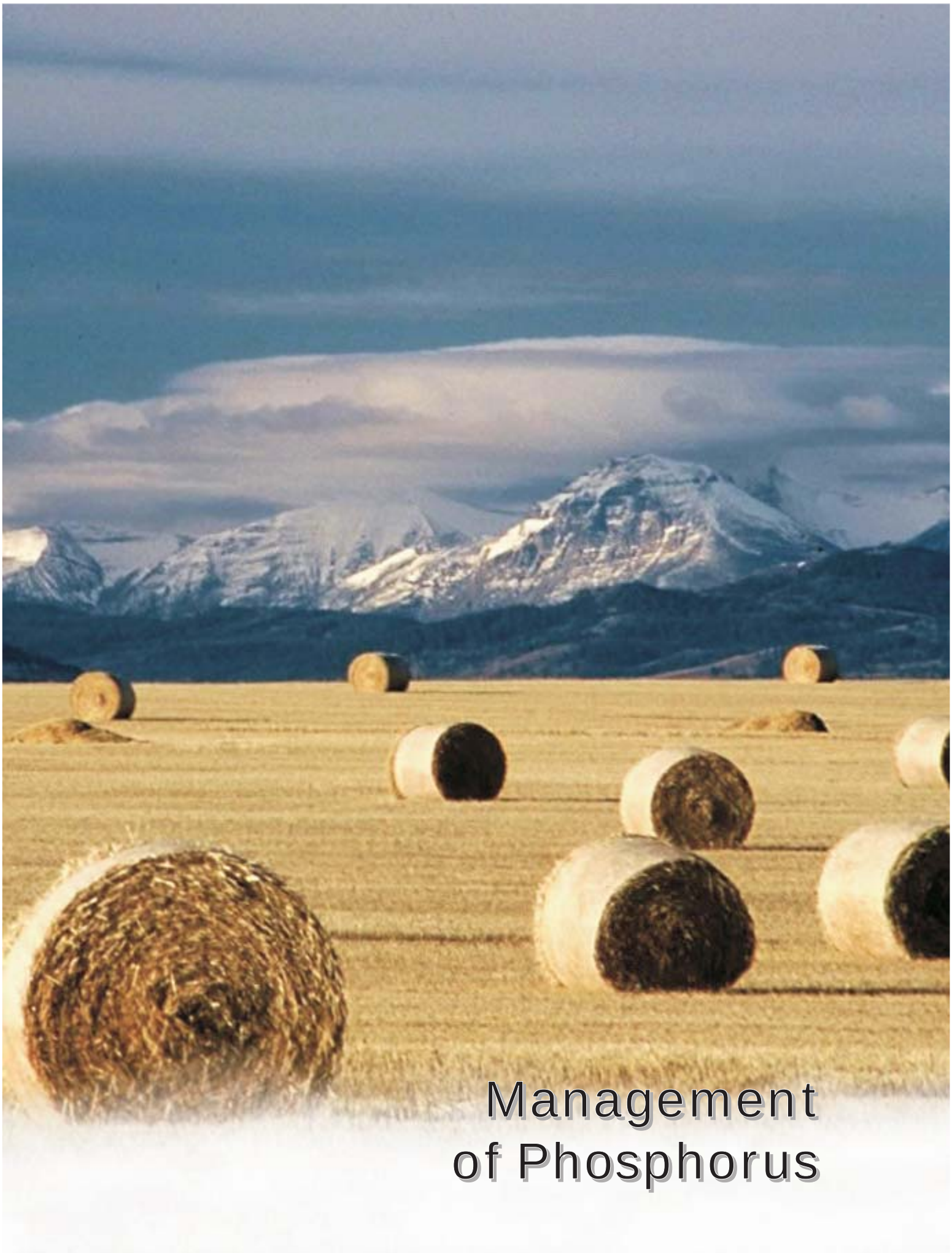


Management of Phosphorus

Introduction

Manure application in Alberta is currently regulated through the Agricultural Operation Practices Act (AOPA) and is based on nitrogen requirements of crops. The Act identifies land requirements for various livestock operations, and the land requirements are based on: typical values for manure production volumes (Province of Alberta 2004); crop nitrogen requirements (Province of Alberta 2004); and crop nitrogen supplied by manure (Province of Alberta 2001). Producers have the option of using the AOPA land base requirement values or of preparing a nutrient management plan, which is approved by the Natural Resources Conservation Board. Producers can use their own values for manure production, manure nutrient content, and crop nitrogen requirements in the nutrient management plan.

Relative to the nitrogen-based standards and current manure management systems, the two ways to prevent phosphorus accumulation in soil are to reduce the amount of phosphorus in the manure, or spread manure on a larger land base. Based on the AOPA data, 300 head of beef finishers in the Brown or Dark Brown soil zones require 37 ha of land to dispose of the manure (Province of Alberta 2004). Table 6 shows how the current nitrogen-based land requirements were calculated for the AOPA. Using a similar approach, a phosphorus-based land requirement value was calculated, which shows that 2.4 times more land is required to accommodate the manure for the 300 head of beef cattle finishers in the Brown or Dark Brown soil zones. For other soil zones, the AOPA data showed that the land base requirements increased from 1.5 to 2.7 for the main livestock types (feedlot cattle, hog, dairy, and poultry).

Alberta's agricultural industry, in cooperation with the federal and provincial governments, initiated research, extension, and financial support programs that promote the adoption of beneficial management practices (BMPs) by producers. While these programs have been successful in raising producer awareness and understanding of water quality problems associated with current agricultural management systems, they have not led to widespread adoption of BMPs throughout the province. A likely reason for this is that most BMPs recommended in manuals and extension publications have not been field-tested on a regional basis to determine if they are:

Demonstration day

Table 6. Nitrogen-based land requirements as determined for the Agricultural Operation Practices Act and calculated phosphorus-based land requirements using the same approach as for nitrogen. The example is for beef finishers in the Brown or Dark Brown soil zones.

