

**Managing Manure Phosphorus on the Farm:
Adapting and Adopting Beneficial Management Practices**

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Introduction

Public concern regarding the quality of surface water in Manitoba, including Lake Winnipeg, is rising. Much of this concern is directed towards the increased severity and frequency of algae blooms, a problem that has been linked to increased concentrations of phosphorus (P) in Manitoba's streams, rivers and lakes. As a part of its response to this concern, the Government of Manitoba is proposing to develop two new sets of regulations that will regulate the application of manure phosphorus onto agricultural land.

One series of proposed regulations is meant to control the application of manure phosphorus from livestock operations in Manitoba through amendments to the Manitoba Conservation's Livestock Manure and Mortalities Management Regulation. Although Manitoba Conservation's proposed regulations have not been formally announced (as of January 8/06), these regulations may be based on recommendations of the Manitoba Phosphorus Expert Committee. A summary of the committee's recommendations is presented in Tables 1 and 2; a more detailed description of these recommendations can be downloaded from Manitoba Conservation's website.

Table 1. Recommended soil test phosphorus (P) ranges for regulating manure P application rates from the Manitoba P Expert Committee¹

Soil Test P Threshold (Olsen P or equivalent) ²	Intent of Threshold	Manure P Application ³
< 60 ppm	No restriction on P application	Apply on the basis of crop nitrate-nitrogen (N) requirements. Soil N concentrations are subject to Section 12 of the LMMReg. ⁴
60 - 119 ppm	Control soil P accumulation rate	Apply P up to 2 times the crop removal rate ^{5,6}
120 - 179 ppm	Prevent further increases in soil P concentrations	Apply P up to 1 times the crop removal rate ^{5,6}
> 180 ppm	Depletion at a rate controlled by crop removal	Starter P application only

¹ Manitoba Conservation 2005

² Soil P test threshold pertains to the concentration in extractable phosphorus in soil samples taken in the 0 to 6 inch (150 mm) upper soil layer, using the Olsen sodium bicarbonate extraction procedure or another equivalent method recognized by Manitoba Conservation and prorated accordingly for its efficiency of extraction.

³ Manure P applications must never exceed allowable manure N applications per section 12 of the Livestock Manure and Mortalities Management Regulation.

⁴ LMMReg: *The Livestock Manure and Mortalities Management Regulation* MR 42/98, as amended March 30, 2004.

⁵ In the case of livestock manure, P applications are planned on the basis of total P concentrations in the manure, expressed in P₂O₅ equivalent. The application recommendation of 2 times crop removal of P will control soil test P build-up while a 1 times application rate would prevent further increases in soil test P concentrations over time.

⁶ Crop removal rates are published and updated regularly in the document *Nutrients Removed in Harvested Portion of Crop* (PPI-PPIC, 2005) or the Soil Fertility Guide (MAFRI, 2001), and are expressed in P₂O₅ equivalent. A multi-year removal rate of P₂O₅ (up to 5 years) could be applied in one year followed by no manure for the following years.

Table 2. Livestock manure management practices for Special Management Areas (SMAs) as proposed by the Manitoba Phosphorus Expert Committee¹.

SMA Type	Winter Application / Buffers	Manure Application Setbacks	
		Injection / low level application with incorporation	High level broadcast application / low level application with no incorporation
Red River Valley ² or Flood plains of other rivers ³	Immediate prohibition on all winter application; Incorporation within 48 h or injection of fall applied manure on tilled soils ⁴		
Lakes	Permanently vegetated buffer strip of 15 m; no manure application	15 m setback	30 m setback
Rivers, creeks and large unbermed drains (3rd order or higher) ⁵	Permanently vegetated buffer strip of 3 m; no manure application	3 m setback	10 m setback
Other watercourses and roadside ditches	Permanently vegetated buffer strip of 1 m; no manure application	1 m setback	1 m setback

¹ Manitoba Conservation 2005

² That portion of the Red River Valley regularly inundated during spring snowmelt that includes land subject to overland flooding outside the Red River's 1 in 100 year floodplain.

