Economic Analysis of Soil Phosphorus Limits on Farms in Alberta

Toma and Bouma Management Consultants
202, 10328 - 81 Avenue
Edmonton, Alberta, Canada

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Irrigation Branch
Alberta Agriculture, Food and Rural Development
Agriculture Centre
100, 5401 - 1 Avenue South,
Lethbridge, Alberta
Canada, T1J 4V6
Phone (403) 381-5140

EXECUTIVE SUMMARY

Soil phosphorus levels due to increasing livestock populations are a growing concern in Alberta. This is a particular issue with beef feedlots and hog farms, which are typically confined livestock operations.

Excess phosphorus in agricultural land increases the risk of phosphorus loss to runoff water, and this is a major surface water quality issue. Many jurisdictions have taken action to control excess phosphorus from accumulating in agricultural land. In Alberta, the Soil Phosphorus Limits Project was established in 1999 with the main objective to develop proposed soil phosphorus limits for agricultural land in the province. One of the project's objectives was to assess the economic implications of phosphorus limits on the agricultural industry.

Objectives

The objectives of this study were four-fold:

- to assess the current Alberta livestock industry with respect to manure and related phosphorus production;
- to identify the current benefits and costs associated with livestock manure management;
- to assess the costs, limitations, and benefits of livestock manure management if phosphorus limits are implemented;
- to identify the potential impacts to the Alberta agriculture industry if phosphorus limits are implemented.

Approach

Economic analysis was carried out using two types of farms:

- a beef feedlot with a capacity of 10,000 head of finishers (two turns of cattle per year),
- a hog farrow-to-finish operation with 500 sows.

Three different phosphorus-limit scenarios were analyzed:

- **Scenario 4P –** manure spread at four times the annual phosphorus requirement of the crop. This is a 4-year rotation (manure applied on a given parcel of land once every 4 years).
- **Scenario 2P –** manure spread at twice the annual phosphorus requirement of the crop. This is a 2-year rotation (manure applied on a given parcel of land once every 2 years).
- **Scenario 1P –** manure spread to meet the annual phosphorus requirement of the crop. This requires manure to be spread on the same land every year.

In addition, one nitrogen-limit scenario was analyzed:

- **Scenario 2N –** manure spread at twice the annual nitrogen requirement of the crop. This is a 4-year rotation (manure applied on a given parcel of land once every 4 years).

Key Findings

The statistical overview of the province's livestock industry, combined with case studies, give rise to a number of observations specific to the issue of phosphorus and phosphorus loads.

- Provincial livestock populations are highly concentrated on relatively few farm operations. The statistical analysis illustrates that 1.2% of farms account for approximately 50% of all livestock. The concentrations vary by livestock sector, with 210 operations account for 73.6% of all poultry, 183 operations account for 56% of all hogs, and 73 operations account for 54% of all slaughter (feedlot) cattle.

- Livestock populations are skewed regionally and by municipality. For example, five counties account for 51% of all feedlot cattle in the province, five counties account for 43% of all dairy cattle, and five counties account for 33% of the province's hogs. Lethbridge County is included in all three groupings.

- Calculations of total manure output and associated phosphorus production illustrate that across the entire province only two counties exceed production levels of 12 kg/ha of phosphorus on cropped land. This includes Lethbridge and Ponoka. The addition of tame hay and pasture to the land base leaves only Lethbridge County in excess of this level. All other counties in the province are below 10 kg/ha of phosphorus.

- While the aggregate calculations illustrate that phosphorus loads do not appear problematic at the provincial level, a different picture emerges at the local level. Phosphorus loads are a concern in localities where large-scale individual livestock operations are situated. The case studies confirm this. Phosphorus load levels at the individual site level are observed to be as high as 489 kg/ha of phosphorus at the time of application (manure applied every 4 years). Other observations noted applications ranging from 128 kg/ha of phosphorus (every 2 years) to 353 kg/ha of phosphorus (every 4 years).

Phosphorus-limit regimes are likely to have a much greater cost impact on Alberta beef feedlots than on typical hog operations. Three key factors contribute to these added costs:

- **Added land requirements.** The analysis indicates that a phosphorus-limit regime will require substantial increases in land for the spreading of manure. The analysis suggests that increases may be in the order of 160% (1.6 additional hectares for every hectare that is currently used). On a per animal unit basis, this represents a 0.105 ha per head increase. Thus, a 25,000 head feedlot would require an additional 2,625 ha.

- **Added cost of hauling and spreading manure.** Increased costs are due to (1) increased distances that the manure will need to be hauled, and (2) decreased application rates to comply with the required phosphorus standards. As a result, spreading takes more time and becomes more expensive on a per weight basis. Actual increases will vary from farm to farm and from region to region depending upon the land availability and livestock concentrations. Overall spreading costs could increase by as much as 24% to 128% depending on the average increase in distance that the manure will need to be hauled.

- **Need to purchase commercial fertilizer to meet crop requirements.** A phosphorus-limit regime will meet plant phosphorus requirements; however, nitrogen requirements will not be met. Thus, it will be necessary to purchase additional commercial fertilizers to offset the levels formerly provided by the manure.

Specific to the phosphorus-limit alternatives within the beef feedlot sector, the 4P scenario is the least costly alternative. However, it imposes an additional annual cost of $4.06 per unit of capacity, assuming that the excess manure can be spread within 5 km of the feedlot. If manure is moved 10 km, the cost increases to $7.48 per unit of capacity and to $12.44 per unit of capacity if manure is moved 18 km.

By comparison, the 2P and 1P scenarios become even more costly. In particular, the 1P scenario is the most punitive economic solution and is calculated to cost more than $15.42 per unit of capacity each year. Furthermore, scenario 1P is not technically feasible at the present time given current equipment and spreading practices. It would require new capital investment to the extent that a wholesale change in spreading equipment is necessary, and this cost was not taken into account by this analysis.

The nitrogen-limit scenario (2N) is a lower cost alternative. It requires an added land base of 24%, but does not otherwise increase costs to the feedlot, assuming that land could be located within 5 km of the feedlot. However, under this scenario, phosphorus levels continue to build at an average annual rate of 29.6 kg/ha of phosphorus.

All the phosphorus-limit scenarios create an excess manure situation, and manure exceeds the volumes that the current land base can accommodate. This is problematic, especially if the manure has to be hauled considerable distances from the feedlot. Such a situation will likely occur in specific areas within the province where numerous feedlots operate in close proximity to each other and are already competing for land. In this case, the cost estimates generated by this study would understate the actual costs that would be experienced by individual feedlot operators.

The literature review provides an overview of the economic impacts associated with phosphorus limits. Two main themes emerge.

- Cost impacts at the farm level are highly variable. They depend on several key factors, including the nutrient content of the manure, the availability of the land on which to spread the manure, and the density of the regional livestock population within which the farm operates.

- Regional impacts are also highly variable. In this regard, the net cost impacts can range from levels that threaten the economic viability of farms within the region, to actually providing the region with a net economic benefit resulting from better manure utilization as a source of nutrients and the replacement of commercial fertilizers.

Overall, it can be concluded that excessive phosphorus loads are likely to be problematic on individual farms with large livestock concentrations and within relatively few localities. This is illustrated by the statistical analysis and the aggregate calculations of phosphorus production. Thus, it can be argued that the majority of Alberta farms and municipalities may be able to manage phosphorus loads simply by improved manure utilization on available land in close proximity to livestock operations.

However, there are localities where phosphorus loads are excessive and the availability of land due to competition from neighbouring livestock operations will make it difficult to simply spread manure on land within an economic range. This situation will create significant additional costs to the individual operation if phosphorus standards are implemented. In these cases, special measures will need to be considered to alleviate the cost pressures.

Directions for Policy Development

The findings in this report are directional in nature and require further assessment in the development of policy recommendations.

- **Quantify and qualify the environmental sustainability of a 4P strategy.** The economic analysis clearly demonstrates that a phosphorus standard that allows for the spreading of manure every 4 years is the most economic solution. This practice meets crop phosphorus requirements for four successive crops. Furthermore, it is the only practical solution in view of the limitations with current spreading equipment specific to feedlot manure. However, the environmental risks associated with this phosphorus-limit strategy need to be substantiated. It is important that a thorough risk assessment be undertaken as part of a policy recommendation.

- **Focus on optimizing manure utilization.** As a general measure, we recommend that efforts should first focus on identifying and quantifying economic solutions specific to the value of manure. The objectives are two-fold: (1) encourage producers to test manure for the purpose of establishing the nutrient value, and (2) calculate the economic range within which manure can be transported. These measures will serve to move producers toward managing manure in a more economical manner. This strategy will likely alleviate phosphorus load levels in most municipalities within the province.

- **Encourage crop producers to accept manure as an alternative to commercial fertilizer.** The most significant measure to alleviate excessive phosphorus loads is the willingness of area crop producers to accept manure. Interestingly, even in the livestock intense areas within Alberta, there is evidence to suggest that considerable crop land does not receive any manure[1]. This assessment would suggest that considerable phosphorus load pressures might be alleviated simply by creating incentives to spread manure on land in the immediate vicinity.

[1] This comment was provided by the major custom manure hauler located in Picture Butte. According to this individual, more than 50% of crop land within the immediate area does not receive any manure.

- **Develop a set of analytical tools.** Perhaps the most significant observation made in this study is the relative lack (and/or variability) of a basis for sound economic analysis. The variability in costs estimates and the relative lack of precise information are considerable.

- **Explore options and/or special measures for provincial hot spots.** There exists the possibility that some farms within the province are currently spreading manure on land that has already excessive levels of phosphorus. These situations may call for a complete moratorium on all manure spreading on these lands for an indefinite time. This is clearly problematic and would represent a significant cost to the individual farm operation, and would likely affect beef feedlots located within areas of concentrated livestock populations. The options are two-fold:

  - Spread manure to land elsewhere within the area. The analysis suggests that costs would increase an additional $12.62 per animal unit provided the land is located within a 10-km hauling range.

  - Haul and dump the manure to an alternative use site such as a biodigester or a composter. This would cost up to $15.54 per animal unit if manure is hauled within 18 km. However, the feedlot operation has the opportunity to recoup $6.37 per animal unit if the receiver of the manure pays the reloading costs. However, this study is not able to comment on the economic viability of these options.

- **Establish a nutrient management team.** The findings suggest that there is considerable opportunity to improve manure and nutrient management at the individual farm level. Consideration should be given to assembling a team of technical and economic experts that could be called on to undertake detailed on-farm assessments and develop comprehensive action plans as well as management options.

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INTRODUCTION

Alberta has grown to become a major producer of livestock within Canada and within North America. Currently it is home to more than 70% of the country's fed cattle industry, more than 40% of the national beef herd, and 20% of hog production.

In 1995, the province established the "20/10 by 2010[2]" goal for its agriculture and food industry. The goal is to establish an annual $20 billion value-added food processing industry supported by a $10 billion production sector by the year 2010. Much of the growth is expected to be generated by expansion of the beef and hog sectors.

Increased livestock populations means increased manure production. This in turn raises concerns specific to environmental sustainability, manure management practices, and nutrient runoff. The loss of phosphorus from agricultural land to surface water bodies is a major water quality concern. The movement of phosphorus from the landscape to surface water is a natural process. However, agricultural land-management practices can accelerate the loss of phosphorus and cause reduced water quality through eutrophication (Correll 1998). Increased loss of phosphorus from agricultural land is often associated with intensive livestock production (Sharpley et al. 2003). In many jurisdictions, this has led to the need to develop phosphorus standards and practices to manage phosphorus loading on the landscape in general and to better manage manure usage in particular.

The question of phosphorus standards and how these should be addressed is a major challenge facing the Alberta agri-food sector. The Agricultural Operation and Practices Act (AOPA; Province of Alberta 2001) was revised to include regulations for confined feeding operations. The act was further revised in 2004 (Province of Alberta 2004). The land application of manure in Alberta is currently based on nitrogen limits (Province of Alberta 2004). It is well known that if manure is managed based on nitrogen, phosphorus levels in soil will accumulate and this can pose a risk to surface water quality. In 1999, under the leadership of Alberta Agriculture, Food and Rural Development, the Alberta Soil Phosphorus Limits Project was initiated. The main objective of the Soil Phosphorus Limits Project was to develop proposed soil phosphorus limits for agricultural land in Alberta (Olson and Paterson 2005).

A review of approaches within several jurisdictions was carried out. The lessons learned from this review illustrated that certain regulations have the potential to impose significant costs to producers, particularly those with confined feeding operations (Soil Phosphorus Limits Committee and Landwise Inc. 2006). These costs are associated with manure storage structures, additional transportation/hauling and the possibility that some producers may have to relocate from where they currently operate due to excessive costs and/or environmental restrictions. Therefore, a second objective of the Soil Phosphorus Limits Project was to determine implications of soil phosphorus limits (Olson and Paterson 2005).

This report addresses the question of economic impacts to farming operations that may arise

[2] The goal was established by the Honourable Walter Pazkowski, Minister of Agriculture, Food & Rural Development, 1995.

from the implementation of phosphorus standards. It does not comment on what those standards should be. Rather, the study examines the broader issue of manure (and related phosphorus content) at the regional level and follows with an examination of costs at the individual farm level using a case-study approach. It is important that these findings be received as directional and not be regarded as definitive, since they are not based on a quantitative financial survey. Instead, they may be used as a basis to develop a preliminary set of policy directions that will need to be evaluated in more detail.

Study Objectives

The study addresses four objectives:

- to assess the current livestock industry in Alberta with respect to numbers, location, manure, and related phosphorus production;
- to identify the current benefits and costs of livestock manure management to producers in terms of nutrient values as well as the costs of transport and spreading;
- to assess the costs, limitations, and benefits of livestock manure management if the implementation of phosphorus limits takes place;
- to identify the potential cost impacts to the agriculture industry in Alberta that may arise from the implementation of phosphorus standards.

Study Approach

The following steps were undertaken to address the objectives.

Step 1 **Literature review –** a review of relevant economic studies and research papers specific to manure economics and the cost impacts associated with the implementation of application standards.

Step 2 **Assessment of the Alberta livestock industry** – a detailed analysis of livestock types and location by municipality (county level) and associated manure and phosphorus production.

Step 3 **Case studies** – a detailed study of nine individual farms comprising three hog operations, three dairy operations, and three beef feedlots. The case studies were selected to be representative of larger production units located throughout the province.

Step 4 **Economic analysis –** an overview of the costs and benefits associated with the transportation and application of manure at the farm level including a preliminary assessment of economic impacts at the sector level.

Step 5 **Farm level impact analysis** – a detailed analysis of the cost impacts using a representative beef feedlot and a representative hog operation. The analysis built on the case farm findings and addressed several different application scenarios and distances that manure is transported.

Step 6 **Recommendations and directions –** a set of recommendations and directions to be considered in the development of policies specific to the management of phosphorus.

BACKGROUND

The Context

During the past 50 years, agricultural specialization and intensification has resulted in a separation of livestock and crop production systems in North America and Europe. The challenge of manure management has intensified as numerous large-scale livestock operations have inadequate cropland on which to utilize the nutrients in manure. Coupled with the long-term trends of increasing numbers of animals per livestock farm (Food and Agriculture Organization 1978; Gassman and Bouzaher 1995; Council of Agricultural Science and Technology 1996) and increasing confinement of animals within housing or lots, these operations generate significant volumes of manure that create economic, social, and environmental concerns for producers and their surrounding neighbours.

The Alberta Soil Phosphorus Limits Project undertook to identify the potential impacts of phosphorus standards adaptation in Alberta (Soil Phosphorus Limits Committee and Landwise Inc. 2006). The objectives of that assessment were

- to evaluate the economic and environmental implications of phosphorus limits in Alberta,
- to evaluate mechanisms and time frames for implementation of soil phosphorus limits in Alberta,
- to identify management options to assist producers to meet soil phosphorus limits.

The report did not address the economic impacts, although several potentialities were highlighted. It was pointed out that eutrophication can cause significant negative economic impact on fisheries, recreational use of surface water, drinking water treatment costs, and health costs (Soil Phosphorus Limits Committee and Landwise Inc. 2006). In addition, potential costs at the farm level, including closures, relocation, nutrient management planning, implementation of better management practices, and conflict resolution, were identified.

Manure Economics: An Overview

Historically, the most common and efficient method of handling livestock manure has been to apply it to cropland. Clearly, this was the standard practice prior to 1940, when manure was the primary source of crop nutrients (Sharpley et al. 1999). However, with the availability of commercial fertilizer as an inexpensive substitute for manure, farmers no longer needed to rely on animal manure for crop production. This trend, combined with the increased specialization and the separation of livestock from crop enterprises, has resulted in larger individual operations and greater concentrations of operations within certain regions of the country.

Freeze and Sommerfeldt (1985) investigated the economics of hauling manure as a substitute for commercial fertilizer nearly 20 years ago. The study concluded that large farm feedlots using typical loading and spreading equipment could haul manure up to 15 km and recover all costs. Additionally, Freeze and Sommerfeldt (1985) determined that custom operators using larger equipment with lower per unit operating costs could transport manure up to 18 km. These calculations were based on the assumption that nutrients contained in the manure were equal in value to the nitrogen and phoshorus supplied by commercial fertilizer (assuming no nutrient loss and 100% availability over the long term). The study also made the observation that the nutrient content in manure is variable and it may be economic to haul manure even further distances when nutrient contents are higher. More recently, Freeze et al. (1993) reported that hauling distances could be further extended if manure was used to restore eroded soils. Based on some additional work on this subject, Freeze et al. (1999) concluded that composted cattle manure could be economically hauled about twice as far as fresh manure.

Jenner (1998) suggested that the microbial activity and organic matter in composted manure may be more valuable than the nutrient content. Further to this observation, Moncrief et al. (1999) suggested that besides the nutrient value of manure, the physical and biological qualities of manure should be considered, though it is more difficult to assign economic values on these benefits. Nevertheless, the manure producer must be able to sell the nutrient value of manure to other landowners. However, such transactions are limited by the lack of established markets for the sale of manure. Jenner (1998) suggested that the current system is flawed because the environmental and economical considerations of manure management are not aligned. However, attempts have been made to facilitate the economical distribution of manure. Burman (1998) described a manure brokering system in Iowa, United States, and Erb (1998) described a manure bartering system in Wisconsin, United States.

Jenner (1998) stated that marketing manure and manure products has the potential to provide economical and environmental benefits. He suggested a five-step approach to developing manure product markets: (1) understand the basics, (2) identify and focus on potential markets, (3) take inventory of the resources, (4) provide good technical support, and (5) assess the risks. Janzen et al. (1999) argued that manure can be a liability if managed simply as a waste for disposal, but can be an economic benefit when managed as a resource. This study suggests that manure management needs to balance the ecological and economical considerations. Using a steady-state model, Janzen et al. (1999) concluded that processed manure used on high value crops could allow break-even distribution distances of more than 300 km. Consequently, the regional distribution of manure among regions of surplus nitrogen with regions of deficient nitrogen becomes a reasonable possibility.

Cost Impacts of Phosphorus Application Standards

Several recent studies have addressed the potential cost impacts of phosphorus standards. These range from actual farm case studies to general economic impact assessments using aggregate data and applied to geographic regions or watersheds. Our background review is limited to studies conducted in Canada and the United States.

In an economic analysis of a 500-head dairy operation in Minnesota, United States, Schimmel et al. (1998) found that switching from nitrogen-based to phosphorus-based manure application caused application costs to increase by $3,754[3] but was offset with a decrease of $2,193 for reduced commercial fertilizer costs. This resulted in a net cost of $1,561 or an average of $3.12 per milking cow.

[3] All costs in the background section are reported in United States dollars.

Nagy et al. (1999) addressed the question of economic returns and hauling distances for hog and cattle manure by measuring crop response data relative to the application of manure. Using custom application rates, the study determined that hog manure could be hauled anywhere from 0.5 to 13.6 km, whereas beef manure could be hauled anywhere from 1.0 to 7.9 km. The low economic hauling distances were due to the lower crop response to the applied nutrients. Nagy et al. (1999) identified two key factors to explain the wide ranges: (1) variable soil conditions, and (2) varying nutrient content.

Innes (2000) developed a farm-scale analytical model to evaluate the economic impacts of various regulations on livestock production. The study concluded that increased size results in inefficiencies with respect to manure handling and producers will always chose to spread manure at rates that exceed crop requirements. In these instances, Innes (2000) suggests that regulating manure spreading practices might enhance economic efficiency. Interestingly, Pease et al. (1998) found that the imposition of nitrogen standards to dairy farms in Virginia increased net returns for many dairy producers, indicating the manure was being treated as a waste and not being utilized for its full nutrient potential. However, a phosphorus restriction, while optimizing nutrient use even further, reduced dairy and poultry incomes to the point of threatening the viability of the entire enterprise due to the increased spreading costs. Similarly, Babcock et al. (1997) found that compliance to nutrient standards was sufficient to hurt Iowa’s competitiveness as a hog-production state.

The question of on-farm impacts due to phosphorus-based manure management was addressed by Yap et al. (2001). Using a representative farm model, the study found that moving from a nitrogen-based policy to phosphorus-based policy reduced farmer net returns, even allowing for changes in feed rations. These findings concur with an earlier study conducted by Fleming et al. (1998), who concluded that manure application based on phosphorus levels increased costs due to the need for more land for spreading.

Fleming and Long (2002) examined the cost effectiveness of reducing the maximum permissible slope to which hog manure could be applied from 18 to 12% in Kentucky, United States. Though this study did not address nitrogen and phosphorus limits, greater restriction of hill slope has similar effects, namely, restricting the available land base and increasing transportation costs. They concluded that a more restrictive slope policy would increase manure management costs. However, they acknowledged that their investigation only considered one-half of the equation and that environmental and other economical benefits need to be considered as well.