	Nitrogen based	Phosphorus based
Number of animals	300	300
Annual manure production (tonnes/animal)[z]	2.16	2.16
Nutrients from manure (kg/tonne)[y]	3.2	1.68
Crop nutrient requirement (kg/ha)[x]	56	12.2
Land base required (ha)[w]	37	89

[z] From AOPA (Province of Alberta 2004).

[y] From AOPA (Province of Alberta 2001). The nitrogen value (3.2 kg/tonne) is crop nitrogen content, which is the portion of total nitrogen estimated to become available in the first year after application. The crop phosphorus value (1.68 kg/tonne) is 70% of the total phosphorus content and expressed as elemental phosphorus (P).

[x] The crop phosphorus requirement value was obtained from the 2001 version of AOPA (Province of Alberta 2001) and expressed as elemental phosphorus (P).

[w] Nitrogen-based land requirement = 300 x 2.16 tonnes/year x 3.2 kg/tonne ÷ 56 kg/ha = 37 ha/year
Phosphorus-based land requirement = 300 x 2.16 tonnes/year x 1.68 kg/tonne ÷ 12.2 kg/ha = 89 ha/year

- Effective in reducing nutrient losses to surface water or groundwater;
- Technically feasible to implement; and
- Economically possible for a producer.

Until a comprehensive field-testing program is completed, widespread BMP adoption may not take place.

Beneficial Management Practices

Over-wintering sites can represent a significant source of livestock phosphorus losses to rivers.

Several BMP recommendations for phosphorus control at site-specific locations in Alberta are being tested within the areas of nutrient management, soil conservation, surface runoff reduction, and riparian area management. For cow-calf operations, two key BMPs are recommended. The first is related to riparian area protection through improved livestock management in these areas (Figure 23), and using off-stream watering systems (Figure 24) that limit the direct access of cattle to streams and lakes. Off-stream watering systems not only reduce nutrient loading of waterways, they also promote better pasture utilization and increased weight gain by cattle.

The second BMP is related to over-wintering sites, which can represent a significant source of livestock phosphorus losses to rivers (Figure 25). Under AOPA, wintering sites are required to be set back from surface water, or an interceptor drain should be constructed to minimize the amount of runoff entering the water. This often necessitates moving over-wintering sites away from the water source, and this will require that water be pumped to the cattle.

For confined feeding operations, manure spreading is the leading cause of agricultural phosphorus losses to surface water bodies.

For confined feeding operations, manure spreading is the leading cause of agricultural phosphorus losses to surface water bodies (Figure 26). The key BMP recommendation to reduce phosphorus losses from manured fields relates to manure application rates. The best environmental option is to apply manure to meet annual crop phosphorus requirements. This would require producers to apply manure at rates that are significantly lower than those allowed under the AOPA.

Figure 23. Restricting cattle access to streams.

Figure 24. Off-stream watering with a nose pump.

Applying these lower rates raises two critical issues.

- Current technology available to Alberta producers does not allow application of solid or liquid manure at these relatively low rates.
- Even if the technology was available, producers would need to have access to a significantly larger land base to accommodate the lower spreading rates. Both of these issues require further assessment, research, and development.

There are a number of measures that producers can implement to reduce phosphorus losses (Kalischuk et al. 2006).

- Wherever possible, phosphorus application should be according to crop phosphorus requirements, and application should be planned appropriately in relation to timing and location.
- Surface runoff from agricultural land should be minimized as much as possible by using appropriate tillage and irrigation water management, and by maintaining low-lying areas, potholes, and wetlands in their natural state.

Current technology available to Alberta producers does not allow application of solid or liquid manure at annual crop phosphorus requirements.

- Application of manure on snow-covered or frozen ground should be avoided at all times.
- Surface applied manure should be incorporated immediately.
- Injection of manure immediately prior to freeze-up should be avoided, to allow sufficient time for the soil openings to seal.
- Manure application prior to rainfall or in critical source areas is not recommended.
- Fertilizer should be banded or applied with the seed on cultivated land.
- Runoff from over-wintering sites should be prevented from entering surface water.
- Livestock should be effectively managed in riparian areas to ensure a healthy ecosystem.
- Off-stream watering systems should be installed to minimize direct access of livestock to surface water.
- Soil conservation practices should be used to reduce soil erosion, which in turn will reduce

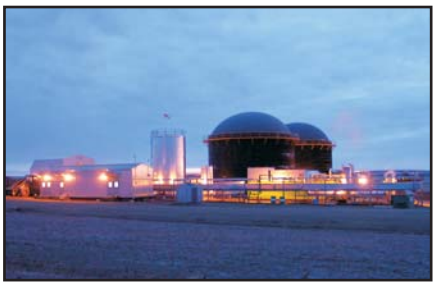
Figure 25. Cattle over-wintering site.

Figure 26. Commercial manure spreading.

the movement of particulate phosphorus from the land.

- Buffer strips should be developed, enhanced, and maintained around surface water bodies and areas that drain into surface waters.
- Alternative uses of manure in Alberta, such as composting and biogas, should continue to be explored.
- Livestock feeding strategies that reduce the amount of phosphorus in manure should be utilized wherever practical.

