silos and storage tanks.
- Stricter requirements for ammonia emission from intensive livestock housing. Applications for environmental permits for existing or new farms are assessed largely on the existence of ammonia reducing measures.
- Strict requirements for the quality of household compost, sewage sludge and other organic fertilisers to minimise contamination of the soil with heavy metals.
- Incentives and extension programmes to stimulate good agricultural practice. There are several successful projects.

Cutting back chemical fertiliser use

Intensive information campaigns and farm consultancy (fertiliser recommendations) have contributed to an impressive reduction in chemical fertiliser use and a considerable improvement of farmers' utilisation of animal manure. Between 1986 and 1998, chemical fertiliser use dropped by 20%. In 1998, the Minerals accounting system was introduced and promptly led to a further reduction in chemical fertiliser use in that year. Currently, chemical fertiliser use has reduced

Chemical fertiliser use in the Netherlands is declining as farm minerals management improves.
Source: Milieucompendium (www.rivm.nl), RIVM/CBS, 2001



by more than 30% compared to 1986 levels. The overall impact of these products on the environment thus declines as well.

Other initiatives include manure transfer through domestic contracts or export, and on reducing the minerals content in animal manure through more balanced feed. In the latter case, changing the composition of pig feed has reduced the concentration of phosphate in pig manure by about 30%.

Surplus manure from pig and poultry farms is now also being distributed more effectively over the country. Fifteen million tonnes of manure are shipped from intensive livestock areas to regions with a low livestock density and a manure shortage. In addition, the export of poultry manure gets rid of several million kilograms of phosphate.

Field trials have been launched to improve the market for manure. Trials include experiments in animal manure composting and the development of mineral concentrates.

Monitoring

In recent years, the top water table class in farmed areas has been regularly monitored and analysed. These analyses were first carried out in sandy soil areas. There, the nitrate concentration of about 85 per cent of the top water table currently exceeds 50 mg/l.

Monitoring schemes will be intensified in the years to come in order to evaluate the effectiveness of the Minerals accounting system and to report to the European Union on the Netherlands' progress in realising the goals of the Nitrates Directive. In addition, with several pilot studies now concluded, schemes will be launched to monitor the top water table class under peaty and clayey soils.

Greenhouse gases

The greenhouse effect, or global climate change caused by ever-higher emissions of certain gases, has raised much concern around the world. Scientists generally recognise the following as greenhouse gases: carbon dioxide (CO_2), the most common greenhouse gas which is released by burning fossil fuels; methane (CH_4), and laughing gas (N_2O). Agricultural activities are currently estimated to account for 45% of methane emissions and 35-40% of laughing gas emissions in the Netherlands. Methane is released by ruminants during the digestive process. Nitrogen applications on agricultural land, either in the form of organic manure or chemical fertiliser, is a main cause of laughing gas emissions.

Over the last few years, governments from around the world have made agreements about reducing greenhouse gas emissions. The Dutch government is now studying how it could realise its commitment to this agreement. Dutch policy aims for a 6% reduction in greenhouse gas emissions expressed in CO_2 equivalents by 2008-2012. Measures are also being developed and implemented in the agricultural sector, for example stricter emission criteria for livestock housing. The aims of the system of so-called Green Label housing units, which aim to reduce ammonia emission, will therefore be broadened (see chapter 6, Preventing ammonia emissions).

The Minerals accounting system (Minas)

3

The Dutch government has developed a unique system to reduce the country's manure surplus. This system is called the Minerals accounting system, or Minas. Participation in Minas has been compulsory for all farmers since 2001. Minas will have consequences for farm management. Restrictively high levies stimulate farmers to take a pro-active attitude towards reducing their minerals surpluses.

Under Minas, farmers must keep an accurate record of mineral inputs and outputs on their farm. A minerals return, stating real phosphate and nitrogen surpluses, must be submitted annually. A levy will be raised if the surplus is to high.

The benefits of Minas

Minas has a number of benefits compared to the Netherlands' original minerals policy. The latter focused on reducing phosphate, so that nitrogen reductions were only an indirect effect of policy. In addition, Dutch policy was originally restricted to animal manure; chemical fertiliser was ignored. Finally, policy did not recognise the enormous differences in manure production and composition per species of animal. These factors can be manipulated through minerals management. Minas effectively redresses some of the shortcomings of earlier policy and stimulates good minerals management. When Minas was introduced in 1998, farmers realised they were dealing with a completely new approach of the manure policy:

1. Policy is no longer focused on phosphate alone; but explicitly includes nitrogen.
2. Policy addresses mineral surpluses as the true problem, and measures therefore apply to animal manure, chemical fertilisers and other organic fertilisers, such as compost, alike.
3. The focus of policy has shifted from specifying measures to setting targets, in this case reducing the minerals surplus. Farmers are free to decide which measures to use to reach this target, provided certain criteria are complied with, of course. For example, there are rules establishing when and how animal manure may be applied on land.