³ Low lying lands and incised river valleys subject to frequent inundation from overflowing watercourses.

⁴ Incorporation or injection of manure is not required on perennial forage or no till systems.

⁵ Drain order may be determined by reference to drainage maps which may be obtained from Water Stewardship or by on-line reference to Agri-Maps on the Manitoba Agriculture, Food and Rural Initiatives website.

A second set of regulations, proposed by Manitoba Water Stewardship is more comprehensive, designed to prevent over-application of N and P from all sources of nutrients (livestock manure, commercial fertilizers, and municipal biosolids) on all agricultural land in Manitoba, through the establishment of Water Quality Management Zones under *The Water Protection Act* (Manitoba Water Stewardship 2005). In an effort to be consistent, most of Manitoba Conservation's proposed regulations for manure P are imbedded within the comprehensive nutrient management regulations proposed by MB Water Stewardship. The detailed plans for how these P regulations will be phased in, who will be affected, and how they will be enforced are not yet known.

In order to comply with these new regulations, livestock producers will need to implement beneficial management practices (BMPs) that are appropriate for their individual farms. Unfortunately, only a few BMPs have been fully evaluated for their environmental effectiveness, technical feasibility and economic cost under Manitoba conditions. Our combination of land and climatic conditions, plus our existing livestock, manure and crop management practices, are different from other areas of the world. Therefore, some of the processes of P loss from land to surface water and the appropriate BMPs to reduce that loss are different from other areas of the world. However, some of the principles of P loss and P management are universal and, with some careful adaptation, we should be able to adopt some of the BMPs developed elsewhere.

Principles and Processes of Phosphorus Loss in Manitoba

Based primarily on research conducted elsewhere (e.g., Haygarth et al. 2005), a proposed framework for describing the process of P loss from agricultural land to surface water and a preliminary set of BMPs for Manitoba has been developed by the Manitoba Phosphorus Expert Committee BMP Task Force (Manitoba Phosphorus Expert Committee Task Force 2005). This information is used as the basis for the remainder of this presentation.

The four basic processes that result in the loss of agricultural P to surface water are loading, mobilization, delivery and impact (Figure 1). These processes account for the transfer of P from the source (the field) to the receptor (the water body) along a transportation pathway, in a manner similar to many other potential contaminants. The manner in which these processes are controlling P loss from different areas of a particular part of a farm will determine the most appropriate combination of BMPs that will reduce that P loss in that particular area. One solution or "size" will not fit all situations.



Figure 1. The four basic processes that result in the loss of agricultural P to surface water are loading, mobilization, delivery and impact (Figure 1). These processes account for the transfer of P from the source (the field) to the receptor (the water body) along a transportation pathway.

1. Loading

Loading is the addition of P to a given area as a result of imports or inputs. Problems arise when imports exceed exports and a surplus is created. Surpluses can be characterized at various scales. Within a region, if more P is imported as feed and fertilizer than is exported as agricultural products, a net accumulation of P (or surplus) in the region will occur. At the farm-scale, if the farm imports more P than it exports in meat, milk, eggs or crops then P will accumulate on the farm. Similarly, at the field scale, if more P is applied to land than can be removed in the harvested portion of the crop, then the remaining P will accumulate in the soil.

Although surpluses can occur on any type of operation, they are most often associated with livestock production. In most instances, P is imported onto a livestock farm in feed and feed supplements. Most of the P that is fed to livestock is excreted in manure and a much lesser amount is exported as meat, eggs or milk. If the land area used for spreading manure is not sufficient and/or if sufficient quantities of crop products are not exported, this can result in a farm-scale surplus. Manure is an unavoidable by-product of livestock production that must be managed. It is also a valuable source of nutrients which is most often recycled on the farm (or nearby farms) as an N fertilizer for crop production. However, it is not a balanced fertilizer. When managed as an N fertilizer, manure often supplies more P than the crops can use which can result in a field-scale surplus. Furthermore, most livestock manure contains relatively dilute concentrations of nutrients; therefore, economically efficient hauling distances for manure are relatively short.