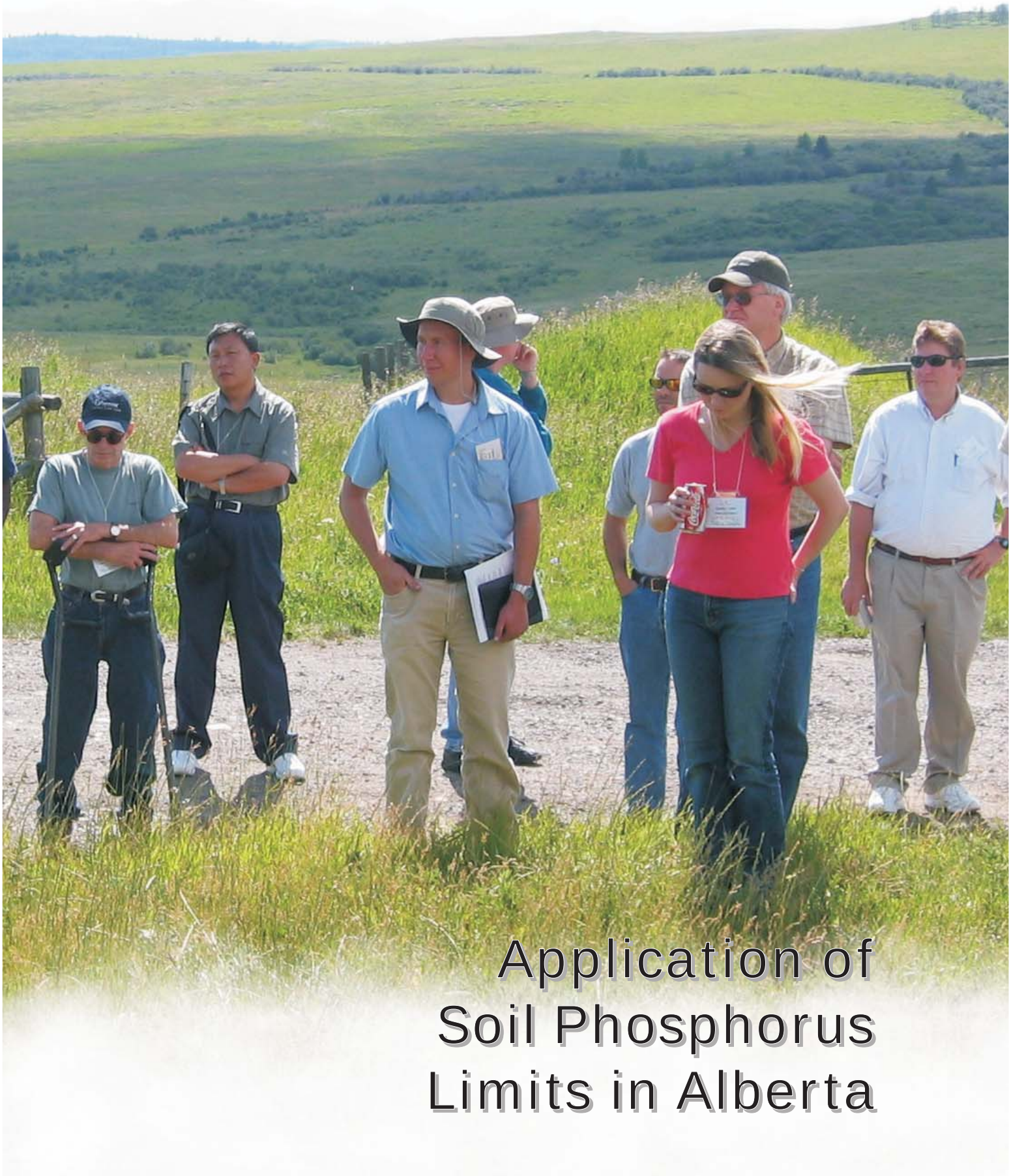
Grassed waterway



Biogas operation

While individual BMPs may reduce phosphorus runoff at a farm level, reducing phosphorus runoff to surface water on a watershed scale is most successful when several BMPs are applied together. However, before widespread producer adoption of BMPs will take place, more rigorous testing of BMPs is needed. In addition, more applied research at the regional watershed scale needs to be conducted to evaluate BMP effectiveness and to determine to what extent we are able to successfully manage phosphorus.

Before widespread producer adoption of BMPs will take place, more rigorous testing of BMPs is needed



Application of Soil Phosphorus Limits in Alberta

Introduction

The field research carried out in the Soil Phosphorus Limits Project shows a strong relationship between STP levels in the soil profile and TP concentrations in runoff water. This relationship, combined with a hypothetical TP runoff water quality limit (TPRWQL), allows the calculation of STP limits for each of the approximately 27,000 AGRASID soil polygons within the agricultural area of Alberta. It is assumed that STP levels in all AGRASID polygons in a watershed can reach the STP limit and TP concentrations in runoff will not exceed the TPRWQL.

For this project, two TPRWQL values (0.5 and 1.0 ppm) were used to calculate STP limits. Currently, Alberta does not have a TPRWQL for non-point source runoff entering surface water bodies. The 1.0 ppm value was chosen because it represents the Alberta Environment limit for point-source discharge from Alberta's waste water treatment plants (A. Pentney, personal communication 2006). If the hypothetical TPRWQL of 1.0 ppm is used to calculate soil phosphorus limits, approximately 8% (1.9 Million ha) of the agricultural area of the province will have STP limits that are less than 30 ppm. These areas are generally considered to be very high risk areas adjacent to streams and rivers. Approximately 35% (8.9 Million ha) of the agricultural area will have STP limits between 30 to 60 ppm. As discussed earlier, 60 ppm is considered the agronomic threshold STP for most crops in Alberta.

Wastewater treatment plant

The results of this research present a number of challenges for producers, researchers, and policy makers in Alberta. If the calculated STP limits (based on a TPRWQL of 1.0 ppm) were adopted as part of Alberta's Agricultural Operation Practices Act (AOPA), producers on 1.9 Million ha of agricultural land would be required to maintain STP levels that are below 30 ppm, which is half of the agronomic threshold of 60 ppm. Producers on 8.9 Million ha would be required to maintain STP levels between 30 and 60 ppm. Even crop producers who only apply commercial fertilizer at annual crop uptake rates would find it difficult, if not impossible, to operate under these STP limits. It would prove even more difficult for Alberta's confined feeding operators.

From a policy perspective, it is not reasonable to require that agricultural producers maintain STP levels below 60 ppm, except in specific areas, such as flood plain and riparian zones, where the risk of runoff and nutrient movement to surface water is very high. If 60 ppm were to become the minimum STP limit (except for very high risk areas), what potential impact could this have on surface water quality? The answer is dependent on the overall development expectations for each watershed. With the exception of a few regions, most agricultural watersheds in Alberta are predominantly occupied by crop producers, who generally apply phosphorus in the form of commercial fertilizers, and only at annual crop requirements. At present, only about 5% of Alberta's agricultural land base receives manure on a regular basis, and confined feeding operations generally occupy a relatively small part of most watersheds. It is unlikely that any watershed will be developed to the extent where STP levels in all AGRASID polygons reach the STP limit. Most watersheds will have a mix; some areas where STP levels exceed the STP limit, and other areas where STP levels are less than the STP limit. As a result, the impact on surface water

From a policy perspective, it is not reasonable to require that agricultural producers maintain STP levels below 60 ppm, except in specific areas, such as flood plain and riparian zones, where the risk of runoff and nutrient movement to surface water is very high.

quality should therefore not be unduly compromised.