The Minas principle

Nitrogen and phosphate are components of nearly all farm products (manure, feed, crops, milk, meat and so on). Under Minas, a farmer records exactly how much nitrogen and phosphate enter his farm (are inputted) and how much leaves the farm (are outputted). The difference between mineral inputs and outputs is the farm's mineral loss, or surplus, which leaches to the environment. Each year, a farmer must complete a minerals return stating his minerals surplus.

A certain quantity of minerals is always lost when manure is applied on land or when livestock is fed. The loss standards in Minas take into account these inevitable losses. Loss standards are expressed as kilograms of nitrogen and phosphate per hectare. If a farm's mineral surplus is higher than the loss standard, the farmer will be charged a levy over the difference. The levies are so high that it is more economical for a farmer to take measures to reduce the mineral surplus than to pay the levies each year. In this way, Minas stimulates farmers to reduce their mineral surpluses. Loss standards are being tightened down to their final level in 2003.

The chart on page 10 gives a brief overview of the input and output categories of the Minerals accounting system. Farmers must report on all of these categories on their annual minerals return form.

Minas is not just a returns system. It can also be used as an aid by farmers in fine-tuning their minerals management, using those methods which best suit their own style of farm management and specific farm conditions.

Under Minas, farmers must maintain an accurate record of nitrogen and phosphate inputs and outputs, as depicted below.

INPUTS

concentrate feed
livestock
by-products
roughage
livestock manure
organic manure
chemical fertiliser
nitrogen fixation
livestock

→

FARM

↓

Inputs - Outputs =
MINERAL LOSS

→

OUTPUTS

products of animal origin
(milk, meat, eggs, etc.)
arable and vegetable crops
roughage
livestock manure

Input and output categories

Input and output categories refer to all inputs at the farmgate. In other words, Minas disregards the mineral flows within the farm system, such as the application of animal manure on land for fodder crops which are later fed to one's own herd.

The purpose of Minas is to obtain an accurate record of phosphate and nitrogen inputs and outputs on each farm. In the case of chemical fertiliser, other organic fertiliser and concentrates, data on the actual minerals content per unit of product is provided by suppliers. In the case of livestock manure, samples are analysed by an authorised laboratory to determine actual minerals content. This is a labour-intensive task as each shipment of manure must be weighed, sampled and analysed.

The mineral amounts for inputs and outputs of animals and animal products are based on given standards per animal or product unit. The minerals content of vegetable products (roughage) and crop yields (other crops) are also calculated on the basis of given standards per hectare.

Loss standards

The loss standards, that is, the allowable surpluses of phosphate and nitrogen, are lowered each year (table 1) until the objectives laid down by the EU Nitrate Directive, including the limit of 50 mg nitrate per litre of groundwater, are met.

Raising levies

Levies are to discourage farmers from exceeding the loss standards for phosphate and nitrogen. The progressively lower standards force farmers to take steps to avoid losses. One possibility is to improve the efficiency of mineral use, so that fewer inputs, such as chemical fertiliser or concentrate feed, are required. Alternatively, a farmer could buy low-minerals feed. The levies are restrictively high, particularly the levy for exceeding the phosphate limit, so that even the most expensive measure of disposing of livestock manure will pay (table 2).

Phased implementation of Minas

Compulsory minerals accounting has been introduced in phases. Minas first became compulsory in 1998 for farms with the highest environmental risk: intensive livestock farmers with more than 2.5 livestock units. In practice, this encompassed nearly all Dutch pig and poultry producers and the more intensive cattle holdings. In 2001, Minas became compulsory for all Dutch farmers: arable farmers, flower bulb growers, field vegetable growers and glasshouse growers.