2. Mobilization

Mobilization occurs on the landscape when conditions are created that start the movement of P to water by separating the P from its attachment to the bulk soil. The P may begin to move as dissolved P through chemical or biological solubilization (e.g., forming phosphorus "tea"), particulate P through detachment (e.g., dislodging of soil particles by rainfall or runoff) or incidental transfer (e.g., the direct removal of freshly applied fertilizer or manure P by rainfall and runoff). Solubilization is most likely to occur when the soil test P concentrations are high, relative to the soil's capacity to retain P. However, solubilization is also affected by cycles of wetting and drying (Turner and Haygarth 2001) or extended periods of flooding. Furthermore, vegetative P is solubilized in substantial quantities after undergoing freezing and thawing (Bechmann et al. 2005, Flaten et al. 2005) making the mobilization of soil P difficult to assess and control in climates such as Manitoba's, where snowmelt is the dominant runoff and loading event. Detachment of particulate P is most likely to occur as a result of erosion; however, given the relatively level landscapes and dry climate of the Canadian Prairies, this process is relatively limited, even on agricultural land in this region.

3. Delivery

Delivery is the movement of P from the point of mobilization to a recognizable surface water channel. At this stage, although P may be moving within a field or out of a field, it might still be intercepted before it enters a significant body of surface water. Employing BMPs that restrict the transport of P, recapturing the P before it enters surface water, will reduce delivery and, ultimately, impact. Most of the BMPs developed for controlling this stage of the P transfer process have been developed where rainfall-induced erosion results in particulate losses of nutrients as the main process of nutrient loading to surface water. However, the majority of P loss in the Prairies is in the form of dissolved P moving during snowmelt, when the majority of runoff occurs. This form of P is much more mobile and difficult to intercept and during snowmelt, most of the soil is frozen and the vegetation is dead or inactive, making interception even more difficult.

4. Impact

Impact is the deterioration of surface water quality, usually in the form of algae growth, due to the addition of excess P. Since this process occurs at the water body, very few agricultural BMPs can be employed at this point to reduce the problems caused by P pollution. As a result, the main objectives of agricultural BMPs for P loss reduction are to reduce loading, mobilization and delivery of P.

Beneficial Management Practices that Reduce Phosphorus Loss to Surface Water

1. Reducing P Loading

Livestock producers have difficulty applying manure to meet crop N requirements without applying P in excess of crop removal, due to the low N:P ratio in manure compared to the N:P ratio in crop material that is removed. For example, at typical rates of hog manure application and crop removal, the accumulation of surplus P may be rapid, especially where perennial forages are grown and particularly where those forages are being grazed rather than harvested as hay (Table 3).

Table 3. Typical liquid hog manure¹ application rates to meet N requirements for barley or grass production

	Barley	Grass
Target Yield	80 bu/ac	3 t/ac
Target N Rate (net basis, lb N/ac) ²	78	150
Manure Application Rate (gal/ac)	3,305	9,415
P Application Rate (lb P ₂ O ₅ /ac)	70	200
P Removal Rate (lb P ₂ O ₅ /ac) ³	35	30
P Surplus (lb P ₂ O ₅ /ac)	35	170

¹ Manure analyses are from Fitzgerald and Racz 2001

² Assumes manure is applied into standing grass, with 35% volatilization loss of N during application, as estimated in Farm Practices Guidelines for Hog Producers in Manitoba, p. 27

³ Assumes that all the grass forage is removed as hay and no additional manure is applied by the farmer or by grazing animals