It is recognized that regardless of the STP limit, whether it is 40 ppm or 200 ppm, the same soil management system will have to be applied at some point in time to ensure that the limit is not exceeded. Ultimately, all producers will have to develop a nutrient management plan that balances phosphorus inputs to the land with phosphorus crop uptake or losses. For confined livestock feeding operations that are being established on previously un-manured land, with relatively low soil phosphorus levels, maintaining STP levels at or below the 60 ppm, or the STP limit if it is higher, should be feasible over the long term. Manure applications that provide multi-year phosphorus requirements for crops are a realistic management practice for new confined livestock feeding operations, but care must be taken to ensure that sufficient time elapses between manure applications so crop uptake can reduce STP to approximately pre-manure levels. The real challenge will be how to deal with existing confined feeding operations where STP levels on manured land already significantly exceed recommended STP limits. It is clear that continued manure applications will further exacerbate phosphorus losses in runoff and increase negative impacts on water quality.

Ultimately, all producers will have to develop a nutrient management plan that balances phosphorus inputs to the land with phosphorus crop uptake or losses.

Manure application

It should also be recognized that manured land is not the only livestock management source of excess phosphorus entering surface water. Direct access of cattle to streams and over-wintering of cattle near streams and rivers can also be significant phosphorus sources. Applying soil phosphorus limits will have little impact on reducing phosphorus runoff losses from these operations. Reducing phosphorus losses from these sources will require that different technologies and management systems be developed, tested, and implemented.

Cow-calf operation

Recommendations for Regulation

It is recognized that Alberta's agricultural industry will have to move to a more sustainable phosphorus management system to reduce the negative impacts on surface water quality. However, the over-riding question remains – what is the best way to achieve the necessary changes, based on the results of this study? Should Alberta implement phosphorus limit legislation, and if so, what time frame is reasonable? Is the science sound enough to support legislation at this time? Or will more effective, long-term change be brought about with time, combined with aggressive research, education, awareness programs, and policy development?

Based on all of the information generated from the Soil Phosphorus Limits Project, it is recommended that phosphorus limits not be regulated in Alberta at this time.

Based on all of the information generated from the Soil Phosphorus Limits Project, it is recommended that phosphorus limits not be regulated in Alberta at

this time. While the study significantly increases our understanding of the link between soil phosphorus and phosphorus in runoff water, and allows us to calculate soil phosphorus limits based on hypothetical water quality limits, there still remains significant questions that need to be answered before legislation should be considered. There are five main issues that should be assessed before legislation is contemplated, and these are discussed below.

1. Technology gaps – It is recognized that long-term, sustainable management of phosphorus will require that a balance be reached between phosphorus inputs to the land and phosphorus outputs. While this is readily achievable when applying commercial fertilizers, it is much more difficult when applying manure. At present, there is no available technology in Alberta that will allow producers to practically apply either liquid or solid manure at low enough rates to meet annual crop phosphorus uptake. This is particularly true when dealing with solid fresh manure from beef feedlots. Commercial manure spreading equipment is only capable of applying solid fresh beef manure at rates that will meet 3 to 4 years of crop phosphorus uptake.

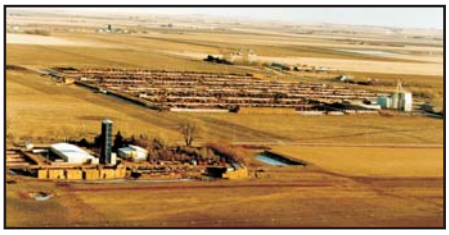
New manure spreading equipment is required that will practically and economically allow producers to apply the lower manure rates to their fields. This equipment can either be developed in Alberta, or adapted from equipment that is currently available in North America or Europe.

2. Lack of runoff water quality limits – At the present time, there are no scientifically supported runoff water quality limits for phosphorus established in Alberta for non-point runoff water. The current surface water quality guideline for total phosphorus (0.05 ppm), which was established for the protection of aquatic ecosystems in streams and lakes, may be unrealistic for tributary streams located in the nutrient rich environment throughout much of the agricultural region of Alberta. Further research is required to develop acceptable phosphorus water quality limits for the protection of aquatic ecosystems, and to extrapolate those values to acceptable runoff water quality limits for phosphorus. The runoff water quality limits should be site- or region-specific and consider whether the flows in receiving streams are entirely dependent on surface runoff, or if they have base flows from either groundwater or snowmelt sources.

Field runoff

Further research is required to develop acceptable phosphorus water quality limits for the protection of aquatic ecosystems, and to extrapolate those values to acceptable runoff water quality limits for phosphorus.

3. Increased manure management costs to industry – Confined feeding operations (CFOs), including hogs, poultry, dairy, and beef cattle, are located throughout the agricultural areas of the province, with more concentrated operations in several regions of the province. The greatest concentration of beef feeding operations is in the southern part of the province, especially in the County of Lethbridge. Many of these operations are less than 1 to 2 km from neighbouring operations. Manure is most commonly applied to areas immediately adjacent to the CFOs. If soil phosphorus limits are implemented, CFO operators will require access to significantly more land to spread their manure. This will generally mean that manure will have to be transported greater distances, resulting in significant added costs to livestock producers. The increased transportation costs could negatively impact the economics of Alberta's agricultural industry and potentially limit expansion of this value-added industry.