Inspection and enforcement

Each year, farmers should submit a minerals return to the Levies Office of the Ministry of Agriculture, Nature Management and Fisheries on the basis of their own registration of mineral inputs and outputs. The return should be accompanied by documentation recording the inputs and outputs, such as receipts for shipments of livestock manure and laboratory reports stating the mineral contents found in samples of these shipments.
Since 2000, farms with more than 2.5 LU per hectare must

Table 1 Loss standards for phosphate and nitrogen, in kg per ha per year

Year	Phosphate loss standard		Nitrogen loss standard					
	arable land	grassland	arable land	arable land clay/peat	arable land dry sand/loess	grassland	grassland clay/peat	grassland dry sand/loess
2001	35	35	150	125	125	250	250	250
2002	30	25	150	100	110	220	190	220
2003 >	20	20	100	60	100	180	140	180

Table 2. Levies on surpluses exceeding the loss standards, in Dutch guilders and euros per kg

	2000/2001	2002	from 2003.
phosphate			
0 - 10 kg/ha	5	20 (€ 9)	20 (€ 9)
> 10 kg/ha	20	20 (€ 9)	20 (€ 9)
nitrogen			
0 - 40 kg/ha	1.50	2.50 (€ 1.15)	5 (€ 2.30)
> 40 kg/ha	1.50	5 (€ 2.30)	5 (€ 2.30)

also present audit statements to verify their declarations. Until 2000, this occurred on a voluntary basis. An audit is easily carried out because mineral inputs and outputs are usually a financial transaction as well as a mineral transaction. In other words, there is a clear connection between the farm's financial administration and its mineral records.

The Levies Office verifies returns:

- by comparing farm records: one farm's outputs (manure, roughage) are another farm's input;
- by comparing farm records to suppliers' statements;
- by looking for the presence of audit statements;
- by comparing a farm's herd administration with its minerals records.

In addition, the Ministry's General Inspection Service carries out scrutiny audits of farms and other establishments in the Minas chain, especially in cases where irregularities were found in the administrative audit. Together with the random checks, farms are likely to be inspected by the General Inspection Service once every six years. The audits by the Levies Office, on the other hand, take place on an annual basis.

An equilibrium on the market for manure

4

The government is taking far-reaching measures which must ensure that the production of animal manure is in keeping with the area of farmland on which manure can be deposited. In addition, a limit is set to the amount of manure that may be applied on a hectare of agricultural land. This limit is based on the input standard of 170 kg N per hectare laid down in the European Nitrate Directive. The Netherlands proposes a higher ceiling for grassland, to be established by derogation.

A set of measures is to prevent manure production from exceeding the amount that can be disposed of. When manure supply far outstrips demand, the risk of fraud in minerals accounts increases. The government hopes to prevent this situation by:

- introducing a system of manure transfer contracts;
- reducing the livestock population, primarily by buying up pig production rights. A smaller livestock population also produces less manure.

Pigs and poultry produce most manure

The Netherlands' sizeable pig and poultry populations are mostly kept on farms with little land. These intensive pig and poultry farmers therefore have little choice but to offer their manure to farms with a manure shortage, usually arable farmers. Using calculations made in the spring of 2001, the total surplus for 2003 is estimated at approximately 8 million kg of phosphate. This forecast is based on a total capacity for manure on all farms in the Netherlands of 158 million kg phosphate, whereas the total manure production will be reduced to 166 million kg phosphate.

Reducing livestock numbers

One of the most important ways to achieve an equilibrium in supply and demand on the manure market is to significantly reduce livestock numbers. The preferred method in the past was to cream off milk quota and manure production rights. In principle, intensive production is frozen at the current level, but farmers can still expand their holdings by buying manure production rights or pig production rights. The government creams off a certain percentage of rights sold in each transaction. This measure gradually reduces the livestock population. In addition, in 1998 the government imposed a generic reduction of 10% in pig production rights at farm level for the entire pig production sector. The government also actively buys up production rights, significantly reducing the livestock population and phosphate and nitrogen surpluses.

A limit to manure production

A ceiling has been set to the production of animal manure on a farm, effective 2003, which will bring the Netherlands in line with the European Nitrate Directive's input standard of 170 kg N/ha. The Nitrate Directive allows for derogation requests, and the Netherlands has requested a higher input standard of 250 kg nitrogen per hectare of grassland. A farmer must of course have enough land on which to deposit the manure. If manure production however exceeds the input standard the surplus must be brought to a farm with a manure shortage, or be processed or exported.

The derogation for grassland is based on several arguments. First of all, grass has a high nitrogen uptake regardless of soil type. And grass grows especially well in the Dutch climate; the growing season here is very long. Farmers can therefore apply more manure on their land without unduly burdening the environment. The standards in the Nitrate Directive which aim to protect the environment can therefore be less strict for Dutch grassland. The standards proposed by the Dutch government (see table 3) enable a national equilibrium in the supply and demand of animal manure without cost to the environment.