The phosphorus index was developed in the United States as a tool to assess the relative vulnerability of potential phosphorus loss, taking into account transport and source factors (Sharpley et al. 2003). However, the phosphorus index does not account for heterogeneous benefits or costs of reducing phosphorus loading potentials (Johansson and Randall 2003). Johansson and Randall (2003) proposed incorporating economic considerations into the phosphorus index. They developed an economic phosphorus index to better target phosphorus loss reduction strategies to achieve water-quality goals at potentially lower costs. Giasson et al. (2003) also carried out a cost-benefit analysis in conjunction with the phosphorus index for a test dairy farm in New York, United States. From the various scenarios tested, they were able to select an optimum combination of practices that resulted in a 45% reduction in the area-weighted phosphorus index, while experiencing a cost increase of less than 2%.

Unterschultz and Jeffrey (2001) carried out a literature review of environmental and economic aspects of manure management in Alberta. They reported that four general approaches have been used to analyze economics of manure management: (1) opportunity costs, (2) crop benefit, (3) cost of business, and (4) business enterprise. They found that very few studies utilized a system approach for economic analysis under Alberta conditions. Studies that attempted a more complete analysis generally showed manure to be a net cost. They also found little farm-gate economic research applicable to Alberta. They recommended that future research should be directed towards economic case studies of selected farms and work towards a system analysis of manure management.

Card (2003) studied the economics of manure management in the northern part of the Lethbridge County. He used a non-linear regional profit model to assess nine scenarios, which included scenarios restricting manure application based on crop phosphorus requirements. Card (2003) concluded that regulating phosphorus application levels is the only means to avoid phosphorus build-up in soil, and there are no economic options currently available to achieve this. The most cost effective option of removing phosphorus from the region was by composting cattle manure and selling the compost to other regions. It was suggested that finding means to lower the cost of composting may result in significant benefits. It was also concluded that increases in nitrogen fertilizer costs do not have a large enough effect to prevent over-application of phosphorus, and that alternative cropping systems offered limited options.

A report written by Ribaudo et al. (2003) is perhaps the most comprehensive work available and has particular relevance to the economic impact questions faced by Alberta farmers. This analysis arose in response to growing concerns regarding the use and disposal of animal manure, which in turn is the result of recent shifts in and increased concentrations of livestock populations. Two regions were noted in particular as symptomatic of these pressures: (1) North Carolina with its high hog population, and (2) the Chesapeake Bay Watershed, which spans 66,600 farms with an estimated 3.4 million ha in 160 counties across six states.

Overall, the study encompassed an extensive review of the entire United States at the county level, by examining livestock populations and manure production in relation to cropping patterns and associated nutrient requirements. On this basis, Ribaudo et al. (2003) included three analytical components to address the range of issues and associated costs with manure disposal: farm-level, regional, and national analysis.

The study concluded that phosphorus-based standards were more costly than nitrogen-based standards due to the need for more land (Ribaudo et al. 2003). The analysis suggested that the relative cost associated with phosphorus standards would be twice that of nitrogen standards, although the cost gap would shrink if regulations allowed phosphorus to accumulate in the soil profile. The major cost impact stems from farms trying to find enough land on which to spread manure. Furthermore, it was noted that the competition for land to spread manure could be severe in regions with high concentrations of animals.

According to the study, the economic impact of moving toward a phosphorus-based standard is dependent upon the degree to which cropland land operators are willing to accept manure as a substitute for commercial inorganic fertilizers (Ribaudo et al. 2003). Further, this willingness was identified as the most important determinant of manure-spreading cost due to uncertain nutrient content, soil compaction as a result of the heavy machinery, and odour. The United States Department of Agriculture (USDA) estimated that a large percentage[4] of cropland receives no manure. If 40% of cropland accepts manure, the overall economic impact was estimated to be $1 billion (or around 3% of current production costs). If only 20% of land accepts manure, production would decrease and net effect would result in higher prices and result in a restructuring of the industry. Those producers who are left would be better off and experience a slight improvement in income (up 0.3% in net revenues). Interestingly, the crop sector would be the beneficiary with an estimated increase in returns of more than $400 million, by substituting manure nutrients for commercial fertilizer.

Significantly and perhaps not surprisingly, the report found that cost impacts varied by livestock species and by region (Ribaudo et al. 2003). For example, the Mid-Atlantic (North Carolina), where hog densities were greater and cropland not as common a land use, cost impacts were considerably higher than other regions within the country. In this region, production costs were forecasted to rise between 2 to 3%. By comparison, hog farms in the Corn Belt would be virtually unaffected for two reasons: (1) livestock densities were substantially lower in comparison to the Mid-Atlantic, and (2) there was generally more cropland growing crops such as corn that require relatively high nutrient levels.

Dairy operations were forecasted to experience a 3% increase in production costs as a result of a phosphorus-based standard. However, production cost increases for small and medium sized livestock operations (defined as less than 1000 animal units[5]) were estimated to be approximately 1% (Ribaudo et al. 2003).

Specific to on-farm impacts, Ribaudo et al. (2003) presented a number of interesting conclusions specifically to the phosphorus-based standards. These are presented as follows.

Hog farms

- Only 21 of all large hog farms (more than 1000 animal units) have enough land to meet a phosphorus-based standard.
- Large farms would have to spread on an additional 405 ha to meet standards. Farms in the west would have to increase 750 ha (up 1,300%) and farms in the south would have to increase an average of 280 ha (up 396%).
- Costs were estimated to increase by as much as 5% for large hog producers (ranging from $1.60 to $27.30 per animal unit).
- Some small farms could experience a cost reduction of $4 per animal unit by spreading to meet standards.
- Costs were lower in the Corn Belt where land to receive manure is more available.

[4] USDA estimated that in 2000, manure was applied to 15% of corn, 10% of soybeans, and 3% of wheat.
[5] An animal unit is defined as one slaughter or feeder head of cattle, or 0.7 mature dairy cow, or 2.5 hogs weighing in excess of 25 kg, or 30 laying hens or broilers.

Dairy farms

- An estimated one-quarter of all large dairies have an adequate land base to meet a nitrogen-based standard. However, only 2% of these dairies would have enough land to meet a phosphorus standard.
- Large farms in the south would have to increase the amount of land by 526%, while farms in the north would need to increase land by 405%.
- Cost increases on a per animal unit for large dairies ranged from $74.10 to $88.20.
- Increased net costs were estimated to increase by 3.25% for large farms, while less for smaller farms.
- Additional manure hauling costs constituted more that 90% of the cost increase.

Overall costs for meeting standards were closely related to how much manure must be moved off the farm. It was also noted that the cost of compliance could instigate structural and geographical shifts to the extent that the highest per unit costs for meeting a nutrient standard were often borne by the largest operations (Ribaudo et al. 2003).

The case study of the Chesapeake Bay Watershed determined that a phosphorus-based standard would require nearly 75% of the available land base (1.9 million ha out of 2.7 million ha of crop and pasture) (Ribaudo et al. 2003). Currently an estimated 10 to 20% of cropland receives manure. The total costs of management, transport, and application were estimated to peak at $155 million (or $79.79 per applied hectare) and an estimated $25 to $35 million higher than with a nitrogen-based standard. This translated to an added cost of $12.85 to $18.04/ha. However, the potential savings in commercial fertilizer were estimated at $60 to $80 million (or $31.38 to $41.19/ha).

Lory et al. (2004) carried out a study of 39 hog operations in east-central United States, where they compared nitrogen and phosphorus limits based on crop requirements. The phosphorus crop requirements were applied as annual phosphorus limits and as rotation phosphorus limits. The rotation phosphorus limit approach was an application of phosphorus not to exceed a 4-year removal capacity of the crop with no further application until the excess phosphorus had been removed by crop harvest. They found that 2.5 times more land was required for phosphorus limits and time required to apply manure increased 24% for rotation phosphorus limits and 41% for annual phosphorus limits. They also determined that phosphorus limits increased the value of manure, but hog operations would have to recover at least 61% of the fertilizer value of manure through manure sales at fertilizer value.

Keplinger et al. (2004) developed a manure transportation model to simulate manure application behaviour in United States livestock production regions. The model seeks to minimize the cost of crop nutrients by drawing from available supplies of manure and/or commercial fertilizer. The core challenge identified by the study was how to effectively deal with increasing supplies of manure in livestock production regions where demand for that manure has not grown. Furthermore, if manure is applied at rates to supply all three key macronutrients (nitrogen, phosphorus, potassium), two of the macronutrients will generally be over-applied.

Interestingly, the model of Keplinger et al. (2004) projects surprisingly large maximum travel distances within which it remains economical to haul manure (58 km for dairy manure, 60 km for hog manure, 312 km for broiler litter). However, the study concluded that actual manure utilization behaviour differed markedly from the optimal solutions generated by the model. This was attributed to three reasons: (1) the uncertainty with respect to nutrient content, (2) uneven distribution of manure, which impacts crop response, and (3) the imperfect nature of manure markets including other ‘transaction costs’ or lack of information that restricts observed maximum hauling distances to less than those predicted in the analysis.

Implications for Alberta

The literature review provides a body of knowledge from which to develop a better understanding of the potential cost impacts of phosphorus standards. Two key themes emerge that have particular relevance for Alberta.

- **Cost impacts at the farm level are highly variable.** They depend on several key factors including the nutrient content of the manure, the availability of the land on which to spread the manure, and the density of the regional livestock population within which the farm operates.
- **Regional impacts are also highly variable.** In this regard, the net cost impacts can range from levels that threaten the economic viability of farms within the region, to actually providing the region with a net economic benefit as a result of better manure utilization as a source of nutrients and the replacement of commercial fertilizers.

There appears to be limited study of the beef feedlot sector in terms of either farm level or regional economic impact analysis. Most of the work to date has concentrated on areas with high hog concentrations (Mid-Atlantic) or high poultry concentrations (Chesapeake Watershed). Significantly, both these regions have high human populations. Similarly, the dairy sector tends to operate in relative proximity to the major urban centers. By comparison, the feedlot sector is concentrated in the western parts of Kansas and Nebraska, as well as the Texas panhandle. These regions have relatively low human populations and may to date not have been subject to the same degree of public and political pressures experienced in the aforementioned areas.

ASSESSMENT OF THE ALBERTA LIVESTOCK INDUSTRY

Livestock Numbers and Distribution by Size Class

The size and location of the Alberta livestock industry was analyzed by examining three factors:

- livestock numbers by species (beef, dairy, hogs, and poultry),
- distribution by farm size in terms of numeric categories for each species,
- location by municipality as defined by County or Special Area.

A special tabulation of Statistic Canada data was requested for this purpose. Highlights of this analysis are presented below. Tables 1 to 6 present the number of farms by size class for cattle, slaughter cattle, dairy cattle, sows, hogs, and, poultry, respectively.

Table 1. Alberta cattle: Farms reporting and number of animals by size class.

Alberta - total cattle	Number of farms	Number of cattle
Total cattle and calves	31,774	6,615,201
1 to 999 head total cattle	31,108	4,353,000
1,000 to 4,999 head total cattle	573	1,052,368
5,000 to 9,999 head total cattle	58	384,609
10,000+ head total cattle	35	825,224

Table 2. Alberta slaughter cattle: Farms reporting and number of animals by size class.

Alberta - slaughter cattle, 1 year and over	Number of farms	Number of cattle
Total slaughter cattle - 1 year and over	9,229	1,753,107
1 to 999 head slaughter cattle	8,933	371,541
1,000 to 4,999 head slaughter cattle	223	453,946
5,000 to 9,999 head slaughter cattle	44	293,953
10,000+ head slaughter cattle	29	633,667
Heifers for slaughter or feeding, 1 year and over	3,815	761,553
Steers - 1 year and over	7,698	991,554

Table 3. Alberta dairy cattle: Farms reporting and number of animals by size class.		
Alberta - dairy cattle	Number of farms	Number of cattle
Total Dairy cattle	1,521	122,529
1 to 49 head dairy cattle	674	5,245
50 to 99 head dairy cattle	309	23,008
100 to 149 head dairy cattle	262	31,065
150 to 199 head dairy cattle	134	22,771
200+ head dairy cattle	142	40,440
Dairy cows	1,422	84,044
Heifers for dairy herd replacement, 1 year and over	1,063	38,485

Table 4. Alberta sows: Farms reporting and number of animals by size class.		
Alberta - sows	Number of farms	Number of sows
Sows and gilts for breeding	1,613	200,478
1 to 199 head sows	1,311	49,816
200 to 499 head sows	229	70,086
500 to 999 head sows	54	34,286
1,000+ head sows	19	46,290

Table 5. Alberta hogs: Farms reporting and number of animals by size class.		
Alberta - hogs	Number of farms	Number of hogs
Total hogs	2,677	2,027,533
1 to 999 head total hogs	2,162	302,880
1,000 to 2,999 head total hogs	332	582,359
3,000 to 4,999 head total hogs	104	404,895
5,000+ head total hogs	79	737,399

Table 6. Alberta poultry: Farms reporting and number of animals by size class.		
Alberta - poultry	Number of farms	Number of animals
Total poultry	5,488	13,259,607
1 to 9,999 birds total poultry	5,131	1,292,454
10,000 to 19,999 birds total poultry	147	2,117,060
20,000 to 39,999 birds total poultry	115	3,206,022
40,000+ birds total poultry	95	6,644,071
Total hens and chickens	5,055	12,175,246
Turkeys	945	864,438
Other poultry	1,516	219,923

A summary of the distribution of farm numbers is shown in Table 7.

Table 7. Summary of farms reporting by large size category and numbers.

Livestock type	Total number of farms reporting	Large size category	Number of farms in the large size category [z]	Proportion of all livestock represented by large size category (%)
Beef: All cattle	31,774	5,000 or more head	93	18.3
Slaughter cattle	9,229	5,000 or more head	73	53.9
Dairy cattle	1,521	200 or more head	142	33.0
Hogs	2,677	3,000 or more head	183	56.3
Poultry	5,488	20,000 birds or more	210	73.6
Totals	**50,689**		**628**	

[z] The column totals to 701 farms; however, the 73 farms with slaughter cattle are double counted and are also included in the 'Beef: All cattle' category. Thus, the actual total of large farms is 628.

The distribution illustrates that a very small number of farms account for a sizeable proportion of the total livestock population. In fact, the data infer that just 628 farms account for approximately 50% of all livestock. By livestock type, 210 poultry farms account for 73.6% of the entire poultry population, 183 hog operations account for 56% of the hog population, and 73 feedlots account for 54% of the feeder cattle population.

The top five counties for each livestock type are listed as follows.

Beef cattle	Lethbridge	583,531 head
	Newell	267,255 head
	Ponoka	244,063 head
	Foothills	238,917 head
	Wheatland	208,903 head
Slaughter cattle	Lethbridge	462,593 head
	Newell	149,837 head
	Foothills	103,835 head
	Wheatland	97,349 head
	Taber	79,349 head
Dairy cattle	Lethbridge	13,468 head
	Leduc	10,776 head
	Ponoka	10,680 head
	Lacombe	10,528 head
	Red Deer	6,810 head
Hogs	Wheatland	149,329 head
	Lacombe	164,821 head
	Lethbridge	132,195 head
	Red Deer	107,865 head
	Kneehill	104,930 head

Poultry	Kneehill	1,048,664 birds
	Camrose	1,037,585 birds
	Lacombe	405,252 birds
	Ponoka	386,798 birds
	Mountain View	332,383 birds

The spatial distribution of the major populations of livestock by municipality is presented in Table 8.

Table 8. Location of major livestock populations by top five counties.

Livestock type	Top five counties	Population within the top five counties	Provincial population	Percentage of provincial population within the top five counties
Beef	Lethbridge, Newell, Ponoka, Foothills, Wheatland	1,542,668	6,615,201	23.3
Slaughter cattle	Lethbridge, Newell, Foothills, Wheatland, Taber	892,963	1,753,107	50.9
Dairy	Lethbridge, Leduc, Ponoka, Lacombe, Red Deer	52,262	122,529	42.6
Hog	Wheatland, Lacombe, Lethbridge, Red Deer, Kneehill	659,140	2,027,533	32.5
Poultry	Kneehill, Camrose. Lacombe, Ponoka, Mountain View	3,210,682	13,259,607	24.2

Two observations are apparent:

- A small number of farms account for a large proportion of the livestock in Alberta. For example, 628 farms (or 1.2%) of all farms account for nearly 50% of the entire livestock population.
- Livestock populations are spatially concentrated in a few areas. For example, the top five counties account for 50% of all slaughter cattle, nearly 43% of all dairy cattle, and one third of the hog population. By comparison, beef cattle (predominately beef cows and calves under 1 year) and poultry are more broadly distributed throughout the province.

Manure Production

An analytical model, which calculates manure production by livestock species, was developed to determine the levels of manure production occurring in Alberta. The model comprises the following components.

- Number of livestock by type for each census division and municipality.
- Manure production coefficients on a per head basis as per the AOPA regulations (Province of Alberta 2004).
- Calculated nitrogen and phosphorus outputs based on AOPA manure nutrient content

(Province of Alberta 2001).

- Levels of nitrogen and phosphorus on a per cropped hectare using crop area as per Statistics Canada.

This was conducted simply to explore the magnitude of manure and associated phosphorus production. An overview of the calculations by census division is presented in Table 9.

Table 9. Manure production and related nitrogen and phosphorus per cropped hectare by census division.

Census division	Total manure production (tonnes)	Manure (tonnes/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)
Division No. 15	20400.37	4.07	43.97	9.68
Division No. 2	3821640.44	5.09	37.99	9.48
Division No. 8	3209169.64	5.90	37.44	9.36
Division No. 9	341168.07	4.15	35.42	8.35
Division No. 14	212093.21	2.99	27.74	6.42
Division No. 3	1392243.06	3.04	22.85	5.66
Division No. 13	1724147.13	2.69	19.76	9.96
Division No. 11	1749314.14	2.77	19.44	4.60
Division No. 4	1044549.62	2.25	16.57	4.20
Division No. 12	735218.74	1.88	16.40	3.98
Division No. 5	2156876.09	2.27	14.06	3.73
Division No. 1	773220.92	1.85	13.36	3.36
Division No. 7	1703991.72	1.80	13.36	3.31
Division No. 10	1792958.19	1.53	11.73	2.96
Division No. 18	164048.82	1.31	11.56	2.82
Division No. 6	765723.81	1.28	11.07	2.70
Division No. 17	364143.70	0.64	5.63	1.36
Division No. 19	482632.48	0.54	4.72	1.14

Phosphorus Production per Cropped Hectare

The calculated levels of nitrogen and phosphorus per cropped hectare are presented in Table 10. This table lists the top 10 counties in descending order based on phosphorus levels. It can be seen that Lethbridge County, which has the largest livestock populations in the province, is the leading municipality in terms of 17.41 kg of phosphorus per cropped hectare, followed by Ponoka County at 13.21 kg, and Newell County at 11.63 kg.

Table 10. Manure production and related nitrogen and phosphorus per cropped hectare: Top 10 counties.				
County/regional municipality	Total manure production (tonnes)	Manure (tonnes/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)
Lethbridge County	1911640.81	9.14	70.88	17.41
Ponoka County	1032451.05	7.85	54.24	13.21
Newell County	712315.97	5.61	47.72	11.63
Ranchland	8391.87	4.30	46.88	10.23
Barrhead County	664490.36	5.98	35.67	9.19
Lacombe County	1095721.97	6.52	35.42	9.06
Clearwater County	341168.07	4.15	35.42	8.35
Pincher Creek	328182.52	3.98	34.16	8.35
Bighorn	10157.65	3.33	36.06	7.93
Special Area No. 2	622761.52	4.32	29.52	7.58

Phosphorus Production per Crop, Tame Pasture, and Seeded Pasture Hectare

An additional set of calculations was made using an area base, which included crops, tame pasture, and seeded pasture. This expanded land base reduced the calculated rates of nitrogen and phosphorus. For example, in Lethbridge County, the calculated phosphorus levels dropped to 16.50 kg/ha (Table 11). Ponoka County dropped to a level of 9.06 kg/ha, followed by Newell County at 8.18 kg/ha. All other municipalities fall below 8.0 kg/ha.

Table 11. Manure production and related nitrogen and phosphorus loads for the top 10 counties by phosphorus per total hectares of crop, tame pasture, and seeded pasture.				
County/ municipality	Total manure production (tonnes)	Manure (tonnes/ha of crop, tame and seeded pasture)	Nitrogen (kg/ha of crop, tame and seeded pasture)	Phosphorus (kg/ha of crop, tame and seeded pasture)
Lethbridge County	1911640.81	8.67	67.13	16.50
Ponoka County	1032451.05	5.38	37.25	9.06
Newell County	712315.97	3.93	33.54	8.18
Lacombe County	1095721.97	5.09	27.64	7.06
Pincher Creek	328182.52	3.26	27.96	6.82
Barrhead County	664490.36	4.32	25.74	6.64
Foothills	457630.49	2.52	25.83	6.15
Red Deer County	1078743.24	3.51	23.14	5.78
Bighorn	10157.65	2.22	23.98	5.26
Special Area No. 2	622761.52	2.96	20.16	5.19

Distribution of Large Farms by Top Ten Counties

Finally, we undertook to analyze the number of large livestock farms located in the top 10 counties[6] as defined by the production of manure produced per cropped hectare (Table 10). The number of farms by livestock type and the total number of animals represented by those farms within the county is presented in Tables 12 to 19.

Table 12. Lethbridge County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals	Percent of total animals in the county [z]
Cattle (5,000 + Animals total cattle)	32	376,695	64.55
Dairy (150 + Animals dairy cattle)	40	9,286	68.95
Hogs (3,000 + Animals total hogs)	7	53,375	40.38
Poultry (20,000 + birds total poultry) [z]	26	1,387,504	96.76

[z] Percent of total animals calculated using total chickens and hens, instead of total poultry due to data suppression.