Intensive livestock operations

Alberta producers who do not have the land base required for manure application may need to develop a manure exchange agreement with non-livestock crop producers. Even though manure application to cropland provides many benefits, and can reduce costs for conventional fertilizers, convincing crop producers to accept manure from CFOs can be a challenge. Intensive livestock producers have difficulty finding willing crop producers who will take excess fresh manure, even if the manure is delivered and dumped on their fields. Many crop producers have concerns about weed management on manured land. More enterprising intensive livestock producers have recently begun to negotiate deals with crop producers who are beginning to appreciate the value of nutrients contained in manure. A typical negotiated deal will involve the intensive livestock producer delivering and dumping the manure free of charge to the fields specified by the crop producer. The crop producer will then hire a commercial manure handling company to spread the manure on each field (S. Thiessen, personal communication, 2005). As the price of commercial fertilizer continues to increase, more crop producers may see the value of manure for their operations.

The increased transportation costs could negatively impact the economics of Alberta's agricultural industry and potentially limit expansion of this value-added industry.

Intensive livestock producers have difficulty finding willing crop producers who will take excess fresh manure.

The Alberta experience with manure exchange is supported by research in the United States. A recent study examined barriers to manure exchange agreements between intensive livestock producers and crop producers (Battel and Krueger 2005). About 50% of the 340 farmers in the Kalamazoo River Watershed, Michigan, responded to a survey about their manure management practices. The study showed that the primary concern regarding spreading manure was the introduction of weeds. Other major concerns were the cost of transporting manure and odour complaints. The survey revealed that there are different opinions concerning manure exchange. Not surprising, more livestock producers thought manure was a reliable fertilizer source than non-livestock farmers. Buyers and sellers of manure also had different opinions on the value of their transaction. Sellers believed they were providing valuable fertilizer, while the buyers thought they provided a benefit to help the livestock owner dispose of the waste (Battel and Krueger 2005). The survey showed that as the cost of manure increased, buyers were less interested in purchasing it, even if it was affordable. Manure exchange often does not occur because farmers want to avoid odour complaints from their neighbours. In fact, farmers were more concerned about their neighbours' complaints than they were of environmental concerns (Battel and Krueger 2005). The latter finding supports a previous study that found that rural neighbours were three times more likely to be concerned about manure odour than runoff (Kelsey and Vaserstein 2000).

4. Insufficient testing of beneficial management practices – Beneficial management practices (BMPs) are being applied or promoted throughout the agricultural industry to reduce agriculture's impact on water quality. There are support programs and financial incentives available to producers that implement BMPs.

However, not all producers readily adopt BMPs, despite their environmental concerns and available assistance programs. In Alberta, a significant obstacle to BMP implementation may be the lack of science-based testing of BMPs to resolve identified problems in specific geographic regions of the province. Many producers who have expressed interest in implementing BMPs want to know: which BMP will be most effective for their situation; what it will cost; and how practical it is to put into practice. To date, widespread testing of BMPs has not been carried out, and as a result, answers to the producers' questions are not available.

Another barrier to BMP adoption may be the inconsistent recommendations and interpretations that occur when there are several objectives for implementing the BMP (Sharpley et al. 2005). Objectives for BMP implementation may include habitat development, soil and water conservation, and water quality protection. The prescribed BMPs will vary depending on their purpose, and in some cases the prescribed BMPs may improve one problem but exacerbate another. For example, manure incorporation is recommended to reduce the risk of phosphorus loss, but in some situations, incorporation may increase the risk of nitrogen leaching and sediment transport (Dampney et al. 2003). Risk assessment must be part of the BMP recommendation process and education programs should ensure that BMP recommendations are clear and concise in their purpose. Based on survey results, Kim et al. (2005) concluded that continued education on BMP implementation had a very important and positive impact on adoption rates. They also found that funding support programs are important.

Widespread testing of BMPs has not been carried out, and as a result, answers to the producers' questions are not available.

In addition to the challenge of BMP adoption, there are challenges with appropriate implementation. If a research initiative is established to evaluate BMPs, most often researchers implement the BMPs or the researchers greatly assist producers in implementation and maintenance. In these cases, the expert knowledge and amount of time to implement the BMPs help ensure implementation is appropriate, but such a scenario will not be available for most producers. For example, Shepard (2005) conducted a survey to assess the effectiveness of nutrient management plans that were widely implemented, with varying degrees of knowledge and effort. Slightly more than half of the 127 farmers had nutrient management plans in two Wisconsin watersheds, where nutrient management plans had been extensively promoted. Farmers with nutrient management plans tended to apply fewer nutrients than farmers without a plan. However, even with a nutrient plan, 37% of the farmers still over-applied nutrients (Shepard 2005). Over-application most often occurred because the farmers failed to recognize and account for nutrient inputs from the farm, especially manure. Shepard (2005) concluded that nutrient management plans need to be extended past the initial plan to include on-farm follow ups, maintenance, and long-term goals that can be modified to accommodate changes in farming practices.

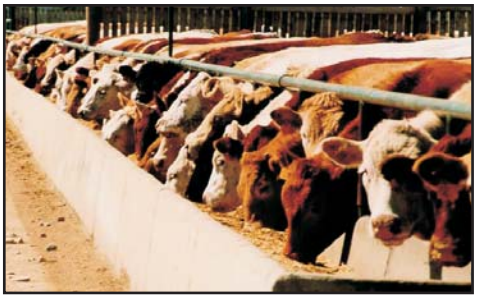
5. Time required to effect necessary changes – Alberta's cropping and livestock industry has evolved during the past 100 years to become one of the most efficient systems in the world. While the industry is relatively old, the issues related to water quality are comparatively new. Only since the late 1990s has science-based information been available showing that agriculture is having a negative impact on surface water quality in Alberta. The Soil Phosphorus Limits Project is the first comprehensive research in Alberta that clearly identifies the link between phosphorus in the soil and phosphorus in runoff water from agricultural land. During the past decade, agricultural industry partners and Alberta Agriculture, Food and Rural Development have worked together to assess and implement beneficial management practices that will minimize agriculture's impact on water quality degradation. Programs such as the Alberta Environmental Farm Plan are increasing environmental awareness among agricultural producers, and providing recommendations for on-farm management practices that individual producers can implement. These types of programs will hopefully lead to long-term, sustainable practice change for the majority of agricultural producers. Before legislation is considered, a reasonable amount of time should be provided to allow the agricultural industry to implement management practices that will improve water quality in agricultural watersheds.