Table 3. Nitrogen application limit of livestock manure (in kg per hectare of cultural land)

	2002	from 2003
Grassland	300	250
Arable land	170	170
Land under maize	210	170

Table 4. Annual nitrogen production rates per animal for certain animal species (2003)

	kg nitrogen
Dairy cattle	104.7
Pork pig	7.9
Breeding pig	19.7
Laying hens (older than 18 weeks)	0.474
Broilers	0.371

Manure transfer contracts

Since 1 January 2002 farmers who produce too much livestock manure have to dispose of their surpluses by entering into contracts with arable farmers or manure processors. Farmers who are unable to dispose of their manure will have to reduce their livestock numbers.

Before entering into a manure contract, a farmer must calculate how much nitrogen is produced per animal. This calculation is based on the number of animals and a statutory fixed rate of nitrogen production per animal species. These statutory rates are laid down in the regulation which came into force on 1 January 2002. The farmer must work out how much manure can be deposited on his own land and how much he has to sell to third parties. Some of the surplus manure might be applied on a neighbouring arable farmer's land; but contracts may also be signed with authorised manure processing plants.

The following example clearly illustrates the manure transfer contracts system. In 2003 a farmer keeps 2000 pork pigs on a yearly average. The standard manure production per pork pig is 7.9 kg N. This means that the farm as a whole produces 15,800 kg N per year. The pig farmer has 10 hectares of land under maize, on which he may deposit 1700 kg N (10x170 kg N per hectare). The remaining 14,100 kg nitrogen will have to be disposed of elsewhere, for example on an arable farm with a manure shortage. The arable farmer, too, may only use 170 kg N per hectare. He therefore needs 82.9 ha of arable land.

Efficient distribution of manure

The system of manure transfer contracts will realise a more efficient distribution of manure in the Netherlands. Livestock farms with little to no land - usually pig and poultry farms or intensive dairy farms - sell their manure to farmers who produce little to no manure (arable farms or extensive dairy farms). At a national level, the system effectively ties livestock production to the land.

The system will ultimately create a balance in the supply and demand of manure, which will reduce fraudulent minerals accounting by livestock farmers desperate to get rid of manure.

Registration of plots

To monitor compliance with the new system the Levies Office has established a central registration bureau, which also records information on land. Farmers have to send data regarding their plots to this bureau every year. Only registered plots can be used in manure disposal contracts. The land registry will also aid the enforcement of nitrogen and phosphate surplus reductions on farms.

Applying fertiliser

5

In the Netherlands the Soil Protection Act provides for the protection of the soil against pollution. Under this Act rules are given for the periods when farmers may apply manure and the way it should be done. It also contains rules about the quality of sewage sludge and compost. Details of the conditions for manure application can be found in Chapter 6 'Preventing ammonia emissions'.

Soil type, soil use and status of an area
The rules govern the moment of application and manner of application. They are dependent on the situation according to:

- soil type (vulnerability to leaching)
- soil use (grassland, arable land, nature, other)
- status of an area (designated areas).

Provincial authorities can designate areas for special protection. This may be necessary to protection the soil or groundwater intended for drinking water. In such cases more stringent rules may be in force for the application of livestock manure. The period when application is allowed may also be shorter.

Rules for applying livestock manure
If livestock manure is applied in the growing season, the crop's mineral uptake is high and the risk of leaching to ground or surface waters much lower. Spring and summer are thus the most suitable periods for applying manure on the land. The government has identified some soil areas, such as sandy soils, where the soil is highly susceptible to leaching. In these areas no manure may be applied between 1 September and 1 February. This ban also applies to grassland outside these designated areas from 16 September. On arable land outside the designated areas animal manure may be applied throughout the year.

There is a permanent ban on the application of livestock manure on frozen or snow-covered land because when the thaw sets in minerals will run off fields and pollute surface water. This ban applies throughout the year and to all agricultural land. To prevent farmers applying manure in periods that it is forbidden, they must have adequate storage capacity, either on their own farm or elsewhere. A new regulation will be introduced in mid-2002 which stipulates that farmers must have a minimum of 6 months' storage capacity on their own farms.

New requirements were introduced on 1 January 2002 limiting the application of livestock manure on steep slopes (> 7%) to combat leaching in hilly areas.