Table 13. Ponoka County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	% of total animals [z]
Cattle (5,000 + animals total cattle)	1	x	x
Dairy (150 + animals dairy cattle)	24	5,774	54.06
Hogs (3,000 + animals total hogs)	5	x	x
Poultry (20,000 + birds total poultry)	7	x	x

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

Table 14. Newell County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	Percentage of total animals [z]
Cattle (5,000 + animals total cattle)	5	x	x
Dairy (150 + animals dairy cattle)	7	1,464	56.29
Hogs (3,000 + animals total hogs)	6	x	x
Poultry (20,000 + birds total poultry)	5	x	x

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

[6] Only eight counties are listed. The other two counties listed in the top 10 include Ranchland and Bighorn. However, due to confidentiality, no further breakdown of the number of farms in each category is available.

Table 15. Barrhead County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	Percent of total animals [z]
Cattle (5,000 + animals total cattle)	1	x	x
Dairy (150 + animals dairy cattle)	8	x	x
Hogs (3,000 + animals total hogs)	3	x	x
Poultry (20,000 + birds total poultry)	6	x	x

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

Table 16. Lacombe County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	Percent of total animals [z]
Cattle (5,000 + animals total cattle)	1	x	x
Dairy (150 + animals dairy cattle)	31	6,995	66.44
Hogs (3,000 + animals total hogs)	15	92,879	56.35
Poultry (20,000 + birds total poultry)	6	x	x

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

Table 17. Clearwater County: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	Percent of total animals [z]
Cattle (5,000 + animals total cattle)	0	0	0
Dairy (150 + animals dairy cattle)	1	x	x
Hogs (3,000 + animals total hogs)	0	0	0
Poultry (20,000 + birds total poultry)	1	x	x

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

Table 18. Pincher Creek: Farms reporting and number of animals by largest size classes.

Livestock category	Number of farms	Number of animals [z]	Percent of total animals [z]
Cattle (5,000 + animals total cattle)	4	x	x
Dairy (150 + animals dairy cattle)	2	x	x
Hogs (3,000 + animals total hogs)	2	x	x
Poultry (20,000 + birds total poultry)	3	83,800	54.12

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

Livestock category	Number of farms	Number of animals[z]	Percent of total animals[z]
Cattle (5,000 + animals total cattle)	3	x	x
Dairy (150 + animals dairy cattle)	2	x	x
Hogs (3,000 + animals total hogs)	3	x	x
Poultry (20,000 + birds total poultry)	0	0	0

Table 19. Special Area No. 2: Farms reporting and number of animals by largest size classes.

[z] "x" denotes that less than five operations fall into this category. To protect confidentiality, Statistics Canada does not report the actual number of head associated with these producers.

CASE STUDIES

Introduction

To better understand current manure management practices and associated costs, nine case studies were undertaken. The selected case studies were representative of the larger livestock operations in the province and were comprised of those livestock types that are generally regarded as the major manure producers, such as hog operations, dairy farms, and beef feedlots. Nine case studies were conducted, comprising three case studies within each of the three major livestock types.

All nine case studies were located in the Highway 2 corridor. Specific locations are not identified to protect the confidentiality of the co-operating producers. Further we normalized[7] one case study to protect confidentiality. Again it must be emphasized that the case study findings are directional in nature since the number of observations are too few to state conclusions with any statistical validity. Nevertheless, patterns emerge and a number of observations were made.

The case study data are presented as follows.

- Hog case studies – Tables 21 to 24.
  - Case 1: Farrow-to-finish operation operating on two sites and composting feeder pig manure.
  - Case 2: Farrow-to-finish operation operating on three sites (one farrowing site and two finishing sites).
  - Case 3: Farrow-to-finish operation operating on a land base that is farmed by a third party crop producer.

- Dairy case studies – Tables 25 to 29.
  - Case 1: Operator who spreads manure twice daily – year round.
  - Case 2: Operator who manages a dairy herd and a beef cow-calf herd.
  - Case 3: Operator who farms on irrigated land.

- Beef feedlot case studies – Tables 30 to 34.
  - Cases 1 and 3: Both approximately 10,000 head. Manure is spread directly on the land.
  - Case 2: Feedlot and beef cow herd. Manure is stockpiled for a period of 6 months before spreading.

[7] By normalizing, the data from one beef feedlot were converted to a 10,000-head equivalent.

Hog Case Studies

Table 20. Livestock size for hog case studies.

Livestock	Case 1	Case 2	Case 3
Sows – farrow to wean (F to W)	240 (1 site)	2,500 (1 site)	
Sows – farrow to finish (F to F)			700
Feeders	2,000 (1 site)	7,500 (2 sites)	

Table 21. Land availability for manure application for hog case studies.

Land area	Case 1	Case 2	Case 3
Total land (ha)	1,135	1,295	777
Owned (ha)	567	907	388
Leased (ha)	568	388	388
Total crops (ha)	1,114	1,215	777
Land available for manure (ha)	1,114	1,215	777
Land use for manure (ha)	65 – for F to W 40 – for feeders	810 each year	195 each year

Table 22. Manure management and systems for hog case studies.

Manure system	Case 1	Case 2	Case 3
Sows – F to W	Liquid lagoon	Liquid lagoon	
Sows – F to F			Liquid Lagoon
Feeders	On straw - compost	Liquid lagoons	
Capacity	7 months	Sow site – 18 months Site 2 – 18 months Site 3 – 9 months	Several years
Application	Fall	Mostly fall	Fall
Test manure	No	Yes	No
Estimated costs	Total estimate[z]: $24,000 for F to F $21,100 for feeders	Estimate $10 per sow; and total of $30,000 for feeders	Estimate $25,000 to $35,000/year depending on distances
Fertilizer adjustment	Purchase 56 kg/ha less nitrogen No change in phosphorus	Fertilize to crop requirements	No compensation or adjustments

[z] Calculated as follows: (1) Farrow to finish: 40 days at 6 hours/day at $100/hour = $24,000, (2) Feeders – Custom Costs - $3,600 plus 35 days at 5 hours/day at $100/hour = $21,100.

Table 23. Estimate of phosphorus (P) loads for hog case studies.

	Case 1	Case 2	Case 3
Total manure production [z]	1.8 million litres of liquid 2,720 tonnes of solid	Sows – 18.5 million litres; feeders – 19.5 million litres Total: 38.4 million litres	16.8 million litres
P (kg/tonne)	1.1 for liquid 1.5 for solid	1.1	1.1
Total P (kg)	1,980 from liquid 4,080 from solid	41,800	18,480
Land area (ha)	65 (sow site) 40 (feeder site)	810	195
P applied (kg/ha)	30.5 for sow site 102.0 for feeder site 4-year rotation	51.6 2-year rotation	94.8 4-year rotation

[z] Manure production based on AOPA coefficients unless estimated by producer.

Table 24. Estimate of haulage costs for hog case studies.

	Case 1	Case 2	Case 3
Total manure (tonnes)	4,520	38,000	16,800
Estimated costs	\$24,000 for liquid \$21,100 for solid	\$55,000	\$25,000 to \$35,000
Average cost (\$/tonne)	Liquid: \$13.33 Solid: \$7.75	\$1.45	\$1.48 to \$2.08
Radius of haul (km)	< 3	< 5	< 5

Dairy Case Studies

Table 25. Livestock size for dairy case studies.

Livestock	Case 1	Case 2	Case 3
Milking cows	170	75	135
Dry cows	50	23	35
Heifers/calves	160	65	130
Other	50 Steers	25 Beef cows and 162 calves/steers	

Table 26. Land availability for manure application for dairy case studies.

Land area	Case 1	Case 2	Case 3
Total land (ha)	810	516	194
Owned (ha)	259	65	194
Leased (ha)	551	451	
Total crops (ha)	648	516	194
Land available for manure (ha)	810	516	194
Land used for manure (ha)	130 (pasture/hay ground)	49	32 to 40 mostly on corn

Table 27. Manure management and systems for dairy case studies.

Manure system	Case 1	Case 2	Case 3
Dairy cows	Collect daily and spread	Press system Contained storage	Earthen lagoon
Replacements/calves	Bedding pack on 6-week cycle	Bedding pack	Bedding pack
Other	Liquid wash tank		
Capacity	7 months	6 months	7 months
Application	Daily	Mostly fall; bedding pack spread every 6 weeks in summer	Spring and fall
Test manure	No	No	No
Estimated costs	$21,900 for cows; $22,880 for other $9,600 for dairy wash. Total: $54,380	Estimate $10,000 per year ($100 per cow) of which $3,900 are custom fees	Custom costs - $8,640 Own costs - $3,300 Estimate $12,000/year
Fertilizer adjustment	No use of manure on field crops	Adjust for manure Best manure on corn land Use 30% less fertilizer on barley	Don’t fertilize barley Apply to corn but add more nitrogen

Table 28. Estimate of phosphorus (P) loads for dairy case studies.			
	Case 1	Case 2	Case 3
Total manure production [z]	7.14 million litres for cows 244 tonnes of solid	Dairy – 2,728 tonnes of solid manure Beef – 269 tonnes of solid manure	Estimated: Cows - 6 million litres Other – 494 tonnes
P (kg/tonne)	0.9 in liquid 2.4 in solid	0.9 in dairy 2.4 in beef	0.9
Total P (kg)	7,007	3,101	5,845
Land area (ha)	130	49	36
P applied (kg/ha)	53.9 Every year	63.3 4-year rotation	162.4 4-year rotation

[z] Manure production based on AOPA coefficients unless estimated by producer.

Table 29. Estimate of haulage costs for dairy case studies.			
	Case 1	Case 2	Case 3
Total manure (tonnes)	7,384	2,997	6,494
Estimated Cost	$54,380	$10,000	$12,000
Average cost ($/tonne)	$7.36	$3.34	$1.85
Radius of haul (km)	< 1	< 6	< 1

Beef Case Studies

Table 30. Livestock size for beef case studies.

Livestock	Case 1	Case 2	Case 3
Feedlot cattle	10,000	8,000	12,000
Cows		1,500	

Table 31. Land availability for manure application for beef case studies.

Land area	Case 1	Case 2	Case 3
Total land (ha)	562	648	709
Owned (ha)	337	583	514
Leased (ha)	225	65	195
Total crops (ha)	562	648	709
Land available for manure (ha)	562	648	709
Land use for manure (ha)	281/year (2-year cycle)	162/year (4-year cycle)	177/year (4-year cycle)

Table 32. Manure management and systems for beef case studies.

Manure system	Case 1 [z]	Case 2 [z]	Case 3 [z]
Feedlot	Bedding pack	Bedding pack	Bedding pack
Other		Stockpile and allow to compost	
System	Clean twice a year	Clean once a year	Some spring cleaning
Capacity	Not an issue	Not an issue	Not an issue
Application	Spring and fall	Spring and fall	Fall
Test manure	Random sample for moisture, N and P	Test for nutrient content	No
Estimated costs	Estimate: $8 per head	Estimate: $6 per head plus grooming at $0.50 per head	Estimate $5 to 6 per head ($12 per unit of capacity)
Fertilizer adjustment	Soil test and fertilize accordingly. Use little or no fertilizer on barley	Only apply additional N No purchase of P and K Estimate savings of $100/ha on manured land	Do not fertilize. Check soils for N and may apply if necessary in Year 4

[z] N = nitrogen, P = phosphorus, K = potassium.

Table 33. Estimate of phosphorus (P) loads for beef case studies.			
	Case 1	Case 2	Case 3
Total manure production (tonnes) [z]	Estimated: 15,000	33,000	26,000
P (kg/tonne)	2.4	2.4	2.4
Total P (kg)	36,000	79,200	62,400
Land area (ha)	281	162	177
P applied (kg/ha)	128	489	353
	2-year rotation	4-year rotation	4-year rotation

[z] Manure production based on AOPA coefficients unless estimated by producer.

Table 34. Estimate of haulage costs for beef case studies.			
	Case 1	Case 2	Case 3
Total manure (tonnes)	15,000	33,000	26,000
Estimated costs	$120,000	$100,000	$132,000
Average cost ($/tonne)	$8.00	$3.03	$5.08
Radius of haul (km)	< 8	< 1.6	< 5

Case Study Observations

The case study data provided the basis for a number of observations as follows.

- Overall phosphorus loads on a per hectare basis varied widely. These ranged from a low of 30.5 kg/ha phosphorus on the site of one hog operation to a high of 489 kg/ha phosphorus on a beef feedlot site.
- Generally, phosphorus loads were highest among beef feedlots and ranged anywhere from 128 kg to 489 kg/ha phosphorus at the time of application. (Note: the 489 kg/ha application was part of a 4-year rotation and could be considered the equivalent of 122 kg/ha/year).
- Phosphorus loads among the dairy case studies were lower and ranged from 53.9 kg/ha phosphorus up to 162 kg/ha phosphorus. The latter application was part of a 4-year rotation on irrigated land. Phosphorus loads were also lower among the hog case studies, ranging from 30.5 to 102 kg/ha phosphorus at the time of application. The latter was on a 4-year rotation.
- Of the nine case studies, three operations (2 dairy and 1 hog) had a substantial land base, and this was much larger than the land base required to accommodate the annual manure production. Four case studies (2 feedlots, 1 hog operation, and 1 dairy operation) applied manure to land on a 4-year rotation. The remaining two case studies (1 feedlot and 1 hog operation) applied manure as part of a 2-year rotation.
- Only one case study (a hog operation) tested manure for nutrient content on a systematic

and regular basis. This individual approached manure as a source of nutrients and managed crop requirements accordingly by means of regular soil and crop-tissue tests. Two feedlots tested manure for moisture and nutrient content from time to time. The remaining six case studies did not test.

- All the case studies employed soil tests that were typically conducted by their farm/fertilizer supplier as part of a broader program. On most operations, little or no fertilizer was applied to manured land, with the exception of additional nitrogen, which may have been applied in subsequent crop years (typically year three or four within a 4-year rotation).
- Overall, the case study participants prescribed an economic value to the nutrients provided by the manure. However, the exact value is less precise. A number of estimates were provided, such as “56 kg/ha less nitrogen” to “no use of fertilizer on barley” to savings ranging from \$120 to \$240/ha. In all cases, it was recognized that the nutrients supplied by the manure fully replace (or largely replace) any nutrients that would otherwise need to be supplied by commercial fertilizer. One case study participant was able to directly compare a block of land he farmed some distance from his feedlot versus land in the vicinity of his feedlot. In the case of the former, he purchased an average of \$158.13 of fertilizer for each hectare of barley versus no fertilizer costs on the latter.
- The issue (and challenge) of manure economics generated some interesting commentary. Most agreed that the economics associated with manure are very inexact and perhaps a relatively underdeveloped management practice. There are several factors that contribute to this situation. Firstly, nutrient content is not well known and/or can be highly variable. Secondly, the economics of how far one can transport are rather inexact and are dependent upon a number of variables including nutrient content, moisture content, and the efficiency of the equipment. Thirdly, it is difficult to establish a value to provide incentives for neighbouring crop producers to use manure as a crop nutrient instead of commercial fertilizer. Interestingly, subsequent to the 2002 drought, it was observed that liquid manure applied to barley crops notably out produced fertilized crops and this has drawn interest and more demand for manure.
- Manure hauling costs varied among operations. They ranged from \$1.45/tonne to \$13.33/tonne. It was also apparent that estimated costs provided by those operators who spread their own manure, were higher than those operators who used custom operators. For example, the highest cost (\$13.33/tonne) was experienced by a hog producer who spent 40 days and an average of 6 hours/day spreading liquid manure. Another high cost case was a dairy producer who spread manure on a daily basis at a cost of \$7.36/tonne. By comparison, those producers using custom operators on a one time per year basis had costs in the \$1.45 to \$3.35/tonne range, assuming that the manure was spread within a range of 5 km. The variable costs and associated economics are discussed further in the ‘Establishing a base for economic analysis’ section of this report.
- The case study participants generally agreed that the cost of hauling manure doubled when the haul distance reached a range of 5 to 6 km (one way) in comparison to spreading in areas adjacent to the manure storage site. In other words, to achieve the same volume of manure spread per hour, one would need to double the number of trucks when hauling this distance, hence double the cost.
- The degree of concern with respect to manure and associated phosphorus loads varied considerably by participant and is very much dependent upon the land base in question.

As previously mentioned, the three case studies with substantial land holdings (owned and/or rented) had no concern and in fact voiced a position that they could easily use much more manure. Of the remaining six case studies, four operators were comfortable with their current manure management practices, while the two beef feedlots acknowledged that applications are high and potentially problematic. However, in the case of the latter, there are no penalties or apparent direct costs with current practices.

- Interest in new technologies and/or manure management practices also varied among the case studies depending upon land base. Several of the case-study operators have analyzed and/or considered a number of options including composting (stockpiling) or bio-digesters, to name two. There was a considerable interest in the latter; however, two main concerns prevail: (1) the capital cost, which is thought to be substantive;[8] and (2) the yet to be proven operations of the technology itself. For example, there are very few working digesters in western Canada, and it is known that operations in cold weather conditions are problematic as well as costly. Furthermore, the comment was made that sourcing objective information is a challenge.
- Other options that were being considered included the use of phytase in hog feed to reduce phosphorus outputs, technologies (i.e., genetic engineering) that enhance phosphorus uptake by crops, growing higher 'nutrient use' crops such as corn, the move to composting to enable more efficient transportation (making longer hauls affordable), and technologies that can process potable water from liquid manure.
- Overall, the case participants expressed strong concerns toward any policies that do nothing but add costs to their operations. Margins are already low and any new costs will erode an already stressed financial situation. Thus, any measures considered should first explore the possibility of improving returns to producers. To this end a number of practical suggestions were offered.
    - Encourage optimal nutrient use from manure with more rigorous testing.
    - Develop incentives to encourage transactions between livestock producers and crop producers.
    - Improve the quality of the manure by taking such measures as removing salt and ensuring freedom from weed seeds.
    - Encourage cluster development of bio-digesters in intense areas of livestock.
    - Allow for 'net metering' that will enable a contributor to the electricity grid to sell power without transaction charges.
    - Develop composting solutions. For example, there are opportunities to ship composted manure in Lethbridge County to nearby potato land. Incentives may be required to facilitate these transactions.

[8] One case-study participant suggested that a bio-digester for a large sow operation could cost anywhere from $2 to $5 million with a 5- to 7-year payback at best. He indicated it would be better to invest in another production facility with a more certain return.

ESTABLISHING A BASE FOR ECONOMIC ANALYSIS

Loading and Spreading Costs

The most critical factor impacting the economics of manure is the cost associated with loading and spreading. The case studies in the previous section provided a wide range in hauling cost ($1.34 to $13.33/tonne; Table 35).

Table 35. Hauling costs at the farm level.

Case study	Manure system	Hauling cost ($/tonne)	Haul radius (km)
Case 1a: Hogs	Liquid	$13.33	< 3 spread by operator
Case 1b: Hogs	Solid	$7.75	< 1.5 but composted
Case 2: Hogs	Liquid	$1.45	< 5
Case 3: Hogs	Liquid	$1.48 to $2.08	3 to 5
Case 1: Dairy	Liquid/solid	$7.36	<1 spread daily by operator
Case 2: Dairy	Liquid/solid	$3.34	< 6
Case 3: Dairy	Liquid/solid	$1.85	< 1
Case 1: Feedlot	Solid	$8.00	< 8
Case 2: Feedlot	Solid	$3.03	< 1.6 with stockpiling
Case 3: Feedlot	Solid	$5.08	< 5

The variability is due to numerous factors, including type of manure, average distance hauled, as well as the costs assigned to time and equipment by individual operators. As noted in the previous section (Case studies), those operators employing custom services appear to have lower costs. As well, these costs appear to lie within a narrower range.

To this end, we spoke with two major custom spreaders of manure and arrived at the custom rates for liquid manure typical of hog and dairy operations (Table 36) and for solid manure typical of beef feedlots (Table 37).

Each custom operator was first asked to estimate the total cost[9] of applying manure to land adjacent to the source of the manure. This estimate was used as the base cost. Subsequently, the custom operator was asked to determine how far manure could be hauled at double the cost.

Costs for some additional haul distances were also provided. For example, the liquid custom

[9] Total cost is defined as all costs including loading, hauling, and spreading.

hauler hauled a maximum distance of 13 km, which was another doubling of the cost (or four times the cost of hauling to adjacent land). In the case of the solid manure custom hauler, a 16-km haul estimate was provided, and this was 40% higher than the 6-km estimate due to the use of paved roads (and higher speeds).

Table 36. An estimate of custom rates for liquid manure.

Distance (one way)	Cost per 1 million litres	Tonnes	Cost per tonne February 2006
Adjacent land	$1,769	1,000	$1.77
5.6 km (the doubling point)	$3,538	1,000	$3.53
8 km	$4,549	1,000	$4.54
13 km	$7,077	1,000	$7.07

Table 37. An estimate of custom rates for solid manure.

Distance (one way)	Total cost	Tonnes	Cost per tonne February 2006
Adjacent land	$18,900	6,400	$2.95
5 km	$29,500	6,400	$4.61
6.4 km (the doubling point)	$35,400	6,400	$5.53
16 km	$48,300	6,400	$7.55

Interestingly for both manure types, the doubling point occurred in the range of 5.6 to 6.4 km. This is consistent with the case study estimates.

It should also be noted that the solid manure custom hauler charges on an hourly basis determined by the equipment complement employed. Thus, the numbers provided above are general estimates. Detailed cost estimates for the spreading of liquid and solid manure by varying distances and application rates are presented in Appendix 1.

The Economics of Hauling Manure

The economics of hauling manure for each livestock species was determined by establishing the following.