While the industry is relatively old, the issues related to water quality are comparatively new.

Guidelines for Change

While legislation is not recommended at this time, there are steps that the agricultural industry should take to move towards the long-term, sustainable management of soil phosphorus that will achieve a balance between phosphorus inputs to the land and phosphorus outputs.

A key management option that was not assessed in this study relates to livestock feeding strategies. If nutrients such as phosphorus can be reduced in the livestock feed, or more effectively utilized by the animal, significantly less phosphorus will accumulate in the manure. Even with current manure handling technologies, this could significantly reduce the land area required to spread existing manure supplies. Further research is required to assess the potential to reduce phosphorus in the manure.



Cattle feeding

Achieving a soil phosphorus balance is more easily achieved with commercial fertilizers than with manure because, compared to manure, commercial fertilizers have a more concentrated nutrient content, are easily stored and transported, are established market products, and can be precisely applied with numerous application options. Also, commercial fertilizers are required operational input products; whereas, manure is often considered to be a waste product of livestock production.

If nutrients such as phosphorus can be reduced in the livestock feed, or more effectively utilized by the animal, significantly less phosphorus will accumulate in the manure.

Achieving this balance will be a greater challenge for confined feeding operations because of issues related to: land availability; manure transportation costs; and manure application equipment technology. In all cases, it is recommended that a comprehensive nutrient management plan be developed to help the producer objectively assess nutrient availability relative to cropping requirements. Alberta Agriculture, Food and Rural Development has adopted the Manure Management Planner (MMP), which is a computer program, to help producers better manage their manure in relation to existing land bases.

Commercial fertilizer application

The following provides some guidelines that may help the industry move in the right direction.

1. Commercial fertilizer management – To ensure that phosphorus losses from commercially fertilized land are minimized, the following actions are recommended.

a. Producers are encouraged to have their soil tested annually to determine the amount of nutrients that are available in the soil profile, and to assess how much fertilizer to apply for optimum crop production.

b. Do not over-apply fertilizer phosphorus. Follow fertilizer recommendations, and consult with soil and crop specialists to develop fertilizer strategies for different fields and crops.

c. Fertilizer should always be incorporated into the soil profile through banding or application with the seed. If at all possible, do not surface apply phosphorus fertilizer on cultivated land, as this will increase the potential for the phosphorus to be lost in runoff water that occurs as a result of precipitation or spring snowmelt.

2. Existing confined feeding operations – Many existing confined feeding operations have STP levels on manured land that significantly exceed even the highest possible STP limit that might be established in Alberta. The first challenge

will be to reduce these soil phosphorus levels during a reasonable amount of time, which means that either manure application rates will have to be reduced, or more land made available for manure application. It is recognized that the potential economic impacts to confined feeding operators could be significant, particularly in those areas of the province where confined feeding operations are in relatively close proximity to each other.

The following actions are recommended for consideration.

a. For land with STP levels that are at least five times higher than the identified STP limits, consideration should be given to terminating any further manure applications until the STP levels fall below the STP limit due to crop uptake and removal. For fields with extremely high STP levels approaching 1000 ppm in the top 15 cm, this could mean that phosphorus should not be applied for 30 to 40 years.

b. For land where the STP levels are three to five times higher than the identified soil phosphorus limits, it is recommended that manure application rates be reduced from current rates to allow the STP levels to reduce through crop removal. This may mean re-calibrating manure application equipment to apply manure at three times the annual crop phosphorus uptake rate (rather than four times), and increasing the number of years between manure applications from 4 to 5 years. This would mean that confined feeding operators will need to find additional land to spread existing manure supplies. The logistical and financial challenges may be manageable, particularly for hog, dairy, and poultry operations not in close proximity to other confined feeding operations.

3. New confined feeding operations – New feeding operations have an advantage compared to existing operations, in that planning can be carried out to ensure that manure management can more closely match land capabilities. The following actions will help maintain a long-term sustainable phosphorus balance in the soil profile.

a. Wherever possible, proposed new confined feeding operations should be established in a watershed, or the area of a watershed that has the highest possible STP limits. Ensure there is sufficient distance between confined feeding operations to allow manure to be spread based on long-term crop phosphorus requirements.

Cropped production

b. Ensure that current STP levels are significantly less than the identified soil phosphorus limits on any land that will receive manure. This will allow more flexibility in manure application rates and not exceed the STP limits. In general, land that has not previously received manure will have the lowest STP levels.

c. Calculate the total amount of phosphorus in the amount of manure that is expected to be generated each year. Using annual crop phosphorus requirements, based on soil testing, calculate the amount of land required to utilize the total manure supply to prevent the accumulation of excess phosphorus in the soil profile.

d. Given the current capabilities of manure application equipment (solid and liquid), it is impractical to apply manure at low enough rates to meet annual crop phosphorus requirements. However, manure applications that meet multiyear crop phosphorus requirements are acceptable as long as: STP limits are not exceeded; and manure is not applied again until STP levels

Riparian zone

have reduced to approximately pre-manure levels. Depending on the amount of manure applied in the first year, supplemental nitrogen fertilizer may be needed to meet annual crop nitrogen requirements.

e. Manure should not be applied to areas that have a high risk of runoff water entering a surface water body. Any fertilizer applied to these areas should be banded or applied with the seed. Surface broadcasting should be avoided on cultivated land.

Special consideration should be given to these high-risk riparian and flood plain zones, and they must be managed differently than other landscape zones.

4. Critical source area management – Many riparian and flood plain zones, which are located adjacent to streams and rivers, have historically been used by the cow-calf industry for grazing, access to surface water, and over-wintering and calving. It is now recognized that these areas are critical phosphorus source areas, and are also highly sensitive ecosystems within any watershed. Higher loss rates of phosphorus deposited on these landscape zones are expected, and given their close proximity to streams and rivers, a greater percentage of the phosphorus losses are likely to end up in surface water.