Other organic fertilisers
Other organic fertilisers apart from livestock manure and chemical fertilisers are used in agriculture, such as sewage sludge and household compost. These fertilisers are also subject to government quality standards.

Maximum levels of heavy metals and arsenic also apply to these materials (see table 5). The government also regulates the quantity and way in which these fertilisers may be used (see table 6).
The rules for applying sewage sludge are the same as those for livestock manure.

Environmental assessment
An environmental assessment is currently being developed to check the quality of fertilisers that do not fall under the category of livestock manure or sewage sludge, compost or black soil and materials not recognised as fertilisers within the EU, for instance lime residues from the lime industry.
Ammonia emissions from manure are harmful for the

Table 5. Rules for the composition of sewage sludge and compost, and permissible levels in agricultural soil for the use of sludge. Maximum levels of heavy metals and arsenic in mg per kg dry matter (dm)

	Sewage sludge	Normal compost	Very clean compost	Agricultural soil example*
organic matter as % of dry matter or acid neutralising value	>50% >25	>20%	>20%	
cadmium (Cd)	1,25	1	0,7	0,45
chromium (Cr)	75	50	50	56
copper (Cu)	75	60	25	17
mercury (Hg)	0,75	0,3	0,2	0,2
nickel (Ni)	30	20	10	13
lead (Pb)	100	100	65	55
zinc (Zn)	300	200	75	61
arsenic (As)	15	15	5	17

** Permissible levels for agricultural soil (maximum content of heavy metals and arsenic). These are equivalent to the target values for clean soil. Calculated for a lutum content of 3% and a humus content of 1.5%.*
Source: Besluit kwaliteit en gebruik overige organische meststoffen (Boom)

Table 6. Maximum application of other organic fertiliser in tonnes of dry matter per hectare

	liquid sewage sludge	solid sewage	compost	very clean compost
Arable land and land under maize	2 tons/year	4 tons/2 year	6 tons/year, or 12 tons/2 year	limited by Minas standards
Grassland	1 ton/year	2 tons/2 year	3 tons/year, or 6 tons/2 year	limited by Minas standards
Other land	not allowed	not allowed	6 tons/year, or 12 tons/2 year	limited by Minas standards
Nature areas	not allowed	not allowed	not allowed	not allowed

Source: Decision on Quality and Use of Other Organic Fertilisers

Preventing ammonia emissions

6

environment, as they cause acidification and eutrophication. The primary aim of ammonia policy is to reduce ammonia emissions during the application of manure on land and emissions from manure storage tanks. Stricter requirements with respect to ammonia emissions and livestock housing for intensive production are also being drawn up and will probably come into effect in 2002. Until then, the building of low-emission housing is stimulated with incentives. In the Netherlands, local authorities are responsible for drawing up zoning plans establishing where livestock housing is allowed. By extension, these local authorities also set the environmental criteria that livestock housing in their municipality must meet.

Two-track policy

The objectives of Dutch ammonia policy are pursued along two tracks. There are general rules on manure storage and on allowed methods and periods for manure application, which aim to reduce the average ammonia concentration in the air. And there are rules addressing specific farm situations. The latter ensure that the best measures are taken in view of local circumstances. For example, when assessing environmental permit applications, local authorities must consider the desirability that a farm exists or is expanded at a particular location.

Reducing emissions during manure application

Farmers may not spread livestock manure on top of the soil, because this method is linked to unacceptably high emission levels. The Decree on the Use of Livestock Manure prescribes application methods that minimise emissions. On grassland, farmers must inject manure into the ground. On arable land, farmers must inject manure into the ground or plough it in right away.

Reducing emissions from manure storage

Livestock manure may only be applied on land during a relatively brief period, roughly in spring and summer. Farmers must have sufficient storage capacity to store manure during the rest of the year. Storing manure next to livestock housing, rather than under it, goes hand in hand with higher ammonia emissions. Outdoor storage is therefore only allowed if the manure stores concerned are covered.

Environmental licences

In the Netherlands, a farmer keeping livestock must apply for an environmental licence from the municipality where the farm is established. Licences are granted on condition that the farm satisfies all environmental criteria set by the local authorities, including criteria about ammonia emissions.