- Transportation coefficients for a kilogram of nitrogen and phosphorus. To this end, we used the custom rates as presented in Tables 36 and 37 for liquid and solid manure, respectively.

- Comparative value of commercially delivered and applied nitrogen at $1.09/kg.[10]
- Comparative value of commercially delivered and applied phosphorus at $0.69/kg.[11]

These values provide the basis to calculate breakeven points to determine the distances that manure can be transported before it becomes more economical to purchase commercial fertilizers.

For each livestock type, several scenarios were examined. These are described as follows.

Scenario 1 Assumed that phosphorus was 80% available. This is the base case.

Scenario 2 Assumed that phosphorus availability ranged between 40% and 90%.

Scenario 3 Assumed that the price of nitrogen fertilizer increases 40% and the price of phosphorus fertilizer increases 10%. Phosphorus was assumed to be 40% available.

Scenario 4 Assumed nitrogen and phosphorus contents of liquid hog and dairy manure were variable and ranged from 20% less than the AOPA coefficients to 80% higher than the AOPA coefficients (these are examined in increments of 20%).

A summary of the key findings is presented in Table 38 followed by the detailed calculations for the hog, dairy, and beef scenarios.

Table 38. Economic range of hauling manure under differing assumptions.

Scenario	Description	Liquid hog manure (km)	Liquid dairy manure (km)	Feedlot manure (km)
1	Phosphorus availability at 80%	4.29	3.89	11.13
2	Phosphorus availability at 40%	2.43	2.35	4.99
3	Nitrogen price up 40%, and phosphorus price up 10%	7.07	6.21	18.82
4	Varying nitrogen and phosphorus content	Up to 10.15	Up to 9.66	see note [z]

[z] Beef manure is assumed to have a constant nutrient content for Scenario 4 since solid manure tends to be more consistent than liquid manure.

[10] Based on 46-0-0 price FOB dealer of $481.67/tonne plus delivery and application charge of $18.0/tonne for a total of $499.67/tonne.
[11] Based on 11-51-0 price FOB dealer of $452.11/tonne plus delivery and application, charge of $18.00/tonne for a total of $470.11/tonne.

It was observed that the scenarios generated a wide economic range for each livestock species.

- For hog manure, the economic range varied from 2.43 km (phosphorus availability at 40%) to 10.15 km (nitrogen, phosphorus content up 80%).
- Dairy manure was slightly lower in value than hog manure. The analysis above illustrates that it can be hauled economically from 2.35 to 9.66 km depending upon nutrient content and nutrient values.
- Beef feedlot manure can be economically transported the furthest (a range of 4.99 to 18.82 km) depending upon phosphorus availability and nutrient content.

Clearly, as the prices of nitrogen and phosphorus increase, it becomes more economic to transport manure greater distances.

Perhaps the most significant conclusion that can be drawn is the degree of variability in the economic range for hauling manure. Actual calculations at the individual farm level will depend upon three factors:

- actual nutrient content of the manure,
- the availability of the nutrients to the crop in question,
- the cost of haulage.

This information is vital to perform precise economic calculations at the farm level.

Hauling hog manure: Scenario 1 - phosphorus availability at 80%.

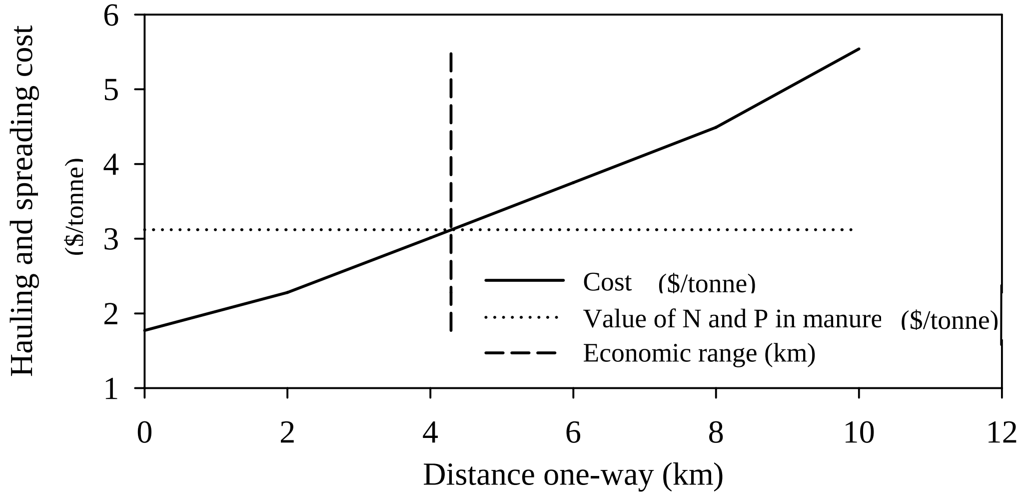

Fig. 1. Economic range for hog manure.

Table 39. Economic range for hog manure – phosphorus 80% available.

	Distance one-way (km)					
	Adjacent	2	4	6	8	10
Cost of hauling and spreading ($/tonne)	1.77	2.28	3.01	3.75	4.49	5.54
Value of N and P in manure ($/tonne)	3.12	3.12	3.12	3.12	3.12	3.12
Price of purchased N ($/kg)	1.09	1.09	1.09	1.09	1.09	1.09
Price of purchased P ($/kg)	0.69	0.69	0.69	0.69	0.69	0.69
Economic range one-way (km)	4.29	4.29	4.29	4.29	4.29	4.29

Notes

- Adjacent refers to land next to where the manure is stored.
- Distance at which the cost of spreading and hauling is equal to the economic value is 4.29 km one-way.
- Nitrogen and phosphorus values were based on current fertilizer prices. Content of crop nitrogen and total phosphorus value per tonne were taken from the Alberta Agricultural Operation Practices Act (Province of Alberta 2001).
- Costs were based on spreading rates of 85 to 100 tonnes/ha.

Hauling hog manure: Scenario 2 - varying the availability of phosphorus.

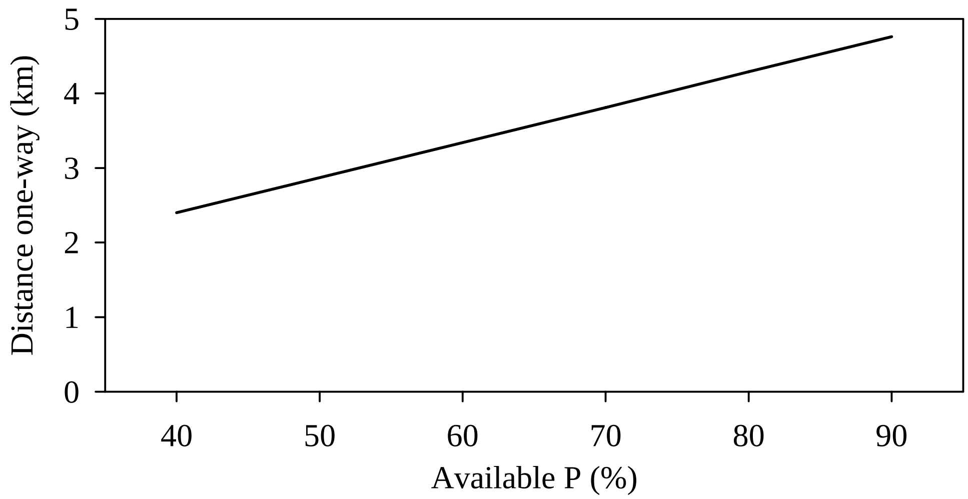

Fig. 2. Economic range for hog manure by varying the availability of phosphorus (P).

Table 40. Economic range for hog manure by varying the availability of phosphorus.

	Available phosphorus (%)					
	40	50	60	70	80	90
Economic range one-way (km)	2.40	2.87	3.34	3.81	4.29	4.76
Cost of hauling and spreading ($/tonne)	2.43	2.60	2.78	2.95	3.12	3.30

Phosphate in manure is present in mineral and organic forms. The amount available to a crop in the following year varies with the rate of manure breakdown and is generally considered to be at least 50%. Phosphate tends to bind tightly to the soil, and in time most may become available. The value of phosphorus in manure, as applied, should be considered to be in the range of 85 to 95% of the full value.

Hauling hog manure: Scenario 3 - varying the price of nitrogen.

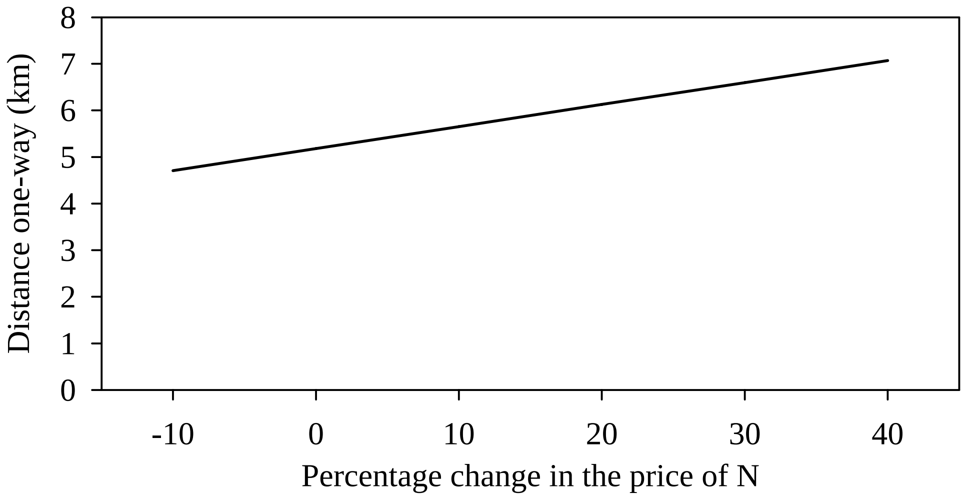

Fig. 3. Economic range for hog manure by varying the price of nitrogen (N).

Table 41. Economic range for hog manure by varying the price of nitrogen.

	Percentage change in nitrogen price					
	-10	0	10	20	30	40
Economic range one-way (km)	4.71	5.18	5.65	6.13	6.60	7.07
Cost of hauling and spreading ($/tonne)	3.28	3.45	3.63	3.80	3.97	4.15

Notes

- Phosphorus price assumed to increase 10%.
- Prices of urea have risen by an average of about 9% per year for the past 5 years. Urea prices are very closely correlated to natural gas prices, and thus are quite volatile, with a year-to-year price differential of 29% between 2000 and 2001. Phosphate prices have been less volatile, with the average yearly price rising about 2% per year over the past 5 years, and the maximum year-to-year price differential being about 9% between December 2004 and December 2005.

Hauling hog manure: Scenario 4 - varying the nutrient content.

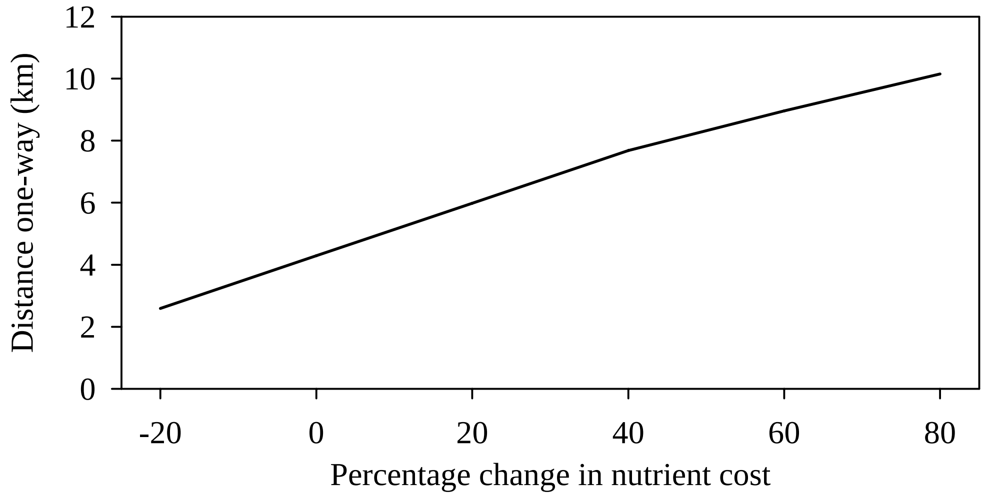

Fig. 4. Economic range for hog manure by varying nutrient content.

Table 42. Economic range for hog manure by varying nutrient content.

	Percentage change in nutrient content					
	-20	0	20	40	60	80
Economic range one-way (km)	2.59	4.29	5.98	7.68	8.96	10.15
Cost of hauling and spreading ($/tonne)	2.50	3.12	3.75	4.37	5.00	5.62

Research work, as well as anecdotal field reports, indicates there is considerable variance in the nutrient content of hog manure. As with manure in general, with hogs - the richer the feed the richer the manure in terms of nutrients. The manure from feeder pigs is higher in nutrients than that from sows. Moreover, the manure from feeder pigs has a lower water content and this has the effect of raising the percentage of nutrient content in the manure.

As Fig. 4 illustrates, the nutrient percentage of liquid manure is an important determinant of the economic distance that it can be transported, and hence the value of testing.

The above example shows economic hauling distances up to 10 km with a nitrogen content that is 80% higher than what is specified in the AOPA tables. Research indicates these can be normal levels of nitrogen and phosphorus in feeder hog manure.

Hauling dairy manure: Scenario 1- phosphorus availability at 80%.

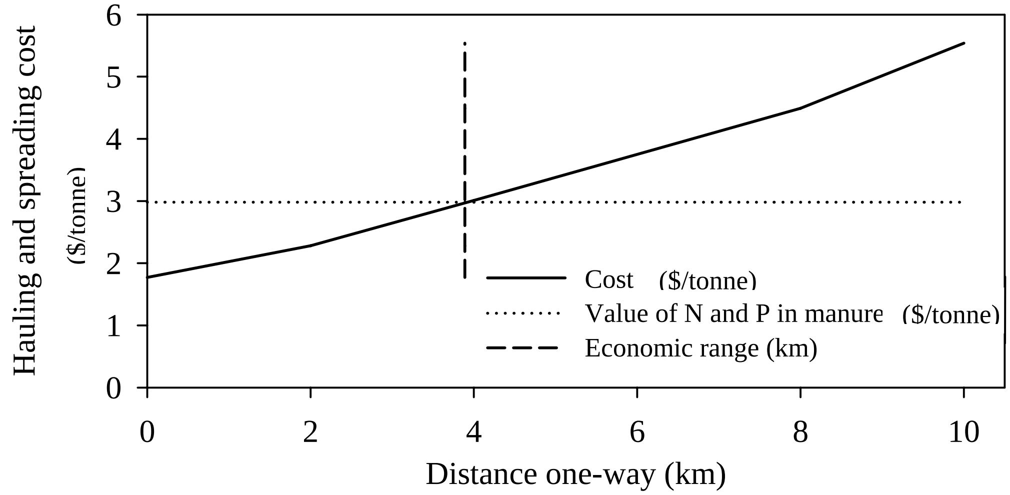

Fig. 5. Economic range for dairy manure.

Table 43. Economic range for dairy manure – phosphorus 80% available.

	Distance one-way (km)					
	Adjacent	2	4	6	8	10
Cost of hauling and spreading ($/tonne)	1.77	2.28	3.01	3.75	4.49	5.54
Value of N and P in manure ($/tonne)	2.98	2.98	2.98	2.98	2.98	2.98
Price of purchased N ($/kg)	1.09	1.09	1.09	1.09	1.09	1.09
Price of purchased P ($/kg)	0.69	0.69	0.69	0.69	0.69	0.69
Economic range one-way (km)	3.89	3.89	3.89	3.89	3.89	3.89

Notes

- Adjacent refers to land next to where the manure is stored.
- Distance at which the cost of spreading and hauling is equal to the economic value is 3.89 km one-way.
- Costs were based on spreading rates of 85 to 100 tonnes/ha.

Dairy farms are typically smaller than hog farms in terms of animal units. The case studies suggest that the economic range within which land is available for the spreading manure was not an issue. Dairy farms need about one-half a hectare per cow for manure application, and there would rarely be a problem given the economic spreading range is up to about 3.89 km one-way.

Hauling dairy manure: Scenario 2 - varying the availability of phosphorus.

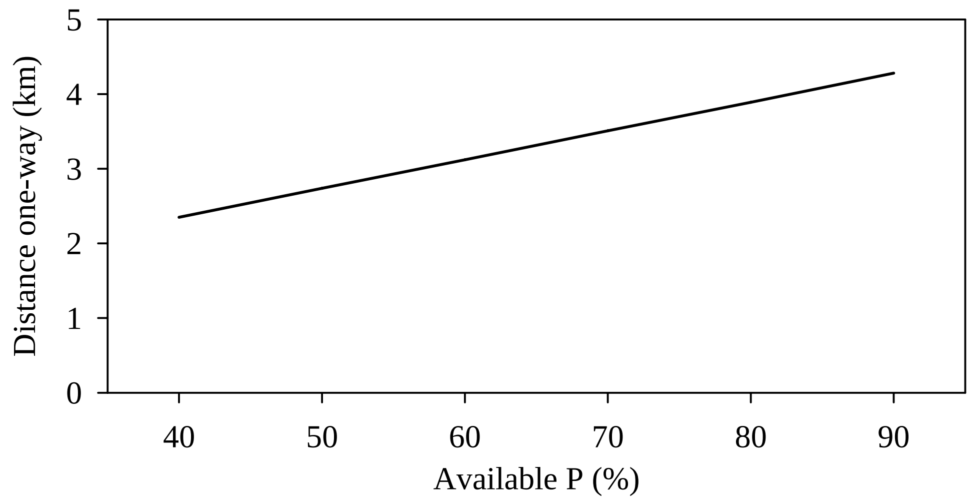

Fig. 6. Economic range for dairy manure by varying the availability of phosphorus (P).

Table 44. Economic range for dairy manure by varying the availability of phosphorus.

	Available phosphorus (%)					
	40	50	60	70	80	90
Economic range one-way (km)	2.35	2.74	3.12	3.51	3.89	4.28
Cost of hauling and spreading ($/tonne)	2.41	2.55	2.70	2.84	2.98	3.12

Phosphorus levels were slightly lower in dairy manure than in hog manure. As a consequence, the economic range for hauling dairy manure was slightly less.

Phosphate in manure is present in mineral and organic forms. The amount available to a crop in the following year varies with the rate of manure breakdown, and is generally considered to be at least 50%. Phosphorus tends to bind tightly to the soil, and in time most may become available. The value of phosphorus in manure, as applied, should be considered to be in the range of 85 to 95% of the full value.

Hauling dairy manure: Scenario 3 - varying the price of nitrogen.

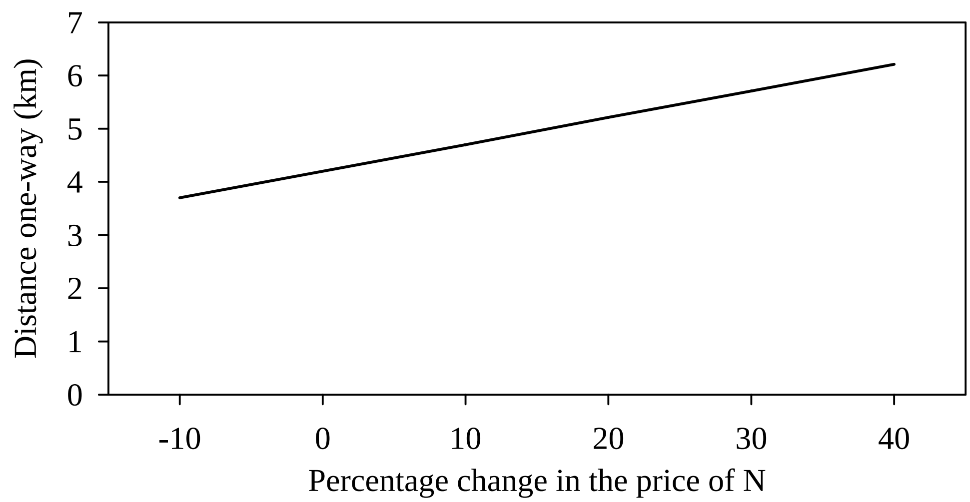

Fig. 7. Economic range for dairy manure by varying the price of nitrogen (N).

Table 45. Economic range for dairy manure by varying the price of nitrogen.

	Percentage change in nitrogen price					
	-10	0	10	20	30	40
Economic range one-way (km)	3.70	4.20	4.70	5.21	5.71	6.21
Cost of hauling and spreading ($/tonne)	2.91	3.09	3.28	3.46	3.65	3.83

Notes

- Phosphorus price assumed to increase 10%.
- Dairy manure has a slightly higher level of crop-available nitrogen than hog manure, although hog manure has more total nitrogen.

Hauling dairy manure: Scenario 4 - varying the nutrient content.

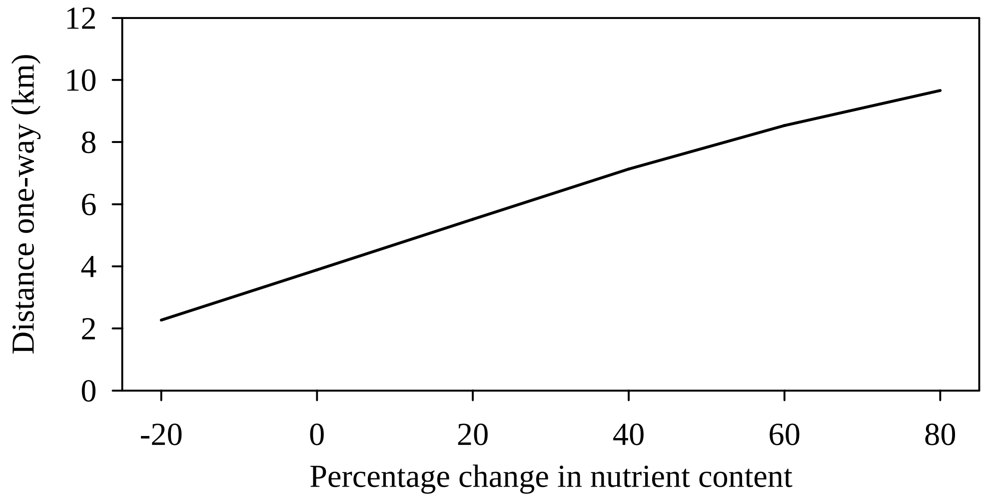

Fig. 8. Economic range for dairy manure by varying nutrient content.