Special consideration should be given to these high-risk riparian and flood plain zones, and they must be managed differently than other landscape zones. Given the restrictions of current manure application equipment, this would likely mean that application of manure would be excluded from these zones. If commercial fertilizer phosphorus is being applied to these zones for the production of crops, it should only be applied at annual agronomic rates, and should be incorporated into the soil profile through banding or application with the seed.

Conclusions and Recommendations

Conclusions

The following general conclusions were developed from the background information and research findings generated through the Alberta Soil Phosphorus Limits Project.

Phosphorus as a nutrient

1. Phosphorus is an essential nutrient in agricultural systems and is important in nutrient management to achieve optimum crop production. Soil-test phosphorus (i.e., plant-available phosphorus) levels do not need to exceed 60 ppm (about 120 kg/ha) in the top 15 cm of soil to achieve optimum growth for most crops grown in Alberta. Crops grown on soils with phosphorus levels in excess of 60 ppm generally do not respond to phosphorus additions.
2. Most soils in Alberta are deficient in soil-test phosphorus. Analysis of soil test records from the agricultural areas has shown that most soils have soil-test phosphorus levels that are significantly below 60 ppm, which is considered the agronomic threshold level for most crops. Crops grown on these soils will benefit from addition of phosphorus. In general, soil phosphorus levels in the 1990s were similar to phosphorus levels in the 1960s for most agricultural areas in Alberta.
3. Even though soil-test phosphorus levels are generally low, phosphorus losses from agricultural land are recognized as a significant contributor to surface water quality degradation. Livestock production systems, including cow-calf operations and confined feeding operations, are considered the primary source of agricultural phosphorus losses. For cow-calf operations, over-wintering of cattle near surface water bodies can be a significant source of agricultural nutrient losses. Manure spreading related to confined feeding operations is also a significant source of excess phosphorus in surface water.

Phosphorus in runoff

4. Excess phosphorus in agricultural runoff appears to mainly affect water quality in streams and tributaries, and has little impact on the major river systems, such as the Bow and Oldman rivers. However, if agricultural impacts are not controlled, impacts on these major rivers could become significant in the future.
5. Surface water in Alberta tends to have naturally high nutrient concentrations, with many streams exceeding phosphorus water quality guidelines under natural conditions. Most streams are therefore sensitive to relatively small phosphorus additions. While the amount of phosphorus lost from land is usually very small compared to phosphorus additions and the concentration in soil, these amounts can have an adverse impact on phosphorus concentrations in surface water.
6. A large majority of surface runoff in Alberta's agricultural area occurs during the spring snowmelt. Even though runoff at the beginning of the snowmelt period occurs on fully or partially frozen ground, significant amounts of phosphorus are found in runoff water. Relatively few summer precipitation events result in significant runoff from fields, particularly those fields where forages are grown, or where annual crops have emerged.
7. There is a direct, linear relationship between soil-test phosphorus levels and the phosphorus concentration in runoff water in the agricultural areas of Alberta (Figure 21). As the amount of phosphorus in the upper soil profile increases, so does the concentration of phosphorus in runoff water. This relationship holds true regardless of whether the soil phosphorus is from non-manured or manured soil.

   The standard composite core soil sampling depth of 0 to 15 cm, which is currently recommended for producers to determine crop fertilizer requirements, is acceptable to compare actual soil-test phosphorus levels with the soil-test phosphorus limits.
8. A direct relationship was found between soil-test phosphorus levels and the phosphorus in simulated rainfall runoff from freshly applied manure and 1 year after manure application,

although values of both variables were less with time. The relationship between soil-test phosphorus levels and phosphorus in simulated rainfall runoff from soils 1 year after manure application was similar to the relationship determined in other field-scale monitoring studies.

9. Runoff volumes and concentrations of phosphorus in runoff water decreased with manure incorporation for the freshly-manured soils near Beaverlodge. However, manure incorporation did not have a significant effect on runoff volumes and phosphorus concentrations in runoff water at the two rainfall simulation sites near Lacombe and Wilson. A relatively small portion (less than 3%) of the phosphorus applied with manure was actually removed by runoff from the freshly-manured soils and even less was removed 1 year after manure application.

Soil-test phosphorus limits

10. Soil-test phosphorus limits were determined for all agricultural land in Alberta (Figure 22). Using a hypothetical total phosphorus runoff water quality limit of 1.0 ppm resulted in soil-test phosphorus limits in the 0 to 15 cm layer that were:
    a. Less than 60 ppm for about 43% of the agricultural land base;
    b. 60 to 180 ppm for about 48% of the land base; and
    c. Greater than 180 ppm for about 9% of the land base.

    The results of this research present a number of challenges for producers, researchers, and policy makers in Alberta. If the calculated soil-test phosphorus limits (based on a total phosphorus runoff water quality limit of 1.0 ppm) were adopted as part of Alberta's Agricultural Operation Practices Act, producers on 1.9 Million ha of agricultural land would be required to maintain soil-test phosphorus levels that are below 30 ppm, which is half of the agronomic threshold of 60 ppm. Producers on 8.9 Million ha would be required to maintain soil-test phosphorus levels between 30 ppm and 60 ppm. Even crop producers who only apply commercial fertilizer at annual crop uptake rates would find it difficult, if not impossible, to operate under these soil-test phosphorus limits. It would prove even more difficult for Alberta's confined feeding operators.

11. From a policy perspective, it is not reasonable to require that agricultural producers maintain soil-test phosphorus levels below 60 ppm, except in specific areas, such as flood plains and riparian zones, where the risk of runoff and nutrient movement to surface water is high. If 60 ppm were to become the minimum soil-test phosphorus limit (except for very high risk areas), what potential impact could this have on surface water quality? The answer is dependent on the overall development expectations for each watershed. With the exception of a few regions, most agricultural watersheds in Alberta are predominantly occupied by crop producers, who generally apply phosphorus in the form of commercial fertilizers, and only at annual crop requirements. At present, only about 5% of Alberta's agricultural land base receives manure on a regular basis, and confined feeding operations generally occupy a relatively small part of most watersheds. It is unlikely that any watershed will be developed to the extent where soil-test phosphorus levels in all Agricultural Region of Alberta Soil Inventory Database soil polygons reach the soil-test phosphorus limit. Most watersheds will have a mix; some areas where soil-test phosphorus levels exceed the soil phosphorus limit, and other areas where soil-test phosphorus levels are less than the soil-test phosphorus limit. As a result, the impact on surface water quality should therefore not be unduly compromised.