Reducing ammonia from housing

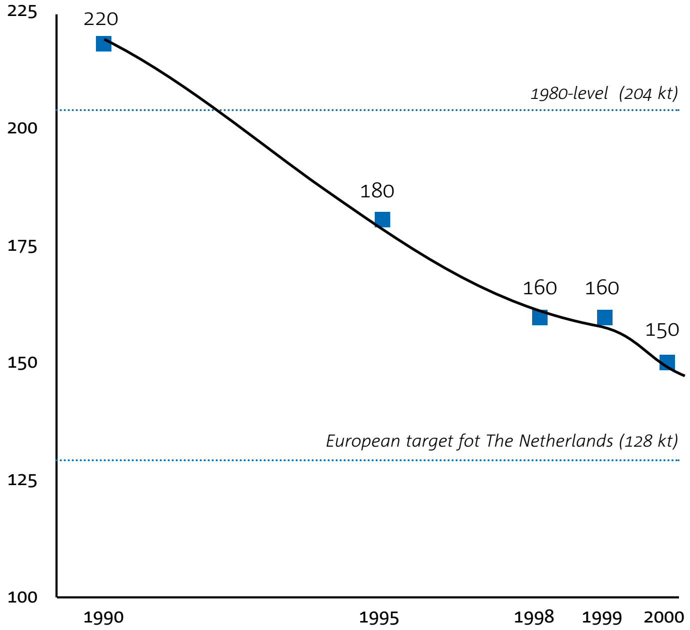
The development of low-emission housing has been encouraged in recent years with the introduction of the squality mark. The government plans to make low-emission housing compulsory in the course of 2002. In addition there will be tax incentives to encourage the use of even cleaner animal-friendly housing.

Requirements for ammonia emission apply per animal housed based on the ALARA principle (As Low As Reasonably Achievable) which balances economic costs and environmental interests. In 2008 low-emission housing will be compulsory for all pig and poultry holdings.
Stricter requirements are being drawn up for holdings near sensitive nature areas.

National emission ceiling

The countries on the European continent have agreed emission ceilings for all substances which contribute to environmental acidification. The Dutch emission ceiling for ammonia is 128 kilotonnes a year, to be achieved in 2010.

Agriculture is the greatest producer of ammonia emissions. Emissions from animal manure have been reduced significantly since 1990.
Source: RIVM/CBS (2001)



The target is laid down in the European directive on acidification, the so-called NEC directive.
The requirement that all new livestock housing must be low-emission housing is expected to have the greatest effect on the reduction of ammonia emissions to acceptable levels in the Netherlands.

Glossary

Acid deposition
The mechanisms by which acidity reaches the earth's surface. These include gaseous and particle pollutants in dry, occult or wet form.

Acidic equivalent
Pollutants differ in their acidic effect per gram. A pollutant's acidic effect is expressed in acidic equivalents.

Acidification
The process by which a soil becomes exceedingly acidic. This can be caused by the precipitation of sulphur dioxide, nitrogen dioxide and ammonia.

Agricultural Levies Office
An agency under the Ministry of Agriculture, Nature Management and Fisheries which carries out the administrative audits required under Dutch minerals policy. It also imposes levies when loss standards are exceeded.

ALARA principle
As Low As Reasonably Achievable, according to which rules and regulations are based on a balanced assessment of available technology, economic costs and environmental interests.

Ammonia emission
The emission of ammonia (NH_3) from, for instance, animal housing, manure storage or land where livestock manure is spread.

Application regulations
Rules indicating when and by what method amounts of livestock manure, sewage sludge and black earth may be spread on the land.

Central Registration Bureau
A service of the Ministry of Agriculture, Nature Management and Fisheries at which the size and use of farm land is registered.

Compound concentrate
Feed made up of various ingredients.

Deposition
Matter laid down by water or wind. The deposition of ammonia salts ($NH4^+$) for instance, has a negative impact on the environment

Derogation
Exemption or relaxation of a rule. Thus an EU Member State may assume a derogation from EU law by exceeding the maximum input of nitrogen laid down in the Nitrate Directive.

Designated areas
Areas identified under Dutch minerals policy where farmers are allowed to plough livestock manure into the soil in accordance with a prescribed low-emission technique. The areas are indicated on a map issued by the government.

Emission ceiling
Maximum amount of gas (NH3) allowed to be discharged into the air. For each EU Member State a different emission ceiling applies. For the Netherlands the target for 2010 is 128 kilotonnes.

Environmental licence
Licences to be applied for if one wishes to build or expand. Licences are granted on the condition that all environmental criteria are satisfied, including criteria on ammonia emission.

Eutrophication (1)
The process by which water or soil becomes rich in minerals, such as nitrogen and phosphorous. It often means that animal and plant communities change. In water this causes the proliferation of algae, and grasses take over on land.