Table 46. Economic range for dairy manure by varying nutrient content.

	Percentage change in nutrient content					
	-20	0	20	40	60	80
Economic range one-way (km)	2.27	3.89	5.51	7.13	8.53	9.66
Cost of hauling and spreading ($/tonne)	2.38	2.98	3.58	4.17	4.77	5.36

Research from sources other than AOPA tables provides some different nutrient coefficients in the content of dairy manure. For example, Ontario Ministry of Agriculture and Food tables showed content levels of 1.68 kg/tonne nitrogen and 1.4 kg/tonne phosphorus.

In practice, much variation can be accounted for by differences in handling of wash water. Water conservation practices can keep the manure as concentrated as possible, thus increasing the economic range.

Hauling beef feedlot manure: Scenario 1 – phosphorus availability at 80%.

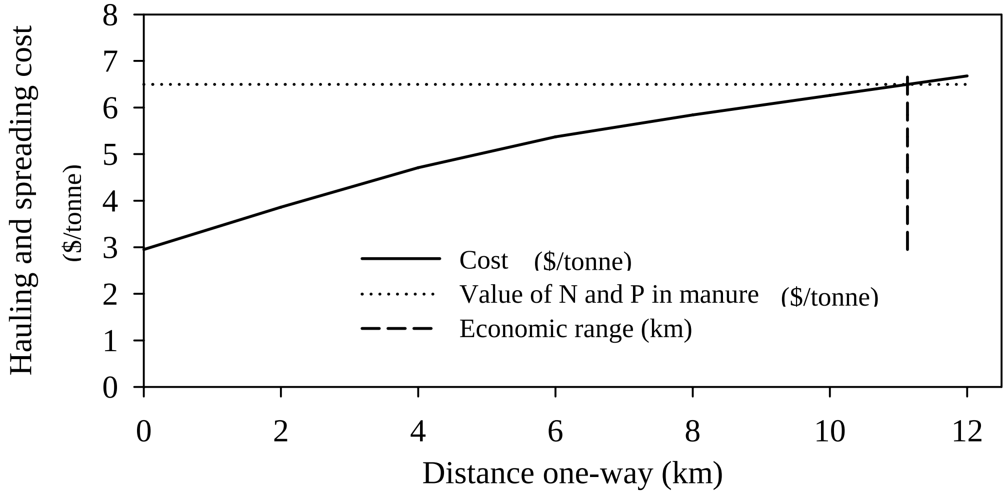

Fig. 9. Economic range for beef feedlot manure.

Table 47. Economic range for beef feedlot manure – phosphorus 80% available.

	Distance one-way (km)						
	Adjacent	2	4	6	8	10	12
Cost of hauling and spreading ($/tonne)	2.95	3.86	4.71	5.37	5.84	6.26	6.68
Value of N and P in manure ($/tonne)	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Price of purchased N ($/kg)	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Price of purchased P ($/kg)	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Economic range one-way (km)	11.13	11.13	11.13	11.13	11.13	11.13	11.13

Notes

- Adjacent refers to land next to where the manure is stored.
- Distance at which the cost of spreading and hauling is equal to the economic value is 11.13 km one-way.
- Value of nitrogen and phosphorus in manure was calculated at $6.50/tonne using current prices of urea and mono-ammonium phosphate as a basis. The distance at which the cost of hauling and spreading is equal to the nitrogen and phosphorus value is approximately 11.13 km one-way.
- Costs were based on spreading rates of 100 to 140 tonnes/ha.

Hauling beef manure: Scenario 2 - varying the availability of phosphorus.

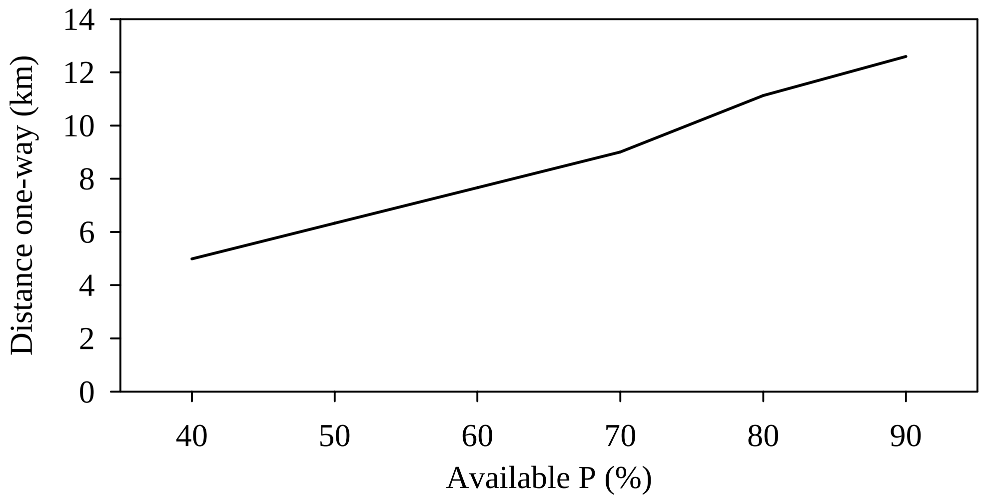

Fig. 10. Economic range for beef feedlot manure by varying the availability of phosphorus (P).

Table 48. Economic range for beef feedlot manure by varying the availability of phosphorus.

	Available phosphorus (%)					
	40	50	60	70	80	90
Economic range one-way (km)	4.99	6.33	7.66	9.00	11.13	12.59
Cost of hauling and spreading ($/tonne)	4.99	5.37	5.74	6.12	6.50	6.88

Phosphate in manure is present in mineral and organic forms. The amount available to a crop in the following year varies with the rate of manure breakdown, and is generally considered to be at least 50%. Phosphate tends to bind tightly to the soil, and in time most may become available. The value of phosphorus in manure, as applied, should be considered to be in the range of 85 to 95% of the full value.

Hauling beef manure: Scenario 3 - varying the price of nitrogen.

Fig. 11. Economic range for beef feedlot manure by varying the price of nitrogen (N).

Table 49. Economic range for beef feedlot manure by varying the price of nitrogen.

	Percent change in urea price					
	-10	0	10	20	30	40
Economic range one-way (km)	10.58	12.23	13.88	15.52	17.17	18.82
Cost of hauling and spreading ($/tonne)	6.46	6.80	7.15	7.50	7.85	8.19

Notes

- Phosphorus price assumed to increase 10%.
- Prices of urea have risen by an average of about 9% per year for the past 5 years. Urea prices are very closely correlated to natural gas prices, and thus are quite volatile, with a year-to-year price differential of 29% between 2000 and 2001. Phosphate prices have been less volatile, with the average yearly price rising about 2% per year over the past 5 years, and the maximum year-to-year price differential being about 9% between December 2004 and December 2005.

FARM LEVEL IMPACTS

Introduction

Potential changes and/or restrictions to manure management practices are a primary concern to Alberta farmers. This is a particular concern to beef feedlots and hog operations, which are characterized by large livestock populations in confined areas.

Current regulations in Alberta for manure application are based on nitrogen limits. However, the application of manure based on nitrogen limits results in accumulation of excess phosphorus in soil. To reduce or prevent the accumulation of excess phosphorus, manure management practices based on phosphorus limits typically require reduced application rates as well as changes in application frequency (every 4 years versus every 2 years or every year). The major question associated with such proposed changes is the nature and degree of the farm level economic impacts.

The objective of this analysis was to determine cost impacts at the farm level if a phosphorus limit policy is implemented. In addition, the analysis identifies any further limitations and/or benefits that may arise.

Based on the case study findings in the previous section, two types of operations were analyzed:

- a beef feedlot with a capacity of 10,000 head of finishers (two turns of cattle per year),
- a hog farrow-to-finish operation with 500 sows.

The analysis was not conducted for a dairy operation since it was observed in the case studies that available land for the application does not appear to be a major concern within this production sector.

Three differing phosphorus-limit scenarios were analyzed:

- **Scenario 4P –** manure spread at four times the annual phosphorus requirement of the crop. This is a 4-year rotation (manure applied on a given parcel of land once every 4 years).
- **Scenario 2P –** manure spread at twice the annual phosphorus requirement of the crop. This is a 2-year rotation (manure applied on a given parcel of land once every 2 years).
- **Scenario 1P –** manure spread to meet annual phosphorus requirement of the crop. This requires manure to be spread on the same land every year.

In addition, one nitrogen-limit scenario was analyzed:

- **Scenario 2N –** manure spread at twice the annual nitrogen requirement of the crop. This is a 4-year rotation (manure applied on a given parcel of land once every 4 years).

Beef Feedlot Farm Level Impacts

Assumptions. The beef feedlot is comprised of a composite of characteristics derived from the case farm studies. The farm was modeled as a 10,000 finishers capacity operation on irrigated land in southern Alberta. It operates on 640 ha of land growing 480 ha of barley silage in rotation with 160 ha of canola. The operation grows sufficient barley silage to provide 1.25 tonnes of harvested silage per animal unit. Barley silage yields were assumed at a dry-weight yield of 4.1 tonnes/ha (Appendix 2).

All manure production (Province of Alberta 2004) and nutrient content levels (Province of Alberta 2001) were based on AOPA Standards. The nitrogen and phosphorus availability and decay series were assumed as follows.

- Nitrogen - 10 kg/tonne total nitrogen of which 3.2 kg was available within the first year of application and 2.0 kg was available within the second year of application.
- Phosphorus - 2.4 kg/tonne total phosphorus with assumed availability of 85%. Further, phosphorus was assumed to be available during a 2-year period (70% in Year 1 or 1.7 kg; and 15% in Year 2 or 0.36 kg).

All nutrient and uptake coefficients were based on values compiled by the Canadian Fertilizer Institute (2001). The specific application rates for nitrogen and phosphorus in the production of 10 tonnes/ha barley silage were 174.7 kg/ha and 26.07 kg/ha, respectively. Spreading and hauling costs were based on cost data received from the major custom manure hauling operator in southern Alberta (Table 37).

The operation spread manure on a 4-year land rotation at an annual rate of 135 tonnes/ha within 5 km of the feedlot. Thus, 160 ha received manure annually under the base case. In view of this basic rotation, it was assumed that the feedlot land base (640 ha) was divided into four equal areas, each 160 ha. The manure spreading rotation was as follows, Area 1 received manure in Year 1, Area 4 received manure in Year 2, Area 3 received manure in Year 3, and Area 2 received manure in Year 4. The nitrogen provided in the manure was available for a 2-year period, while phosphorus was available for the entire 4-year period or more.

The additional land required to accommodate the lower manure spreading rates, as prescribed by the scenarios described in the preceding section, was assumed to be cost neutral. In this regard, the model does not require that the operator purchase this additional land. Rather, it assumes that the land would be available in the vicinity of the feedlot and that an arrangement can be made between the operator and the land owner to receive the manure. In reality, this will vary by individual situation.

Additional nitrogen was purchased at $1.09/kg.

Application rates and associated land requirements. The manure application rates and associated land requirements are presented in Table 50. The immediate impact of the phosphorus-limit regime was a drastic reduction in the manure application rates. For example, the 4-year rotation (4P scenario) allows for a rate of 51.2 tonnes/ha, which is less than one-half of the current 135 tonnes/ha rate of application. As a result, all of the phosphorus limit scenarios (4P, 2P, and 1P) required a 164% increase in land requirements. By comparison, the 2N scenario required a 24% increase in land and had a much reduced impact. However, this scenario generated an annual average phosphorus surplus of 29.6 kg/ha.

Table 50. Changes in land requirements for beef feedlot manure.

Scenario	Manure rate (tonnes/ha)	Area manured (ha)	Total area (ha)	Increase over base (%)
Base case	135	160	640	-
4P	51.2 [z]	422	1,689	+ 164
2P	25.6	845	1,689	+ 164
1P	12.8	1,689	1,689	+ 164
2N	109 [y]	198	791	+ 24

[z] Under the 4P scenario, the allowable manure application rate was calculated as follows. The 4P scenario allows for four times the annual requirement of phosphorus to be made available (26.07 kg x 4 = 104.3 kg). Each megagram of manure supplied 2.4 kg of total phosphorus or 2.04 kg of available phosphorus (85% availability). Therefore, the amount of manure required to supply this amount equals 104.3/2.04 or 51.2 tonnes. The 2P and 1P scenarios are 50% and 25% of this rate, respectively.

[y] Under the 2N scenario, the allowable manure application rate was calculated as follows. The 2N scenario allows for two times the annual requirement of nitrogen to be made available (174.7 kg x 2 = 349.4 kg). Each megagram of manure supplied 3.2 kg in the year that it was spread. Therefore, the amount of manure required to supply this amount equals 349.4/3.2 or 109 tonnes.

Spreading and hauling costs. The costs of spreading and hauling are presented in Table 51. These were based on actual cost data received from a custom hauler (Appendix 1). The costs per megagram[12] increased as spreading rates decreased – up 24% for scenario 4P, up 56% for scenario 2P, and up 128% for scenario1P. Costs associated with the 2N scenario were the same as for the base case (Appendix 1).

Table 51. Changes in hauling and spreading costs for beef feedlot manure.

Scenario	Cost per megagram [z]	Total cost within 5 km	Change over base (%)
Base case	$5.03	$108,648	-
4P	$6.24	$134,784	+24
2P	$7.83	$169,128	+56
1P	$11.48	$247,968	+128
2N	$5.03	$108,648	-

[z] See Appendix 1.

Added nitrogen purchases. The reduced levels of manure prescribed by the phosphorus-limit scenarios required that the feedlot operation purchase additional commercial nitrogen to meet crop requirements. The total purchases of nitrogen are shown in Table 52. It can be seen that the base case required $60,731 of nitrogen purchases each year. By comparison, scenarios 4P, 2P, and 1P required a total of $75,231 (or a $14,500 increase over the base case), while scenario 2N remain unchanged.

Scenarios 4P, 2P, and, 1P created a situation where more than 60% of the feedlot manure must be moved off site. Scenario 2N required that approximately 20% of the manure be moved off site.

Overall impact analysis. The overall effect of the varying cost factors (Table 53) was analyzed in terms of the impact to the feedlot operation. This was calculated on a per unit of capacity basis.

Since the feedlot required an additional 1,049 ha more than the base of 640 ha to meet the phosphorus standards, the analysis examined three different distance scenarios within which manure may be hauled (5 km, 10 km, and 18 km). This was in view of the unlikelihood that the operator will be able to secure all the necessary land to spread the manure within a 5-km radius of the feedlot.

[12] Cost per megagram calculations for the lower spreading rates (below 50 tonnes/ha) are based on extrapolated calculations and not empirical data. Currently, no producer or custom hauler spreads at such low levels.

Table 52. Changes in commercial nitrogen (N) purchases for beef feedlot manure.[z]					
Scenario	Area 1[z]	Area 2	Area 3	Area 4	Total N purchased
Area (ha)[y]	160	160	160	160	
Base[x]	-		$30,365	$30,365	$60,731
4P[w]	$1,916	$12,584	$30,365	$30,365	$75,231
2P	$16,140	$21,475	$16,140	$21,475	$75,231
1P	$18,808	$18,808	$18,808	$18,808	$75,231
2N			$30,365	$30,365	$60,731

[z] Totals in this table and all subsequent tables may not add perfectly due to rounding.

[y] To model the 4-year rotation, the land base (640 ha) was divided into four areas, each 160 ha in size. Nitrogen was supplied to meet barley silage requirements (174.7 kg/ha). Manure was applied to Area 1 in Year 1, Area 4 in Year 2, Area 3 in Year 3, and Area 2 in Year 4. Scenario 2P means that manure was spread on Areas 1 and 3 in Year 1 and Areas 2 and 4 in Year 2. Scenario 1P means manure was spread every year on all four areas.

[x] For the base case, it was necessary to purchase nitrogen in Years 3 and 4 of the rotation (174.7 kg/ha at $1.09/kg = $189.78/ha or $30,365 for the 160-ha area).

[w] All the phosphorus scenarios (4P, 2P, and 1P) required additional purchases of nitrogen in each year of the rotation. For example, the 4P scenario of 51.2 tonnes/ha of manure supplied 163.7 kg/ha nitrogen in Area 1 and 102.3 kg/ha nitrogen in Area 2 (second year after spreading). This requires additional purchases of nitrogen (11 kg/ha in Area 1, 72.4 kg/ha in Area 2, and the entire 174.7 kg/ha for Areas 3 and 4). Scenario 2P means that manure is spread on Area 1 and Area 3 in Year 1 and Area 2 and Area 4 in Year 2. Scenario 1P means that manure was spread every year on all four areas. Both scenarios required additional purchases of nitrogen for all areas. (Note: Manual calculations will differ somewhat from what is reported in the table due to rounding).

Table 53. Annual cost impact by varying distances for beef feedlot manure.			
Scenario	Cost impact per unit of capacity – 5 km	Cost impact per unit of capacity – 10 km	Cost impact per unit of capacity – 18 km
Base	-	-	-
4P	$4.06	$7.48	$12.44
2P	$7.50	$11.15	$15.88
1P	$15.42	$19.75	$24.17
2N	$0.00	$2.65	$6.30

The analysis illustrates the following ranges (5 to 18 km) in terms of cost impacts per unit of capacity.

- **Scenario 4P –** $4.06 to $12.44 (or $40,600 to $124,400 for the 10,000-head feedlot).
- **Scenario 2P** – $7.50 to $15.88 (or $75,000 to $158,800 for the 10,000-head feedlot).
- **Scenario 1P** – $15.42 to $24.17 (or $154,200 to $241,700 for 10,000-head feedlot).

By comparison, the 2N scenario had no cost impact within a 5-km radius, assuming that land was available. However, if there is the need to haul manure up to 10 or 18 km, the cost increases range between $2.65 and $6.30 per animal unit.

It is evident that as the application rates decreased (4P versus 2P versus 1P) and as the distance increased, the relative cost impacts to the feedlot also increased substantially. For example, the 4P scenario added a cost of $4.06 per unit of capacity if manure was hauled within a 5-km radius. However, this increased to a high of $12.44 per unit of capacity if manure was hauled 18 km under the 1P Scenario.

There are three additional considerations:

- Indirect consequences and associated costs. For example, the increased frequency of spreading (every 2 years with the 2P scenario and every year with the 1P scenario) required that heavy equipment pass over cultivated land with increased frequency. Such a practice may cause soil compaction and with time, may impact soil fertility, cultivation practices, and ultimately crop yields.
- The application rates required to meet the 4P scenario and particularly the 2P and 1P scenarios, were well below current standard practices and the equipment used. Currently, it is not possible to spread at rates below 50 tonnes/ha.
- Finally, it was observed that the excess manure (13,422 tonnes), as a result of the phosphorus-limit scenarios, presents either a source of revenue if sold at nutrient value, or a reduced cost if the feedlot operator farms additional crop land to accommodate this manure. The value of this manure was calculated at $8.86/tonne based on current nitrogen and phosphorus fertilizer prices and represents a total value of approximately $119,000.

Move all manure from the feedlot. Some feedlot land within the province has been the recipient of manure applied at high rates for extended periods. In these cases, phosphorus levels in the soil are already high, creating the possibility that a moratorium on the spreading of additional manure may be imposed if phosphorus limits are set.

The potential cost of such action was examined in two scenarios:

- move all manure 10 km,
- move all manure 18 km.

In both these scenarios, it was assumed that no manure was spread on feedlot land and that all manure was moved and ‘dumped’ at a distant location. As a consequence, the operator must purchase all required nitrogen in the form of commercial fertilizer to meet the crop requirements. It was assumed that given the high phosphorus levels no additional phosphate purchases were necessary. No assumption was made regarding the ultimate use of the manure other than the associated cost of reloading it at some future time. The cost impacts of these two distance scenarios are presented in Table 54.

Table 54. Cost impacts associated with moving all manure for beef feedlot manure .		
Distance	Cost impact per unit of capacity	Potential savings if reload cost is not incurred
Move manure 10 km	$12.62	$6.37
Move manure 18 km	$15.54	$6.37

In the case of moving all manure a distance of 10 km, the total additional cost to the feedlot was $12.62 per unit of capacity (or $126,200 for the entire feedlot). This increases to $15.54 per unit of capacity (or $155,400 for the entire feedlot) if the manure was moved 18 km. The additional costs were the result of two main factors:

- The need to purchase a total of $121,461 of fertilizer versus the base purchase of $60,731. This represents a $60,730 increase or $6.07 per unit of capacity.
- The need to reload the manure once it has been dumped. If a third party such as a crop producer or a manure processor is willing to pay this charge, the potential savings equate to $6.37 per animal unit ($63,720).

It can be argued that if the producer does not have to pay reload charges, the cost to move all manure 10 km is $6.25 ($12.62 less $6.37) per unit of capacity. This increases to $9.17 ($15.54 less $6.37) if the manure is transported 18 km. These costs are similar to the increases in costs associated with scenario 2P. However, there are some additional considerations associated with moving all the manure from a feedlot.