Phosphorus management

12. It is recognized that regardless of the soil-test phosphorus limit, whether it is 40 ppm or 200 ppm, the same soil management system will

have to be applied at some point in time to ensure that the limit is not exceeded. Ultimately, all producers will have to develop a nutrient management plan that balances phosphorus inputs to the land with phosphorus crop uptake or loss.

Economic Impacts

13. Beef confined feeding operations generate the highest concentrations of manure per hectare of associated land. This was followed by hog operations, with dairy operations having the lowest concentrations. The most significant cost associated with manure management in Alberta is related to transportation and spreading, and ranges from $1.45/tonne to $13.33/tonne.

14. If soil-test phosphorus limits are applied to confined feeding operations in Alberta, a substantial increase in the amount of land will be required for spreading manure. Transportation and spreading costs may increase by 24 to 128% depending on the average increase in distance that the manure needs to be hauled.

15. Sustainable manure management in Alberta is essentially a transportation issue. There is more than enough cultivated land available to agronomically handle all of the manure generated by the confined feeding industry. More importantly, these lands would benefit from the additional nutrients and organic matter contained in manure. However, there are often large distances between the receiving land and the confined feeding operations, which can pose a significant financial burden to livestock operators.

16. While soil-test phosphorus limits will increase manure handling costs for all confined feeding operations, the most significant concerns will occur in geographic areas of the province with large livestock concentrations. Much of the existing land base in these areas already has high soil phosphorus levels, and new un-manured land is not available within a reasonable distance. Long-distance manure transportation, or development of alternative management (composting) or uses (bio-energy) will have to be considered.

Beneficial management practices

17. There is limited testing in Alberta to assess the economics, effectiveness, and practicality of proposed phosphorus management beneficial management practices. However, there are several beneficial management practices that producers can apply that will not only reduce the likelihood of phosphorus runoff losses, but will also improve the health of riparian areas and aquatic ecosystems.

Recommendations

1. Legislated soil-test phosphorus limits should not be implemented at this time.

The adoption of soil-test phosphorus limits cannot be supported at this time, even though it is recognized that the agricultural industry will need to move towards a phosphorus strategy that balances soil phosphorus inputs with outputs. Adequate time should be provided for the agriculture industry and governments to work together to develop the technologies and follow-up programs and policies that will allow producers to effectively manage phosphorus in the long term.

In addition, further research is required to:

- Develop and test equipment and technologies that can economically apply manure at rates that meet annual crop phosphorus requirements and reduce loss of manure nutrients during application;
- Develop and assess environmentally effective beneficial management practices that producers can economically and practically implement; and
- Determine maximum phosphorus limits for runoff from agricultural land and receiving streams and rivers.

The implementation of soil-test phosphorus limits may result in significant financial hardship to Alberta's intensive livestock industry, particularly the beef feedlot

industry. Additional research and policy analyses are needed to develop alternate methods of managing excess manure from existing operations.

2. ***Regulation of soil-test phosphorus limits should be reviewed in 5 to 7 years to assess legislation requirements.***

   Many jurisdictions in Canada and the United States are moving towards more regulation of the agricultural industry to minimize phosphorus losses to surface water systems. Alberta will need to assess the progress of the agricultural industry in developing and implementing a more sustainable phosphorus management strategy. Progress towards development of a sustainable phosphorus management system should be reviewed in 5 to 7 years.

3. ***The maximum soil-test phosphorus limit for Alberta should not exceed 200 ppm.***

   The soil-test phosphorus limits calculated in this study show that the soil-test phosphorus limits can theoretically be greater than 600 ppm for some very limited areas within watersheds. Values in this range are many times the agronomic threshold limits for crop production, and may pose significant environmental risks that are as yet unknown. A number of states in the United States including Arkansas, Delaware, Ohio, Oklahoma, Michigan, Texas and Wisconsin have identified maximum soil-test phosphorus levels of 150 to 200 ppm. These states recognize that soil-test phosphorus levels in excess of 200 ppm have the potential for unacceptable phosphorus losses in runoff that exceed any reasonable crop requirement concerns.

   A maximum allowable soil-test phosphorus level of 200 ppm (about 400 kg/ha) for Alberta will encourage more efficient use of nutrients, and will ensure that watersheds, or parts of watersheds, cannot be considered as "phosphorus disposal sites". In addition, since manure contains many other substances in addition to phosphorus (e.g. nitrogen, bacteria, and metals), there is concern that allowing very high concentrations of phosphorus to accumulate in the soil profile increases the risk of surface water and groundwater problems by the other substances.

4. ***Design and implement management systems for high risk and sensitive landscapes.***

   While broad-based legislation should not be enacted at this time, special consideration should be given to high risk riparian and flood plain zones. These areas are considered to be critical phosphorus source areas and sensitive ecosystems within any watershed, and should be treated differently than other landscape zones. Higher loss rates of phosphorus applied to these landscape zones are expected, and given the close proximity to streams and rivers, a greater percentage will end up in surface water. Phosphorus should, therefore, only be applied at annual agronomic rates, which generally excludes any form of manure application. Any nutrients applied to these high risk landscape zones should be incorporated into the soil profile through banding, placement with the seed, injection, or tillage.

5. ***Develop, test, and demonstrate beneficial management practices that work in Alberta.***

   Alberta's agricultural industry will need to shift towards a more sustainable management program that balances soil nutrient inputs with nutrient outputs in order to minimize agriculture's impact on surface water and groundwater quality. Alberta Agriculture, Food and Rural Development, in partnership with the agricultural industry, should accelerate the development and field testing of beneficial management practices that can be financially and practically implemented by producers, and that will be environmentally effective in reducing phosphorus losses to surface water.

6. ***Implement an education and awareness program for phosphorus management.***

   Most Alberta producers are interested in applying beneficial management practices