Eutrophication (2)
The process by which water or soil becomes rich in minerals. When the ecological processes are disturbed the quality of drinking water diminishes.

Fixed rate return
Returns on which fixed amounts of mineral inputs and mineral outputs are given. It may be less favourable for farmers than the detailed return but is often used as it makes accounting simpler.

General Administrative Order
A national regulation

General Inspection Service
Inspection Service of the Ministry of Agriculture, Nature Management and Fisheries.

Grass invasion
Overly abundant grass growth in nature areas at the cost of wild flora. It is caused by excessive mineral levels in the soil.

Green Label Certificate
Certificate for environmentally friendly products.

Greenhouse gas
A gas that by absorbing warmth heats up the earth. Examples include CO_2, methane and laughing gas.

Input entry
Total amount of nitrogen or phosphate entering the farm (in fertiliser, livestock manure from other farms, concentrate or fodder) to be entered in the mineral ledger.

Input standard
Maximum amount of nitrogen or phosphate allowed per hectare in accordance with the EU-Nitrate Directive.

Land use declaration
Declaration stating the use of land (crops, livestock). Mostly carried out by farmer who uses someone else's land. This land must be added to his own in the mineral ledger.

Land use record card
Record card stating the number of hectares used and their purpose (grassland, arable, set-aside or nature reserve).

Laughing gas
Nitrous oxide (N_2O). Gaseous nitrogen compound often formed naturally during nitrification in the soil. It is a greenhouse gas.

Leaching
The effect of water as it moves down into the soil. The water removes mineral salts from the upper layers of the soil and carries them further down into the ground. It happens when the soil is saturated.

Livestock record card
Record card stating herd numbers.

Levies Office
See Agricultural Levies Office

Livestock Unit (LU)
Livestock Unit (LU) is a standard used to measure the manure production of various livestock species. One LU equals the phosphate production of one dairy cow.

Loss standard
See Minas-standard

Low-emission application techniques
Techniques where manure is not spread on the surface but is injected into the sod or ploughed in to prevent ammonia emission.

Low-emission housing
Animal housing where ammonia emission is lower than in conventional housing.

Manure transfer contract
Contract between a livestock farmer with a manure surplus on his farm and an arable farmer or other user of agricultural land with a manure shortage, or a manure processing establishment. These contracts allow the farmer to demonstrate that he can transfer the excess of manure produced on his farm.

Manure production right
The right to produce manure which translates into the right to keep animals. The rights may be tied to the land (the land actually used) or not, in which case it is a historical right (as with many intensive livestock farmers). In the pig and poultry sector manure production rights have been replaced by animal production rights.

Methane (CH_4)
A gas that is released during the digestive processes of ruminants or from livestock manure. Methane is a greenhouse gas.

Minas-standard
The amounts of phosphate and nitrogen in kg/ha that may be released into the environment. When losses exceed the Minas-standard a levy must be paid (Loss standard)

Mineral
A nutrient for plants and animals. Mineral use is controlled under Dutch minerals policy.