- The costs presented in this analysis assumed the use of 20-tonne trucks to maximize efficiencies and to minimize costs. These vehicles require wide alleys and are only suitable for the larger feedlots. Costs for smaller feedlots, where 10- or 15-tonne trucks can only be used, would be higher.
- According to the custom hauler, dumping manure (referred to as ‘end dumping’) should only take place in dry conditions. The associated risks increase in wet conditions since manure sticks to the truck bed and the vehicles are more prone to tipping when unloading.
- Finally, the real issue concerning the ‘move-all-manure’ scenario revolves around the ultimate use of the manure. According to the major custom hauler, once manure is dumped on a site some distance from the feedlot, the incentive to reload and spread it diminishes. In periods of financial stress, the incentive decreases even further creating a two-fold problem: first, an environmental liability; and second, a lost opportunity since the source of available nutrients is not being utilized.

Thus, while the move-all-manure scenario may provide some cost relief in comparison to the some of the phosphorus-limit scenarios, it presents another set of challenges, particularly if there is no immediate or ultimate use for the manure.

Hog Farrow-to-finish Farm Level Impacts

Assumptions. The hog farrow-to-finish operation was a composite comprised of characteristics derived from the case farm studies in the previous main section. The farm was modeled as a 500-sow operation on Grey Luvisolic soils in central Alberta. It comprises a total of 555 ha, with a 4-year rotation growing barley grain with an assumed yield of 4,300 kg/ha (Appendix 3).

All manure production (Province of Alberta 2004) and nutrient content levels (Province of Alberta 2001) were based on AOPA Standards. The nitrogen and phosphorus decay series were assumed as follows.

- **Nitrogen –** 3.5 kg/tonne of which 1.6 kg/tonne was available to the crop within the first year of application and 0.7 kg/tonne was available within the second year of application.
- **Phosphorus –** 1.1 kg/tonne with assumed availability of 85%. Further, the phosphorus was assumed to be available for a two-year period (70% in Year 1 or 0.77 kg/tonne; and 15% in Year 2 or 0.16 kg/tonne).

All nutrient and uptake coefficients were based on values compiled by the Canadian Fertilizer Institute (2001). The specific application rates for nitrogen and phosphorus in the production of barley grain at 4,300 kg/ha were 87.0 kg/ha and 16.4 kg/ha, respectively. Spreading and hauling costs were based on cost data received from the major custom manure hauling operator in central Alberta (Table 36).

The operation currently spreads manure on a 4-year rotation at an annual rate of 86.5 tonnes/ha within 2 km of the farm. A total of 139 ha received manure each year. Thus, 139 ha received manure annually under the base case. In view of this basic rotation, the model assumes that the hog operation land base (555 ha) was divided into four equal areas, each 139 ha. The manure spreading rotation was as follows, Area 1 receives manure in Year 1, Area 4 receives manure in Year 2, Area 3 receives manure in Year 3, and Area 2 receives manure in Year 4. The nitrogen provided in the manure was available for a 2-year period, while phosphorus was available for the entire 4-year period or more.

The acquisition of additional land required to accommodate lower spreading rates, as prescribed by the scenarios described in the preceding section, was assumed to be cost neutral. In this regard, the model does not require that the operator purchase this additional land. Rather, it assumes that the land would be available in the vicinity of the feedlot and that an arrangement can be made between the operator and other land owners to receive the manure. In reality, this will vary by individual situation.

Additional nitrogen was purchased at $1.09/kg and phosphorus was purchased at current market prices[13].

[13] Phosphorus is purchased in the form of P_2O_5, which is currently priced at $0.69/kg.

Application rates and land requirements. The manure application rates and associated land requirements are presented in Table 55.

The phosphorus-limit scenarios required additional land compared to the current base. Overall, a 23% increase was required. By comparison, the 2N scenario prescribed a heavier rate of application than the current practice (108.8 tonnes/ha versus 86.5 tonnes/ha) and required 20% less land.

The changes to hauling and spreading costs are summarized in Table 56. Cost data for hauling and spreading were provided by a major custom hauler of liquid hog manure (Appendix 1).

Table 55. Changes in land requirements for farrow-to-finish hog manure.

Scenario	Manure rate (tonnes/ha)	Annual area manured (ha)	Total area (ha)	Increase over base (%)
Base	86.5	139	555	-
4P	70.2 [z]	171	683	+ 23
2P	35.1	342	683	+ 23
1P	17.6	683	683	+ 23
2N	108.8 [y]	110	441	- 20

[z] Under the 4P scenario, the allowable manure application rate was calculated as follows. The 4P scenario allows for four times the annual requirement of phosphorus to be made available (16.4 kg x 4 = 65.6 kg). Each megagram of manure supplied 1.1 kg of total phosphorus or 0.935 kg of available phosphorus (85% availability). Therefore, the amount of manure required to supply this amount equals 65.6/.935 or 70.2 tonnes. The 2P and 1P scenarios are 50% and 25% of this rate, respectively.

[y] Under the 2N scenario, the allowable manure application rate was calculated as follows. The 2N scenario allows for two times the annual requirement of nitrogen to be made available (87 kg x 2 = 174 kg). Each megagram of manure supplied 1.6 kg in the year it was spread. Therefore, the amount of manure required to supply this amount equals 174/1.6 or 108.8 tonnes.

Table 56. Changes in hauling and spreading costs for farrow-to-finish hog manure.

Scenario	Cost per megagram [z]	Within 2 km	Percentage change
Base	$2.28	$27,360	-
4P	$2.34	$28,080	+ 3
2P	$3.04	$36,480	+ 33
1P	$3.57	$42,800	+ 56
2N	$2.28	$27,360	-

[z] See Appendix 1.

Table 57. Changes in commercial nitrogen purchases for farrow-to-finish hog manure.					
Scenario	Area 1	Area 2	Area 3	Area 4	Total N
Area Size [z]	139	139	139	139	
Base	-	$3,982	$13,107	$13,107	$30,196
4P [y]	-	$5,702	$13,107	$13,107	$31,916
2P [x]	$4,647	$9,404	$4,647	$9,404	$28,103
1P	$7,026	$7,026	$7,026	$7,026	$28,103
2N [w]	-	$1,300	$10,425	$10,425	$35,812

[z] Each area was 139 ha or 25% of the total base ha. Nitrogen was supplied to meet barley grain requirements (87 kg/ha). Manure is applied to Area 1 in Year 1, Area 4 in Year 2, Area 3 in Year 3, and Area 2 in Year 4. Scenario 2P means that manure was spread on Areas 1 and 3 in Year 1 and Areas 2 and 4 in Year 2. Scenario 1P means manure was spread every year on all four areas. Both scenarios required additional purchases of nitrogen for all areas.

[y] The 4P scenario required additional purchase of nitrogen in Years 2, 3, and 4 of the rotation. For example, the 4P scenario (70.2 tonnes of manure) supplied 112.3 kg/ha nitrogen in Area 1, and 49.3 kg/ha nitrogen in Area 2, thus requiring an additional 37.9 kg/ha nitrogen to be purchased to meet the 87 kg/ha requirement. The full requirement of 87 kg/ha must be purchased for Areas 3 and 4.

[x] The 2P and 1P scenarios required additional purchases of nitrogen each year for all areas.

[w] Under scenario 2N, 114 ha received no manure. Nitrogen requirements were met by purchasing 87 kg/ha nitrogen at $1.09/kg and 16.4 kg of phosphorus (37.5 kg of phosphate at $0.69/kg) or a total of $120.37/ha (total of $13,663/year). (Note: manual calculations will differ somewhat from what is reported in the table due to rounding).

Overall, the relative cost impacts per sow, which are calculated in the same manner as for the beef feedlot analysis, are as follows.

- **Scenario 4P –** cost of $4.88 per sow (or $2,440 for 500 sows).
- **Scenario 2P –** cost $14.05 per sow (or $7,027 for 500 sows).
- **Scenario 1P** – cost of $26.77 per sow (or $13,387 for 500 sows).
- **Scenario 2N –** cost of $11.23 ($5,616 for 500 sows).

It is evident that as application rates decreased (4P versus 2P versus 1P), the relative cost impacts to the hog operation increased. For example, the 4P scenario adds a cost of $4.48 per sow unit of capacity if manure was hauled within a 2-km radius. This increased to $14.05 per sow unit for scenario 2P and $26.29 per sow unit for scenario 1P. Scenario 2N cost an additional $11.13 per sow unit and was largely due to the oversupply of nitrogen spread in Year 1 and the need to purchase additional fertilizer for land that received no manure.

The most significant finding is the absolute differences in cost impacts compared to the beef feedlot. Even the most restrictive phosphorus-limit regime (1P) imposed a total cost of $13,387. This is markedly different from the feedlot impact analysis where absolute cost impacts were substantially higher. Furthermore, the added land requirements as a result of phosphorus-limit scenarios could easily be mitigated by targeting a higher barley yield, such as 5,375 kg/ha. This would require additional nutrients and in turn accommodate application rates approaching 86 tonnes/ha, which was the rate currently applied in the base case.

Conclusions and Implications

Phosphorus-limit regimes are likely to have a much greater cost impact on Alberta beef feedlots than on typical hog operations. Three key factors contribute to these added costs:

- **Added land requirements.** The analysis indicates that a phosphorus-limit regime will require substantial increases in land for the spreading of manure. The analysis suggests that increases may be in the order of 160% (1.6 ha additional land for every hectare that is currently used). On a per animal unit basis, this represents a 0.105 ha per head increase. Thus, a 25,000 head feedlot would require an additional 2,625 ha in addition to the current land base.
- **Added cost of hauling and spreading manure.** Increased costs are due to (1) increased distances that the manure will need to be hauled and (2) decreased application rates to comply with the required phosphorus standards. As a result, spreading takes more time and becomes more expensive on a per unit weight basis. Actual increases will vary from farm to farm and from region to region depending upon the land availability and livestock concentrations. Overall spreading costs could increase by as much as 24 to 128% depending on the average increase in distance that the manure will need to be hauled.
- **Need to purchase commercial fertilizer to meet crop requirements.** A phosphorus-limit regime will meet plant phosphorus requirements; however, not all of the nitrogen requirements will be met. Thus, it will be necessary to purchase commercial fertilizers to offset the nitrogen levels formerly provided by the manure.

Specific to the phosphorus-limit alternatives within the beef feedlot sector, the 4P scenario was the least costly alternative. However, it imposes an additional annual cost of $4.06 per unit of capacity, assuming that the excess manure can be spread within 5 km of the feedlot. However, if manure is moved 10 km, the cost increases to $7.48 per unit of capacity and to $12.44 per unit of capacity if manure is moved 18 km.

By comparison, the 2P and 1P scenarios become even more costly. In particular, the 1P scenario was the most punitive economic solution and was calculated to cost more than $15.42 per unit of capacity each year. Furthermore, scenario 1P is not technically feasible at the present time given current equipment and spreading practices. It would require new capital investment to the extent that a wholesale change in spreading equipment is necessary, and this cost was not taken into account in this analysis.

The nitrogen-limit scenario (2N) was a lower cost alternative. It required an added land base of 24%, but does not otherwise increase costs to the feedlot, assuming that land could be located within 5 km of the feedlot. However, under this scenario, phosphorus levels will continue to build at an average rate of 29.6 kg/ha phosphorus every year.

All the phosphorus-limit scenarios created an excess manure situation wherein manure exceeds the volumes that the current land base can accommodate. This is problematic, especially if the manure has to be hauled considerable distances from the feedlot. Such a situation will likely occur in specific areas within the province where numerous feedlots operate in close proximity to each other and are already competing for land. In this case, the cost estimates generated by this study would understate the actual costs that would be experienced by individual feedlot operators.

KEY FINDINGS AND DIRECTIONS

Literature Review

The literature review provided an overview of the economic impacts associated with phosphorus limits. Two main themes emerged:

- Cost impacts at the farm level are highly variable. They depend on several key factors, including the nutrient content of the manure, the availability of the land on which to spread the manure, and the density of the regional livestock population within which the farms operate.
- Regional impacts are also highly variable. In this regard, the net cost impacts can range from levels that threaten the economic viability of farms within the region, to actually providing the region with a net economic benefit resulting from better manure utilization as a source of nutrients and the replacement of commercial fertilizers.

In the most comprehensive study of economic impacts, Ribaudo et al. (2003) concluded that the willingness of cropland operators to accept manure is the most critical determinant of the ultimate costs associated with disposal of manure in regions with high animal concentrations.

Statistical Overview of the Alberta Livestock Industry

The statistical overview of the livestock industry in Alberta, combined with case studies, give rise to number of observations specific to the issue of phosphorus and phosphorus loads. These are presented as follows.

- Provincial livestock populations are highly concentrated on relatively few farm operations. The statistical analysis illustrates that 1.2% of farms account for approximately 50% of all livestock. The concentrations vary by livestock sector with 210 operations account for 73.6% of all poultry, 183 operations account for 56% of all hogs, and 73 operations account for 54% of all slaughter (feedlot) cattle.

- Livestock populations are skewed regionally and by municipality. For example, the top five counties with slaughter cattle account for 51% of the provincial total, another group of five counties account for 43% of all dairy cattle, and a third group of five counties account for 33% of the province’s hogs. Lethbridge County is included in all three groupings.

- Calculations of total manure output and associated phosphorus production illustrate that throughout the entire province, only two counties exceed production levels of 12 kg/ha phosphorus on cropped land. This includes the counties of Lethbridge and Ponoka. The addition of tame hay and pasture to the land base leaves only Lethbridge County in excess of this level. All other counties are below 10 kg/ha phosphorus.

- While the aggregate calculations illustrate that phosphorus loads do not appear problematic at the provincial level, a different picture emerges at the local level. Phosphorus loads are a concern in localities where large-scale individual livestock operations are situated. The case studies confirm this. Phosphorus load levels at the individual site level are observed to be as high as 489 kg/ha of phosphorus at the time of application (manure applied once every 4 years). Other observations noted applications ranging from 128 kg/ha of phosphorus (2-year rotation) to 353 kg/ha of phosphorus (4-year rotation).

- The findings associated with the nine case studies (three hog operations, three dairy operations, and three beef feedlots) suggest that beef feedlots are most likely to have the highest concentrations of manure per hectare on associated land. This is followed by hog operations. Dairy operations appear to have fewer concerns. For the most part, dairy operations have sufficient land base to readily accommodate the livestock manure.

- All the case study operators prescribed a value to the manure to the extent that they used little or no fertilizer on the crops grown on lands that are manured. However, only one case-study operator systematically tested the manure and knew the precise nutrient levels from which a definitive crop nutrient plan was developed. The remaining operators used rule of thumb approaches such as 100 to 150 tonnes/ha (in the case of feedlots) or 90 tonnes/ha in the case of liquid hog manure.

- The most significant cost associated with manure is loading and hauling. This varies widely from case to case and ranged from $1.45/tonne to $13.33/tonne. The variability is due to numerous factors, including type of manure, average distance hauled, as well as the actual costs assigned to time and equipment. We noted that operators using custom haulers appear to have lower and more consistent costs.

- The case study data provided a basis to explore several scenarios with respect to the breakeven distance that manure can be transported economically. This is defined as the economic range, namely the distance within which the value of the nutrients is greater or at least equal to the transportation costs. The economic range was 2.35 to 9.66 km for liquid dairy manure, 2.43 to 10.15 km for liquid hog manure, and 4.99 to 18.82 km for solid beef feedlot manure. The actual economic range will vary from farm to farm and depends upon nutrient content, nutrient availability, and the cost of haulage.

Farm Level Impacts

The detailed farm level analysis for beef feedlots generated the following findings.

- A phosphorus limit regime will require substantial increases in land for the spreading of manure. The analysis suggests that increases may be as high as 160% (1.6 ha of additional land for every hectare that is currently used).

- Feedlots will experience increased costs due to increased distances that the manure will need to be hauled and decreased application rates to comply with the required phosphorus standards. As a result, spreading takes more time and becomes more costly on a per unit weight basis. Overall transportation and spreading costs could increase by as much as 24% to 128% depending on the average increase in distance that the manure will need to be hauled. Actual increases will vary from farm to farm and from region to region depending upon land availability and livestock concentrations.

- A phosphorus-limit regime will meet plant phosphorus requirements; however, nitrogen requirements will not be met. Thus, it will be necessary to purchase additional commercial fertilizer to offset the nitrogen levels formerly provided by the manure.

- Specific to the phosphorus-limit alternatives within the beef feedlot sector, the 4P scenario is the least costly alternative. However, it imposes an additional annual cost of $4.06 per unit of capacity, assuming that the excess manure can be spread within 5 km of the feedlot. If manure is moved 10 km, the cost increases to $7.48 per unit of capacity and to $12.44 per unit of capacity if manure is moved 18 km.

- By comparison, the 2P and 1P scenarios become even more costly. In particular, the 1P scenario is the most punitive economic solution and is calculated to cost more than $15.42 per unit of capacity each year, assuming manure is spread within 5 km of the feedlot. Furthermore, Scenario 1P is not technically feasible at the present time, given current equipment and spreading practices. Scenario 1P would require new capital investment to the extent that a wholesale change in spreading equipment is necessary, and this cost was not taken into account in this analysis.

- The nitrogen-limit scenario (2N) is a lower cost alternative. It requires an added land base of 24%, but does not otherwise increase costs to the feedlot, assuming that land could be located within 5 km of the feedlot. However, under this scenario, phosphorus levels continue to build at an average rate of 29.6 kg/ha of phosphorus every year.

- All the phosphorus-limit scenarios create excess manure situations when manure exceeds the volumes that the current land base can accommodate. This is problematic, especially if the manure has to be hauled considerable distances from the feedlot. Such a situation will likely occur in specific areas within the province where numerous feedlots operate in close proximity to each other and are already competing for land. In this case, the cost estimates generated by this study would understate the actual costs that would be experienced by individual feedlot operators.

The detailed analysis for the hog farrow-to-finish operation illustrate that a phosphorus-limit regime would have a relatively small cost impact provided sufficient land is available in the vicinity to receive the manure. Land requirements for manure application are estimated to increase by 23%. The cost impact on a per sow basis ranges from a low of $4.88 (scenario 4P) to a high of $26.77 per sow (scenario 1P). Assuming 20 hogs per sow per year, this translates to a cost impact of $0.24 to $1.34 per market hog.

Overall, it was concluded that excessive phosphorus loads are only likely to be problematic on individual farms with large livestock concentrations and within relatively few localities. This is illustrated by the statistical analysis and the aggregate calculations of phosphorus production. Thus, it can be argued that the majority of Alberta farms and municipalities should be able to manage phosphorus loads simply by improved manure utilization on available land in the vicinity of the livestock operations.

However, there are localities where phosphorus loads are excessive and the availability of land due to competition from neighbouring livestock operations will make it difficult to simply spread manure on land within an economic range. This situation will create significant additional costs to the individual operation if phosphorus standards are implemented. In these cases, special measures will need to be considered to alleviate the cost pressures. These are discussed further in the subsequent section.

Directions

The findings in this report are directional in nature and set the stage for planning further actions as well as developing policy recommendations. The following directions are provided to give guidance to these discussions.

Quantify and qualify the environmental sustainability of a 4P strategy. The economic analysis clearly demonstrates that a phosphorus standard that allows for the spreading of manure once every 4 years is the most economic solution. This practice meets crop phosphorus requirements for four successive crops. Furthermore, it is the only practical solution in view of the limitations with current spreading equipment specific to feedlot manure. However, the environmental risks associated with this phosphorus-limit strategy need to be substantiated. It is important that a thorough risk assessment be undertaken as part of a policy recommendation.

Focus on optimizing manure utilization. As a general measure, we recommend that efforts should first focus on identifying and quantifying economic solutions specific to the value of manure. The objectives are two-fold: (1) encourage producers to test manure for the purpose of establishing the nutrient value, and (2) calculate the economic range within which manure can be transported. These measures will serve to move producers toward managing manure in a more economical manner. In turn, this strategy will likely alleviate phosphorus load levels in most municipalities within the province.

Alberta Agriculture, Food and Rural Development can play a lead role on this initiative as it works with the major livestock organizations (Alberta Cattle Feeders Association, Alberta Pork, Alberta Milk, and Alberta Chicken Producers Association).

Encourage crop producers to accept manure as an alternative to commercial fertilizer. The most significant measure to alleviate excessive phosphorus loads is the willingness of area crop producers to accept manure. Interestingly, even in the livestock intense areas within Alberta, there is evidence to suggest that considerable crop land does not receive any manure[14]. This assessment would suggest that considerable phosphorus load pressures might be alleviated simply by creating incentives to spread manure on land in the immediate vicinity.

Nevertheless, a number of factors impede the use of manure on crops, including uncertain

[14] This comment was provided by the major custom manure hauler located in Picture Butte. According to this individual, more than 50% of crop land within the immediate area does not receive any manure.

nutrient content, soil compaction associated with heavy equipment, and odour. Research is required on how these impediments might be overcome. In addition, the study recommends that education on the benefits of using manure, as well as providing financial assistance (incentives) for crop farmers to use manure, should be explored.

The literature review suggests that a requirement for producers to transport manure greater distances to meet standards has the potential to produce a net economic gain to the overall agriculture production system in some regions. This will only occur if a true market for manure develops and there is a supply of available crop land. This market is internal (a producer hauling manure to owned or rented lands that are currently thought to be outside of an economic range) and external (an actual buy-sell transaction between two producers). Clearly, the market for manure must be based on several factors, including confirmed nutrient content, nutrient availability, manure quality, absence of viable weed seeds, crop response, and the cost of loading as well as transportation.

Develop a set of analytical tools. Perhaps the most significant observation made during this study is the relative lack (and/or variability) of a basis for sound economic analysis. The variability in cost estimates and the relative lack of precise information are considerable.