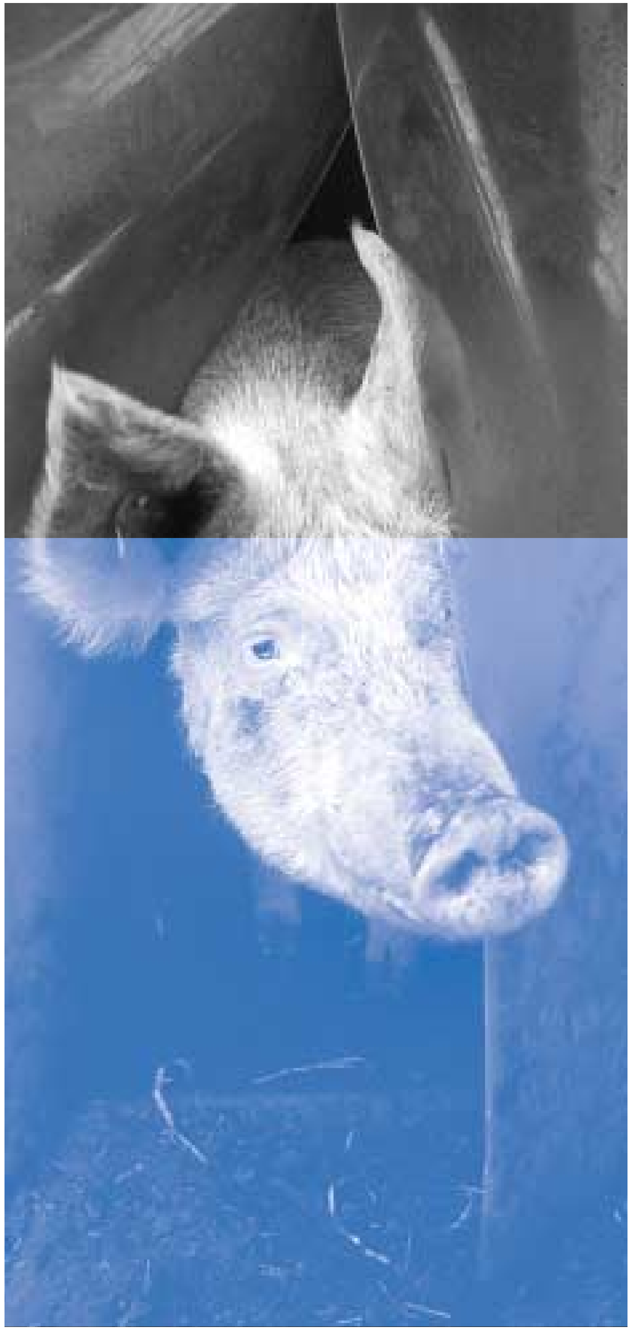
Mineral levy
A levy paid on the amount exceeding the loss standard. A punitive sum which makes it cheaper to adopt management.

Mineral loss
The amounts of phosphate and nitrogen in kg/ha that may be released into the environment.

Minerals accounting system (Minas)
Registration of the nitrogen and phosphate inputs and outputs on a farm. Input and output should be balanced although some loss is considered acceptable (loss standard). Farmers pay a levy when the loss standard is exceeded.

Monitoring
Regularly checking of the quality of soil, water and air and comparing this against targets set. Thus groundwater and surface water are monitored to check the phosphate and nitrate levels..

Nitrate
A salt or ester (organic compound) of nitric acid (see nitrogen).



Nitrate Directive
European directive to prevent nitrate pollution. EU member states must implement this directive in national law.

Nitrate standard
A quality standard. The nitrate standard for groundwater is a maximum 50 mg nitrate per litre.

Nitrogen
A nutrient for crops, often added to the soil. It may cause pollution. One of the two minerals controlled under Dutch minerals policy.

Output entry
Total amount of nitrogen or phosphate leaving the farm (in fodder, livestock manure, livestock, milk and eggs) to be entered in the mineral ledger.

Phosphate
A nutrient for crops, often added to the soil. It may cause pollution. One of the two minerals controlled under Dutch minerals policy.

Phosphate levy
Levy to be paid for the amount of phosphate used on a farm that exceeds the loss standard.

Phosphate saturation
The state when no more phosphate can be absorbed.

Sewage sludge
Accumulated solid material containing large amounts of treated water, which has been separated from waste water during processing.

Single-ingredient concentrate
Plain feed made from one single ingredient.

Target value
Environmental quality values. Values exceeding target levels pose a risk to the environment.

Trace elements
Chemical elements (such as copper or zinc) present in minute quantities in plant or animal tissues and considered essential to these organisms' physiological processes. An overdose, however, is harmful for the organism. Non-essential trace elements such as cadmium are harmful even in very low concentrations.

Vulnerable zones
Zones identified under the EU Nitrate Directive as being vulnerable to nitrate pollution through leaching or run-off.

Colophone

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The brochure 'Manure and the environment' is also available in Dutch, German, French and Spanish. Both printed and electronic versions are available. A glossary is to be found at the end of the brochure. A Danish version of the glossary is also available.
The brochure may be downloaded from the Ministry's Internet site: www.minlnv.nl.
More copies of this brochure in English or in one of the other languages may be ordered free of charge from:

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The Dutch environment is under considerable pressure from the high intensity of agricultural production here. Too much fertiliser, or more precisely too many minerals and ammonia, is being deposited into the environment. The eutrophication of surface water and the deteriorating quality of groundwater are caused largely by minerals leaching into the environment. Ammonia emissions from livestock manure are acidifying the soil and causing grass invasions in nature areas.

The Dutch government first introduced policy to combat the problem of minerals surpluses in the 1980s. The first measures were aimed at minimising the negative effects of minerals surpluses. Over the years, farmers have had to comply with progressively tighter and more comprehensive regulations and standards.