Further to the previous direction, we recommend that a more robust analytical tool be developed. Such a tool should combine the nutrient content of the manure, cost information (such as transportation and spreading costs), as well as crop nutrient requirements. This will assist producers in dealing with manure in the context of nutrient planning in a more economical and beneficial manner. At the same time, the need for more precise manure testing is imperative. This will occur if producers understand the economic benefits to be gained. Finally, there may be opportunities to identify additional benefits in soil fertility that can be realized by utilizing various types of livestock manure over and above the provision of macronutrients.

Explore options and/or special measures for provincial hot spots. There exists the possibility that some farms within the province are currently spreading manure on land that has already excessive levels of phosphorus. These situations may call for a complete moratorium on all manure spreading on these lands for an indefinite time. This is clearly problematic and would represent a significant cost to the individual farm operation, and most likely affect beef feedlots located within areas of concentrated livestock populations. The options are two-fold:

- Spread manure to land elsewhere within the area. The analysis suggests that costs would rise an additional $12.62 per animal unit provided land is located within a 10 km hauling range.
- Haul and dump the manure to an alternative use site such as a biodigester or a composter. This would cost up to $15.54 per animal unit if manure is hauled within 18 km. However, the feedlot operation has the opportunity to recoup $6.37 per animal unit if the receiver of the manure pays the reloading costs. However, this study is not able to comment on the economic viability of these options.

Establish a nutrient management team. The findings suggest there is considerable opportunity to improve manure and nutrient management at the individual farm level. Consideration should be given to assembling a team of technical and economic experts that could be called on to undertake detailed on-farm assessments and develop comprehensive action plans as well as management options.

Two industry organizations, namely the Alberta Cattle Feeders Association and Alberta Pork, could play a vital role in endorsing the approach as well as in creating awareness, providing guidance with respect to the team formation, and providing funding. It is anticipated that the teams would comprise a mix of public sector and private expertise. Clearly, the provincial hot spots will be the primary focus of the teams.

REFERENCES

Babcock, B.A., R. Fleming, and D.S. Bundy 1997. The cost of regulating manure storage facilities and land application techniques. Centre for Agriculture and Rural Development, Iowa State University. Publication 97-BP17 Ames, Iowa, United States.

Burman, S. 1998. The advantages of manure. Pages 18-22 *in* Manure management in harmony with the environment and society. The Soil and Water Conservation Society. Ames, Iowa, United States. February 10-12, 1998.

Canadian Fertilizer Institute. 2001. Nutrient uptake and removal by field crops, Western Canada 2001. Canadian Fertilizer Institute. Ottawa, Ontario, Canada.

Card, G.B. 2003. Economics of manure transportation, utilization, and management in a region of highly concentrated intensive livestock operations. Master of Arts in Agricultural Economics thesis. Department of Agricultural and Resource Economics, Washington State University, Pullman, Washington, United States. 165 pp.

Correll, D.L. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. J. Environ. Qual. **27**: 26-266.

Council of Agricultural Science and Technology. 1996. Integrated animal waste management, pp. 87. Council of Agricultural Science and Technology. Ames, Iowa, United States.

Erb, K.A. 1998. Manure bartering: Linking farmers without manure to those with too much. Pages 37-39 *in* Manure management in harmony with the environment and society. The Soil and Water Conservation Society. Ames, Iowa, United States. February 10-12, 1998.

Fleming, R., Babcock, B., and Wang, E. 1998. “Resource or waste? The economics of swine manure storage and management.” Rev. Agric. Econ. **20**: 96-113.

Fleming, R.A. and Long, J.D. 2002. Measuring the cost of restricting access to cropland for manure nutrient management. Agron. J. **94**: 57-64.

Food and Agriculture Organization. 1978. Organizing recycling in Asia, FAO Soils Bulletin 36, 417 pp. Food and Agriculture Organization of the United Nations. Rome, Italy.

Freeze, B., Heigh, J., Larney, F.L., and Olson, A.F. 1999. Economics of windrow composting and land application of manure. Pages 311-320 *in* Manure management '99: Proceedings of a tri-provincial conference on manure management. Saskatoon, Saskatchewan, Canada. June 22-25, 1999.

Freeze, B.S. and Sommerfeldt, T.G. 1985. Breakeven hauling distances for beef feedlot manure in southern Alberta. Can. J. Soil Sci. **65**: 687-693.

Freeze, B.S., Webber, C., Lindwall, C.W., and Dormaar, J.F. 1993. Risk simulation of the economics of manure application to restore eroded wheat cropland. Can. J. Soil Sci. **73**: 267-274.

Gassman, P.W. and Bouzaher, A. 1995. Livestock pollution: lessons from the European Union. Pages 515-522 *in* K. Steele (ed). Animal waste and the land-water interface, CRC/Lewis Publishers. Boca Raton, Florida, United States.

Giasson, E., Bryant, R.B., and Bills, N.L. 2003. Optimization of phosphorus index and costs of manure management on a New York dairy farm. Agron J. **95**: 987-993.

Innes, R. 2000. The economics of livestock waste and its regulation. Am. J. Agric. Econ. **82**: 97-117.

Janzen, R.A, McGill, W.B., Leonard, J.J, and Jeffrey, S.R. 1999. Manure as a resource - ecological and economic considerations in balance. Trans. ASAE **42**: 1261-1273.

Jenner, M.W. 1998. Producing manure to capture the market. Pages 45-48 *in* Manure management in harmony with the environment and society. The Soil and Water Conservation

Society. Ames, Iowa, United States. February 10-12, 1998.
Johansson, R.C. and Randall, J.R. 2003. Incorporating economics into the phosphorus index: An application to U.S. watersheds. J. Soil Water Conserv. **58**: 224-231.
Keplinger, K., Tanter, A., and Hauch L. 2004. Manure transportation and application: Model development and a general application. Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville Texas, United States. 64 pp.
Lory, J.A., Massey, R.E., Zulovich, J.M., Hoehne, J.A., Schmidt, A.M., Carlson, M.S., and Fulhage, C.D. 2004. Feasibility and costs of phosphorus application limits on 39 U.S. swine operations. J. Environ. Qual. **33**: 1114-1123.
Moncrief, J.F., Mulla, D.J., Cheng, H.H., Eash, N.S., Hansen, N.C., Strock, J.S., Schmitt, M.A., Randall, G.W., Chester-Jones, H., Rosen, C.J., DiCostanzo, A., Clanton, C.J., Bloom, P.R., Goodrich, P.R., Shaeffer, C.C., Richard, T.L., Russelle, M.P., Ginting, D., and Mozaffari, M. 1999. A summary of the literature related to manure and crop nutrients. Pages J1-J142 *in* Generic environmental impact statement on animal agriculture. Prepared for the Minnesota Environmental Quality Board. College of Agriculture, Food and Environnemental Sciences, University of Minnesota, Minnesota, United States.
Nagy, C.N., Schoenau, J.J., and Schoney, A. 1999. Economic returns and hauling distances of hog and cattle manure. Pages 489-499 *in* Manure management '99: Proceedings of a tri-provincial conference on manure management. Saskatoon, Saskatchewan, Canada. June 22-25, 1999.
Olson, B.M. and Paterson, B.A. 2005. Introduction. Pages 1-9 *in* B.M. Olson (ed.). Soil phosphorus limits for agricultural land in Alberta: 2005 progress report. Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta, Canada.
Pease, J., Parsons, R., and Kenyon, D. 1998. "Economic and environmental impacts of nutrient loss reductions on dairy and dairy/poultry farms." Virginia Cooperative Extension Publication 448-231/REAP R033.
Province of Alberta. 2001. Agricultural operation practices act. Published by Alberta Queen's Printer. Edmonton, Alberta, Canada.
Province of Alberta. 2004. Agricultural operation practices act and regulations. Published by Alberta Queen's Printer. Edmonton, Alberta, Canada.
Ribaudo, M., Gollehon, N., Aillery, M., Kaplan, J., Johansson, R., Agapoff, J., Christensen, L., Breneman, V., and Peter, M. 2003. Manure management for water quality: Costs to animal feeding operations of applying manure nutrients to land. United States Department of Agriculture, Economic Research Services. Agricultural Economic Report Number 824. 90 pp.
Schimmel, J.G., Levins, R.A., and Vincze, Z. 1998. Case study: Economic impact of restricting phosphorus fertilization on a Minnesota dairy. Pages 23-27 *in* Manure Management in harmony with the environment and society: Extended abstracts of papers and posters presented. The Soil and Water Conservation Society, West North Central Region. Ames, Iowa, United States. February 10-12, 1998.
Sharpley, A.N., Daniel T., Sims J., Lemunyon, R., Stevens, R., and Parry, R. 1999. Agricultural phosphorus and eutrophication. ARS-149. United States Department of Agriculture, Agricultural Research Service.
Sharpley, A.N., Weld, J.L., Beegle, D.B., Kleinman, P.J.A., Gburek, W.J., Moore, Jr., P.A., and Mullins, G. 2003. Development of phosphorus indices for nutrient management planning strategies in the United States. J. Soil Water Conserv. **58**: 137-152.
Soil Phosphorus Limits Committee and LandWise Inc. 2006. Phosphorus standards in

Alberta: Potential impacts on the agricultural industry. Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada. 61 pp.
Unterschultz, J.R. and Jeffrey, S.R. 2001. Economic evaluation of manure management and farm gate application: A literature review of environmental and economic aspects of manure management in Alberta's livestock sectors. Project Report # 01-03. Department of Rural Economy, University of Alberta, Edmonton, Alberta, Canada. 64 pp.
Yap, C., Foster K., Preckel P., and Doering, O. 2001. The economic impacts of phosphorus based manure management policies on a representative north central Indiana hog-grain farm. Staff Paper #01-3, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana, United States.

APPENDICES

Appendix 1. Manure spreading costs.

Solid Manure

Solid manure spreading cost grid 2006.

	Manure application rate (tonnes/ha)				
Distance	100	87.5	75	62.5	56.25
(km)	($/tonne)				
0	2.95	3.12	3.29	3.47	3.55
1	3.40	3.61	3.80	4.01	4.10
2	3.86	4.09	4.31	4.54	4.65
3	4.33	4.58	4.82	5.07	5.20
4	4.71	4.98	5.24	5.52	5.66
5	5.03	5.33	5.61	5.91	6.06
6	5.37	5.69	5.99	6.31	6.47
8	5.84	6.19	6.51	6.86	7.03
10	6.26	6.64	6.99	7.37	7.55
12	6.67	7.07	7.46	7.86	8.05
15	7.31	7.76	8.19	8.64	8.86
18	7.95	8.43	8.92	9.40	9.64

Solid manure low spreading rate extrapolation grid 2006[z].

	Manure application rate (tonnes/ha)				
Distance	56.25	50	37.5	27.5	13.75
(km)	($/tonne)				
0	3.55	3.64	4.10	4.56	6.69
1	4.10	4.20	4.73	5.27	7.72
2	4.65	4.77	5.37	5.97	8.76
3	5.27	5.40	6.08	6.77	9.92
4	5.68	5.82	6.56	7.30	10.70
5	6.09	6.24	7.03	7.83	11.48
6	6.51	6.66	7.51	8.36	12.26
8	7.09	7.26	8.12	8.98	12.97
10	7.63	7.82	8.67	9.52	13.50
12	8.17	8.37	9.21	10.06	14.02
15	8.87	9.09	9.91	10.73	14.64
18	9.87	10.12	10.92	11.71	15.55

[z] Source: Porcupine Corral Cleaners, February 2006.

Liquid Manure

Liquid manure spreading cost grid[z].

Distance	Manure application rate (tonnes/ha)						
	100	87.5	75	62.5	50	37.5	20
(km)	($/tonne)						
0	1.77	1.77	1.81	1.95	2.18	2.53	3.32
1	1.92	1.92	2.01	2.13	2.36	2.73	3.32
2	2.28	2.28	2.34	2.48	2.74	3.04	3.57
3	2.63	2.63	2.68	2.83	3.10	3.35	3.99
4	3.01	3.01	3.09	3.28	3.56	3.91	4.43
5	3.38	3.38	3.49	3.73	4.03	4.47	5.35
6	3.75	3.75	3.88	4.14	4.54	4.93	6.05
7	4.12	4.12	4.28	4.56	4.97	5.38	6.89
8	4.49	4.49	4.67	4.97	5.41	5.84	7.29
10	5.54	5.54	5.73	6.14	6.67	7.22	8.67
12	6.60	6.60	6.78	7.31	7.93	8.59	10.04
15	8.18	8.18	8.36	9.07	9.82	10.66	12.11

[z] Source: Royal Manure Services, February 2006.

Notes

- The tables were built using information provided by custom manure hauling and spreading companies in 2005 and 2006. The imperial unit calculators that were developed in 2005 was used as the basis to update the cost grids. For 2006, costs have increased in the range of 15 to 25% compared to 2005. The grids were then converted to metric units.
- The cost information presented in the above tables will vary somewhat from the estimates presented in Tables 36 and 37. This is due to the linear equations we constructed to calculate costs over varying distances and application rates.
- Actual costs by farm will vary.

Appendix 2. Beef feedlot model.

Beef feedlot manure: Base case – spring 2006.					
Input parameters		**Nutrient parameters**		**Price parameters**	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario		N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	3.20	Hauling cost factor	1
		N available Year 2	2.00		
Crop grown - (silage)		P content (kg/tonne)	2.40	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	5.5	Hauling cost for 5 km ($)	5.03
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	4.67		
Application rate (tonnes/ha)	135			Value of N in manure ($/tonne)	5.65
Total land requirement per year (ha)	160	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	3.21
Total Land required for rotation (ha)	0	P_2O_5 removal in barley silage (kg/ha)	59.74		
		P limit scenario		Total nutrient value in manure ($/tonne)	8.86
Base area (ha)	640	Total P_2O_5 required (kg/ha)	59.74		
		Manure required (tonnes/ha)	135		
Average hauling distance (km)	5.0				
Average hauling cost ($/tonne)	5.03	N removal in barley silage (kg/ha)	174.7		
Total spreading cost ($)	108,648	N limit scenario			
		Total N required (kg/ha)	349.4		
Total nutrient purchase ($)	60,731	Manure required (tonnes/ha)			
Spreading costs + nutrient purchase ($)	169,379	Total P_2O_5 supplied (kg/ha)	741.5		
		Total P_2O_5 available (kg/ha)	630.3		
Total value of manure ($)	191,379	Total P_2O_5 removed (kg/ha)	239.0		
Net value ($)	82,731	Annual P_2O_5 surplus (kg/ha)	97.8		
		Annual P surplus (kg/ha)	42.7		
Value per unit of capacity ($)	8.27				
Increased per unit cost ($)	(0.00)				

Beef feedlot manure: 4P scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario	4	N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	3.20	Hauling cost factor	1
		N available Year 2	2.00		
Crop grown - (silage)		P content (kg/tonne)	2.40	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	5.5	Hauling cost for 5 km ($)	6.24
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	4.67		
Application rate (tonnes/ha)	51.2			Value of N in manure ($/tonne)	5.65
Total land requirement per year (ha)	422	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	3.21
Total Land required for rotation (ha)	1689	P_2O_5 removal in barley silage (kg/ha)	59.743		
		P limit scenario	4	Total nutrient value in manure ($/tonne)	8.86
Base area (ha)	640	Total P_2O_5 required (kg/ha)	238.97		
Additional area required (ha)	1049	Manure required (tonnes/ha)	51.2		
Additional area required each year (ha)	262	Total P_2O_5 supplied (kg/ha)	281		
Average hauling distance (km)	5.0	Total P_2O_5 available (kg/ha)	238.97		
Average hauling cost ($/tonne)	6.24	Total P_2O_5 removed (kg/ha)	238.97		
Total spreading cost ($)	134784	Average annual P_2O_5 surplus (kg/ha)	0		
Total nutrient purchase ($)	75231				
Spreading costs + nutrient purchase ($)	210015				
Total value of manure ($)	191379				
Net value ($)	56595				
Value per unit of capacity ($)	5.66				
Increased cost over base ($)	40636				
Increased per unit cost ($)	4.06				

Beef feedlot manure: 2P scenario – spring 2006.

Input parameters		**Nutrient parameters**		**Price parameters**	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario	2	N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	3.20	Hauling cost factor	1
		N available Year 2	2.00		
Crop grown - (silage)		P content (kg/tonne)	2.40	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	5.5	Hauling cost for 5 km ($)	7.83
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	4.67		
Application rate (tonnes/ha)	25.6			Value of N in manure ($/tonne)	5.65
Total land requirement per year (ha)	845	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	3.21
Total Land required for rotation (ha)	1689	P_2O_5 removal in barley silage (kg/ha)	59.74		
		P limit scenario	2	Total nutrient value in manure ($/tonne)	8.86
Base area (ha)	640	Total P_2O_5 required (kg/ha)	119.49		
Additional area required (ha)	1049	Manure required (tonnes/ha)	25.6		
Additional area required each year (ha)	525	Total P_2O_5 supplied (kg/ha)	141		
Average hauling distance (km)	5.0	Total P_2O_5 available (kg/ha)	119.49		
Average hauling cost ($/tonne)	7.83	Total P_2O_5 removed (kg/ha)	119.49		
Total spreading cost ($)	169,128	Average annual P_2O_5 surplus (kg/ha)	0		
Total nutrient purchase ($)	75,231				
Spreading costs + nutrient purchase ($)	244,359				
Total value of manure ($)	191,379				
Net value ($)	22,251				
Value per unit of capacity ($)	2.23				
Increased cost over base ($)	74,980				
Increased per unit cost ($)	7.50				

Beef feedlot manure: 1P scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario	1	N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	3.20	Hauling cost factor	1
		N available Year 2	2.00		
Crop grown - (silage)		P content (kg/tonne)	2.40	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	5.5	Hauling cost for 5 km ($)	11.48
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	4.67		
Application rate (tonnes/ha)	12.8			Value of N in manure ($/tonne)	5.65
Total land requirement per year (ha)	1689	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	3.21
Total Land required for rotation (ha)	1689	P_2O_5 removal in barley silage (kg/ha)	59.74		
		P limit scenario	1	Total nutrient value in manure ($/tonne)	8.86
Base area (ha)	640	Total P_2O_5 required (kg/ha)	59.743		
Additional area required (ha)	1049	Manure required (tonnes/ha)	12.8		
Additional area required each year (ha)	1049	Total P_2O_5 supplied (kg/ha)	70		
Average hauling distance (km)	5.0	Total P_2O_5 available (kg/ha)	59.743		
Average hauling cost ($/tonne)	11.48	Total P_2O_5 removed (kg/ha)	59.743		
Total spreading cost ($)	247,968	Average annual P_2O_5 surplus (kg/ha)	0		
Total nutrient purchase ($)	75,231				
Spreading costs + nutrient purchase ($)	323,199				
Total value of manure ($)	191,379				
Net value ($)	(56,589)				
Value per unit of capacity ($)	(5.66)				
Increased cost over base ($)	154,180				
Increased per unit cost ($)	15.42				

Beef feedlot manure: 2N scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario	2	N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	3.20	Hauling cost factor	1
		N available Year 2	2.00		
Crop grown - (silage)		P content (kg/tonne)	2.40	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	5.5	Hauling cost for 5 km ($)	5.03
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	4.67		
Application rate (tonnes/ha)	109			Value of N in manure ($/tonne)	5.65
Total land requirement per year (ha)	198	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	3.21
Total Land required for rotation (ha)	791	P_2O_5 removal in barley silage (kg/ha)	59.74		
		P limit scenario		Total nutrient value in manure ($/tonne)	8.86
Base area (ha)	640	Total P_2O_5 required (kg/ha)			
Additional area required (ha)	151	Manure required (tonnes/ha)			
Additional area required each year (ha)	37.8				
Average hauling distance (km)	5.0	N removal in barley silage (kg/ha)	174.7		
Average hauling cost ($/tonne)	5.03	N limit scenario	2		
Total spreading cost ($)	108,648	Total N required (kg/ha)	349.4		
		Manure required (tonnes/ha)	109		
Total nutrient purchase ($)	60,731				
		Total P_2O_5 supplied (kg/ha)	600.1		
Spreading costs + nutrient purchase ($)	169,379	Total P_2O_5 available (kg/ha)	510.1		
		Total P_2O_5 removed (kg/ha)	239.0		
Total value of manure ($)	191,379	Annual P_2O_5 surplus (kg/ha)	67.8		
Net value ($)	82,731	Annual P surplus (kg/ha)	29.6		
Value per unit of capacity ($)	8.27				
Increased cost over base ($)					
Increased per unit cost ($)	(0.00)				

Beef feedlot manure: Move all the manure 10 km – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units	10000	N in manure (kg/tonne)	10.00	Value of urea 46-0-0	499.67
Manure produced per unit	2.16				
Total amount of Manure (tonnes)	21600	N availability factor- Year 1	0.32	Value of MAP 11-51-0	470.11
N limit scenario		N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	0.00	Hauling cost factor	1
		N available Year 2	0.00		
Crop grown - (silage)		P content (kg/tonne)	0.00	N price ($/kg)	1.09
		P to P_2O_5 factor	0.00	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	174.72	P_2O_5 content (kg/tonne)	0.0	Hauling cost for 5 km ($)	6.26
P_2O_5 requirements (kg/ha)	59.74	Total P_2O_5 available (kg/tonne)	0.00		
Application rate (tonnes/ha)	0			End dump cost (80% of hauling cost)	5.01
Total land requirement per year (ha)	0	**Application rate calculations**		Reload charge (adjacent rate)	2.95
Total Land required for rotation (ha)	0	P_2O_5 removal in barley silage (kg/ha)	59.74		
		P limit scenario	0	Value of N in manure ($/tonne)	0.00
Base area (ha)	640	Total P_2O_5 required (kg/ha)	0	Value of P_2O_5 in manure ($/tonne)	0.00
Additional area required (ha)		Manure required (tonnes/ha)	0		
Additional area required each year (ha)				Total nutrient value in manure ($/tonne)	0.00
Average hauling distance (km)	10.0	N removal in barley silage (kg/ha)	174.7		
Average hauling cost ($/tonne)	5.01	N limit scenario	0		
Total spreading cost ($)	108,173	Total N required (kg/ha)			
	63,720	Manure required (tonnes/ha)	0		
Total nutrient purchase ($)	21,461				
		Total P_2O_5 supplied (kg/ha)	0.0		
Spreading costs + nutrient purchase ($)	93,354	Total P_2O_5 available (kg/ha)	0.0		
Total base case cost ($)	167,191				
Difference from base case ($)	26,163				
Value per unit of capacity ($)					
Increased cost over base ($)					
Increased per unit cost ($)	12.62				

Beef feedlot manure: Move all the manure 18 km – spring 2006.

Input parameters	
Number of animal units	10000
Manure produced per unit	2.16
Total amount of Manure (tonnes)	21600
N limit scenario	
P availability factor	0.85
Crop grown - (silage)	
N requirements (kg/ha)	174.72
P_2O_5 requirements (kg/ha)	59.74
Application rate (tonnes/ha)	0
Total land requirement per year (ha)	0
Total Land required for rotation (ha)	0
Base area (ha)	640
Additional area required (ha)	
Additional area required each year (ha)	
Average hauling distance (km)	18.0
Average hauling cost ($/tonne)	6.36
Total spreading cost ($)	137,376
	63,720
Total nutrient purchase ($)	121,461
Spreading costs + nutrient purchase ($)	322,557
Total base case cost ($)	167,191
Difference from base case ($)	155,366
Value per unit of capacity ($)	
Increased cost over base ($)	
Increased per unit cost ($)	15.54

Nutrient parameters	
N in manure (kg/tonne)	10.00
N availability factor- Year 1	0.32
N availability factor- Year 2	0.20
N available Year 1	0.00
N available Year 2	0.00
P content (kg/tonne)	0.00
P to P_2O_5 factor	0.00
P_2O_5 content (kg/tonne)	0.0
Total P_2O_5 available (kg/tonne)	0.00
Application rate calculations	
P_2O_5 removal in barley silage (kg/ha)	59.74
P limit scenario	0
Total P_2O_5 required (kg/ha)	0
Manure required (tonnes/ha)	0
N removal in barley silage (kg/ha)	174.7
N limit scenario	0
Total N required (kg/ha)	
Manure required (tonnes/ha)	0
Total P_2O_5 supplied (kg/ha)	0.0
Total P_2O_5 available (kg/ha)	0.0

Price parameters	
Value of urea 46-0-0	499.67
Value of MAP 11-51-0	470.11
N price factor	1
P_2O_5 price factor	1
Hauling cost factor	1
N price ($/kg)	1.09
P2O5 price ($/kg)	0.69
Hauling cost for 5 km ($)	7.95
End dump cost (80% of hauling cost)	6.36
Reload charge (adjacent rate)	2.95
Value of N in manure ($/tonne)	0.00
Value of P_2O_5 in manure ($/tonne)	0.00
Total nutrient value in manure ($/tonne)	0.00

Beef feedlot manure: Base case – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.72	174.72	174.72	174.72	
Manure applied (tonnes/ha)	135	0	0	0	
N supplied in Year 1 (kg/ha)	431.7				
N supplied in Year 2 (kg/ha)		269.8			
Added N required (kg/ha)	-257.0	-95.1	174.7	174.7	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	630.3				
Cost ($/ha)			189.78	189.78	
Area size (ha)	160	160	160	160	
Cost per area ($)	-	-	30,365.34	30,365.34	60,730.67

Beef feedlot manure: 4P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.7	174.7	174.7	174.7	
Manure applied (tonnes/ha)	51	0	0	0	
N supplied in Year 1 (kg/ha)	163.7				
N supplied in Year 2 (kg/ha)		102.3			
Added N required (kg/ha)	11.0	72.4	174.7	174.7	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	239.0				
Cost ($/ha)	11.97	78.65	189.78	189.78	
Area size (ha)	160	160	160	160	
Cost per area ($)	1,915.60	12,584.25	30,365.34	30,365.34	75,230.53

Beef feedlot manure: 2P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.7	174.7	174.7	174.7	
Manure applied (tonnes/ha)	25.6	0	25.6	0	
N supplied in Year 1 (kg/ha)	81.8		81.8		
N supplied in Year 2 (kg/ha)		51.2		51.2	
Added N required (kg/ha)	92.9	123.6	92.9	123.6	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	119.5		119.5		
Cost ($/ha)	100.88	134.22	100.88	134.22	
Area size (ha)	160	160	160	160	
Cost per area ($)	16,140.47	21,474.79	16,140.47	21,474.79	75,230.53

Beef feedlot manure: 1P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.7	174.7	174.7	174.7	
Manure applied (tonnes/ha)	12.8	12.8	12.8	12.8	
N supplied in Year 1 (kg/ha)	40.9	40.9	40.9	40.9	
N supplied in Year 2 (kg/ha)	25.6	25.6	25.6	25.6	
Added N required (kg/ha)	108.2	108.2	108.2	108.2	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	59.7	59.7	59.7	59.7	
Cost ($/ha)	117.55	117.55	117.55	117.55	
Area size (ha)	160	160	160	160	
Cost per area ($)	18,807.63	18,807.63	18,807.63	18,807.63	75,230.53

Beef feedlot manure: 2N scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.72	174.72	174.72	174.72	
Manure applied (tonnes/ha)	109	0	0	0	
N supplied in Year 1 (kg/ha)	349.4				
N supplied in Year 2 (kg/ha)		218.4			
Added N required (kg/ha)	-174.7	-43.7	174.7	174.7	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	510.1				
Cost ($/ha)			189.78	189.78	
Area size (ha)	160	160	160	160	
Cost per area ($)	-	-	30,365.34	30,365.34	60,730.67

Beef feedlot manure: Move all the manure 10 km – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.7	174.7	174.7	174.7	
Manure applied (tonnes/ha)	0	0	0	0	
N supplied in Year 1 (kg/ha)	0	0	0	0	
N supplied in Year 2 (kg/ha)	0	0	0	0	
Added N required (kg/ha)	174.7	174.7	174.7	174.7	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	59.7	59.7	59.7	59.7	
Cost ($/ha)	189.78	189.78	189.78	189.78	
Area size (ha)	160	160	160	160	
Cost per area ($)	30,365.34	30,365.34	30,365.34	30,365.34	121,461.35

Assumes P_2O_5 available in soil.

Beef feedlot manure: Move all the manure 18 km – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	174.7	174.7	174.7	174.7	
Manure applied (tonnes/ha)	0	0	0	0	
N supplied in Year 1 (kg/ha)	0.0	0.0	0.0	0.0	
N supplied in Year 2 (kg/ha)	0.0	0.0	0.0	0.0	
Added N required (kg/ha)	174.7	174.7	174.7	174.7	
Total P_2O_5 required (kg/ha)	59.7	59.7	59.7	59.7	
Total P_2O_5 supplied (kg/ha)	59.7	59.7	59.7	59.7	
Cost ($/ha)	189.78	189.78	189.78	189.78	
Area size (ha)	160	160	160	160	
Cost per area ($)	30,365.34	30,365.34	30,365.34	30,365.34	121,461.35

Assumes P_2O_5 available in soil.

Appendix 3. Hog farrow-to-finish model.

Hog farrow-to-finish manure: Base case – spring 2006.

Input parameters		**Nutrient parameters**		**Price parameters**	
Number of animal units (sows)	500	N in manure (kg/tonne)	3.50	Value of urea 46-0-0	
Manure produced per unit (‘000 litres)	24				499.67
Total amount of Manure (‘000 litres)	12,000	N availability factor- Year 1	0.46	Value of MAP 11-51-0	
N limit scenario	0	N availability factor- Year 2	0.20	N price factor	470.11
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	1.60	Hauling cost factor	1
		N available Year 2	0.70		1
Crop grown - (barley grain)		P content (kg/tonne)	1.10	N price ($/kg)	
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	1.09
N requirements (kg/ha)	87.0	P_2O_5 content (kg/tonne)	2.5	Hauling cost for 2 km ($)	0.69
P_2O_5 requirements (kg/ha)	37.6	Total P_2O_5 available (kg/tonne)	2.14		
Application rate (tonnes/ha)	86.5			Value of N in manure ($/tonne)	2.50
Total land requirement per year (ha)	139	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	1.47
Total Land required for rotation (ha)	555	P_2O_5 removal in barley grain (kg/ha)	37.6		
		P limit scenario		Total nutrient value in manure ($/tonne)	3.97
Base area (ha)	555	Total P_2O_5 required (kg/ha)	37.6		
		Manure required (tonnes/ha)	86.5		
Average hauling distance (km)	1.6				
Average hauling cost ($/tonne)	2.28	N removal in barley silage (kg/ha)	87.0		
Total spreading cost ($)	27,360	N limit scenario			
		Total N required (kg/ha)	87.0		
Total nutrient purchase ($)	30,196	Manure required (tonnes/ha)			
Spreading costs + nutrient purchase ($)			218.0		
		Total P_2O_5 available (kg/ha)	185.3		
Total value of manure ($)	47,638	Total P_2O_5 removed (kg/ha)	150.4		
Net value ($)	20,278	Annual P_2O_5 surplus (kg/ha)	8.7		
		Annual P surplus (kg/ha)	3.8		
Value per unit of capacity ($)	40.6				
Increased per unit cost ($)	-				

Hog farrow-to-finish manure: 4P scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units (sows)	500	N in manure (kg/tonne)	3.50	Value of urea 46-0-0	499.67
Manure produced per unit (‘000 litres)	24				
Total amount of Manure (‘000 litres)	12,000	N availability factor- Year 1	0.46	Value of MAP 11-51-0	470.11
N limit scenario		N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	1.60	Hauling cost factor	1
		N available Year 2	0.70		
Crop grown - (barley grain)		P content (kg/tonne)	1.10	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	87.0	P_2O_5 content (kg/tonne)	2.5	Hauling cost for 2 km ($)	2.34
P_2O_5 requirements (kg/ha)	37.6	Total P_2O_5 available (kg/tonne)	2.14		
Application rate (tonnes/ha)	70.2			Value of N in manure ($/tonne)	2.50
Total land requirement per year (ha)	171	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	1.47
Total Land required for rotation (ha)	683	P_2O_5 removal in barley grain (kg/ha)	37.6		
		P limit scenario	4	Total nutrient value in manure ($/tonne)	3.97
Base area (ha)	555	Total P_2O_5 required (kg/ha)	150.4		
Additional area required (ha)	129	Manure required (tonnes/ha)	70.2		
Additional area required each year (ha)					
Average hauling distance (km)	1.6	N removal barley grain (kg/ha)	87.0		
Average hauling cost ($/tonne)	2.34	N limit scenario			
Total spreading cost ($)	28,080	Total N required (kg/ha)	87.0		
		Manure required (tonnes/ha)			
Total nutrient purchase ($)	31,916				
		Total P_2O_5 supplied (kg/ha)	176.9		
Spreading costs + nutrient purchase ($)	59,996	Total P_2O_5 available (kg/ha)	150.4		
		Total P_2O_5 removed (kg/ha)	150.4		
Total value of manure ($)	47,638	Average annual P_2O_5 surplus (kg/ha)	0.0		
Net value ($)	19,558				
Value per unit of capacity ($)	39.12				
Increased cost over base ($)	2,440				
Increased per unit cost ($)	4.88				

Hog farrow-to-finish manure: 2P scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units (sows)	500	N in manure (kg/tonne)	3.50	Value of urea 46-0-0	499.67
Manure produced per unit (‘000 litres)	24				
Total amount of Manure (‘000 litres)	12,000	N availability factor- Year 1	0.46	Value of MAP 11-51-0	470.11
N limit scenario		N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	1.60	Hauling cost factor	1
		N available Year 2	0.70		
Crop grown - (barley grain)		P content (kg/tonne)	1.10	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	87.0	P_2O_5 content (kg/tonne)	2.5	Hauling cost for 2 km ($)	3.04
P_20_5 requirements (kg/ha)	37.6	Total P_2O_5 available (kg/tonne)	2.14		
Application rate (tonnes/ha)	35.1			Value of N in manure ($/tonne)	2.50
Total land requirement per year (ha)	342	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	1.47
Total Land required for rotation (ha)	683	P_2O_5 removal in barley grain (kg/ha)	37.6		
		P limit scenario	2	Total nutrient value in manure ($/tonne)	3.97
Base area (ha)	555	Total P_2O_5 required (kg/ha)	75.2		
Additional area required (ha)	129	Manure required (tonnes/ha)	35.1		
Additional area required each year (ha)					
Average hauling distance (km)	1.6	N removal barley grain (kg/ha)	87.0		
Average hauling cost ($/tonne)	3.04	N limit scenario			
Total spreading cost ($)	36,480	Total N required (kg/ha)	87.0		
		Manure required (tonnes/ha)			
Total nutrient purchase ($)	28,103				
		Total P_2O_5 supplied (kg/ha)	88.5		
Spreading costs + nutrient purchase ($)	64,583	Total P_2O_5 available (kg/ha)	75.2		
		Total P_2O_5 removed (kg/ha)	75.2		
Total value of manure ($)	47,638	Average annual P_2O_5 surplus (kg/ha)	0.0		
Net value ($)	11,158				
Value per unit of capacity ($)	22.32				
Increased cost over base ($)	7,027				
Increased per unit cost ($)	14.05				

Hog farrow-to-finish manure: 1P scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units (sows)	500	N in manure (kg/tonne)	3.50	Value of urea 46-0-0	499.67
Manure produced per unit (‘000 litres)	24				
Total amount of Manure (‘000 litres)	12,000	N availability factor- Year 1	0.46	Value of MAP 11-51-0	470.11
N limit scenario		N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	1.60	Hauling cost factor	1
		N available Year 2	0.70		
Crop grown - (barley grain)		P content (kg/tonne)	1.10	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	87.0	P_2O_5 content (kg/tonne)	2.5	Hauling cost for 2 km ($)	3.57
P_2O_5 requirements (kg/ha)	37.6	Total P_2O_5 available (kg/tonne)	2.14		
Application rate (tonnes/ha)	17.6			Value of N in manure ($/tonne)	2.50
Total land requirement per year (ha)	683	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	1.47
Total Land required for rotation (ha)	683	P_2O_5 removal in barley grain (kg/ha)	37.6		
		P limit scenario	1	Total nutrient value in manure ($/tonne)	3.97
Base area (ha)	555	Total P_2O_5 required (kg/ha)	37.6		
Additional area required (ha)	129	Manure required (tonnes/ha)	17.6		
Additional area required each year (ha)					
Average hauling distance (km)	1.6	N removal barley grain (kg/ha)	87.0		
Average hauling cost ($/tonne)	3.57	N limit scenario			
Total spreading cost ($)	42,840	Total N required (kg/ha)	87.0		
		Manure required (tonnes/ha)			
Total nutrient purchase ($)	28,103				
		Total P_2O_5 supplied (kg/ha)	44.2		
Spreading costs + nutrient purchase ($)	70,943	Total P_2O_5 available (kg/ha)	37.6		
		Total P_2O_5 removed (kg/ha)	37.6		
Total value of manure ($)	47,638	Average annual P_2O_5 surplus (kg/ha)	0.0		
Net value ($)	4,798				
Value per unit of capacity ($)	9.60				
Increased cost over base ($)	13,387				
Increased per unit cost ($)	26.77				

Hog farrow-to-finish manure: 2N scenario – spring 2006.

Input parameters		Nutrient parameters		Price parameters	
Number of animal units (sows)	500	N in manure (kg/tonne)	3.50	Value of urea 46-0-0	499.67
Manure produced per unit (‘000 litres)	24				
Total amount of Manure (‘000 litres)	12,000	N availability factor- Year 1	0.46	Value of MAP 11-51-0	470.11
N limit scenario	2	N availability factor- Year 2	0.20	N price factor	1
				P_2O_5 price factor	1
P availability factor	0.85	N available Year 1	1.60	Hauling cost factor	1
		N available Year 2	0.70		
Crop grown - (barley grain)		P content (kg/tonne)	1.10	N price ($/kg)	1.09
		P to P_2O_5 factor	2.29	P2O5 price ($/kg)	0.69
N requirements (kg/ha)	87.0	P_2O_5 content (kg/tonne)	2.5	Hauling cost for 2 km ($)	2.28
P_2O_5 requirements (kg/ha)	37.6	Total P_2O_5 available (kg/tonne)	2.14		
Application rate (tonnes/ha)	108.8			Value of N in manure ($/tonne)	2.50
Total land requirement per year (ha)	110	**Application rate calculations**		Value of P_2O_5 in manure ($/tonne)	1.47
Total Land required for rotation (ha)	441	P_2O_5 removal in barley grain (kg/ha)	37.6		
		P limit scenario		Total nutrient value in manure ($/tonne)	3.97
Base area (ha)	555	Total P_2O_5 required (kg/ha)	37.6		
Additional area required (ha)	114	Manure required (tonnes/ha)			
Additional area required each year (ha)					
Average hauling distance (km)	1.6	N removal in barley silage (kg/ha)	87.0		
Average hauling cost ($/tonne)	2.28	N limit scenario	2		
Total spreading cost ($)	27,360	Total N required (kg/ha)	174.0		
		Manure required (tonnes/ha)	108.8		
Total nutrient purchase ($)	35,812				
		Total P_2O_5 supplied (kg/ha)	274.1		
Spreading costs + nutrient purchase ($)	63,172	Total P_2O_5 available (kg/ha)	233.0		
		Total P_2O_5 removed (kg/ha)	150.4		
Total value of manure ($)	47,638	Annual P_2O_5 surplus (kg/ha)	20.65		
Net value ($)	20,278	Annual P surplus (kg/ha)	9.0		
Value per unit of capacity ($)	40.56				
Increased cost over base ($)	5,616				
Increased per unit cost ($)	11.23				

Hog farrow-to-finish manure: Base case – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	87.0	87.0	87.0	87.0	
Manure applied (tonnes/ha)	87		0	0	
N supplied in Year 1 (kg/ha)	138.4				
N supplied in Year 2 (kg/ha)		60.6			
Added N required (kg/ha)	-51.4	26.4	87.0	87.0	
Total P_2O_5 required (kg/ha)	37.6	37.6	37.6	37.6	
Total P_2O_5 supplied (kg/ha)	185.3				
Cost ($/ha)		28.72	94.52	94.52	
Area size (ha)	139	139	139	139	
Cost per area ($)	-	3,982.45	13,106.86	13,106.86	30,196.17

Hog farrow-to-finish manure: 4P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	87.0	87.0	87.0	87.0	
Manure applied (tonnes/ha)	70		0	0	
N supplied in Year 1 (kg/ha)	112.3				
N supplied in Year 2 (kg/ha)		49.2			
Added N required (kg/ha)	-25.3	37.9	87.0	87.0	
Total P_2O_5 required (kg/ha)	37.6	37.6	37.6	37.6	
Total P_2O_5 supplied (kg/ha)	150.4				
Cost ($/ha)		41.12	94.52	94.52	
Area size (ha)	139	139	139	139	
Cost per area ($)	-	5,702.09	13,106.86	13,106.86	31,915.81

Hog farrow-to-finish manure: 2P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	87.0	87.0	87.0	87.0	
Manure applied (tonnes/ha)	35		35	0	
N supplied in Year 1 (kg/ha)	56.2		56.2		
N supplied in Year 2 (kg/ha)		24.6		24.6	
Added N required (kg/ha)	30.9	62.4	30.9	62.4	
Total P_2O_5 required (kg/ha)	37.6	37.6	37.6	37.6	
Total P_2O_5 supplied (kg/ha)	75.2		75.2		
Cost ($/ha)	33.51	67.82	33.51	67.82	
Area size (ha)	139	139	139	139	
Cost per area ($)	4,646.91	9,404.47	4,646.91	9,404.47	28,102.77

Hog farrow-to-finish manure: 1P scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	87.0	87.0	87.0	87.0	
Manure applied (tonnes/ha)	17.6	17.6	17.6	17.6	
N supplied in Year 1 (kg/ha)	28.1	28.1	28.1	28.1	
N supplied in Year 2 (kg/ha)	12.3	12.3	12.3	12.3	
Added N required (kg/ha)	46.6	46.6	46.6	46.6	
Total P_2O_5 required (kg/ha)	37.6	37.6	37.6	37.6	
Total P_2O_5 supplied (kg/ha)	37.6	37.6	37.6	37.6	
Cost ($/ha)	50.67	50.67	50.67	50.67	
Area size (ha)	139	139	139	139	
Cost per area ($)	7,025.69	7,025.69	7,025.69	7,025.69	28,102.77

Hog farrow-to-finish manure: 2N scenario – added nitrogen required.					
	Area 1	Area 2	Area 3	Area 4	Totals
Total N required (kg/ha)	87.0	87.0	87.0	87.0	87
Manure applied (tonnes/ha)	109				0
N supplied in Year 1 (kg/ha)	174.0				
N supplied in Year 2 (kg/ha)		76.2			
Added N required (kg/ha)	-87.0	10.9	87.0	87.0	87.0
Total P_2O_5 required (kg/ha)	37.6	37.6	37.6	37.6	
Total P_2O_5 supplied (kg/ha)	233.0				37.6
Cost ($/ha)		11.79	94.52	94.52	120.37
Area size (ha)	110	110	110	110	114
Cost per area ($)	-	1,300.23	10,424.64	10,424.64	13,662.50