Therefore, unless measures are taken to increase N:P ratios in manure, annual applications of manure to meet crop N requirements will eventually increase soil test P values to the thresholds in the proposed regulations. Once those thresholds are reached, the rates of manure that can be applied on an annual P removal-basis are likely to be much lower than what is normally applied according to a crop's annual N requirement. Consequently, at high concentrations of soil test P, land requirements for manure application may increase substantially (Salvano et al. 2004). Given the inevitable requirement to balance P application with P removal, farmers should voluntarily move as quickly as possible towards that goal of P balance. A proactive approach will help delay or avoid reaching the legal threshold and, if the threshold is reached, the additional efforts required for compliance will be minimized. Some of the BMPs that could be employed as part of that strategy are as follows.

Plan for P management in new and expanding operations - The potential for surpluses of P within a region or for an individual farm can be minimized by ensuring that new and expanding operations plan for the management of their manure based on P:

- In most cases, this will require access to adequate, suitable land area and crop exports of P to reduce the potential for farm surpluses of P. Ultimately, the landbase in the region should be able to accommodate application rates based on P removal by the crop.
- Where an adequate supply of suitable land is not available, the proponent should demonstrate that the P can be managed, over the long-term, in another sustainable manner. However, preventive measures such as acquiring access to sufficient spreading lands can reduce the need for more difficult and expensive measures (e.g., manure treatment and export) that will be required if such a surplus is allowed to develop.

Minimize the import of P - Minimizing the import of P onto the farm is a logical first step in balancing on-farm P budgets. Reducing P imports may significantly reduce farm surpluses of P where they exist. For example:

- Minimize supplemental P in animal diets and maximize overall animal production efficiency. For pork producers, reduce the amount of excess P in the diet and improve feed P utilization by:
 - conducting more intensive feed testing
 - designing farm-specific diets
 - minimizing "insurance" additions of mineral P (e.g., "dical")
 - minimizing feed wastage in the pens.
 - phase feeding
 - split-sex feeding
 - genetic selection
 - using feed additives, including enzymes such as phytase
 - using low phytate "highly available phosphorus" (HAP) varieties of corn and barley; however, these types of feed are still under development and not widely available. Furthermore, the effectiveness of HAP feeds, relative to phytase-amended conventional feeds is not fully known.
- Conserve the N in manure during storage, handling and land application. Conserving N will improve the nutrient value and N:P ratio of the manure and reduce over-application of P when manure is applied based on N.
- Replace fertilizer P with manure P for crop production. Manure P that is applied to a field should be deducted from the crop requirement for P, thereby reducing the need for additional commercial fertilizer P.
- Soil test and account for available soil P when establishing manure application rates. Soils should be sampled at appropriate soil depths for P (0-6 in or 15 cm) which are different from those required for N-based manure management planning (0-24 in or 0-60 cm). Acceptable methods of analysis should be followed such as the Olsen (sodium bicarbonate extraction) method or an equivalent method recognized by Manitoba Conservation. Target P inputs based on realistic target yields. Establish manure application rates to control soil test P buildup taking into consideration soil test P concentrations (Table 1).
- Rotate lands if manure application is based on N. Repeated annual applications of manure based on N have a high potential to cause P build-up. Rotating fields for manure application using an N-based rate in one year and only commercial N fertilizer in subsequent years can slow or halt the long-term build-up of soil test P.
- Where the landbase is sufficiently large, prioritize lands for manure additions based on soil test P levels and manure P concentrations. Soils that have lower soil test P levels should be a high priority to receive manure, since they will benefit most from manure application and are least likely to reach regulatory threshold levels.
- Solid-liquid separation of manure may allow the P-rich solids to be managed separately from the more dilute liquids. Soils that have lower soil test P levels should receive the P-rich solids and the more dilute liquids should be applied to soils with higher soil test P levels. However, the technical and economic efficiency of this practice has not been well documented under Manitoba conditions.
- Select manure application equipment and calibrate to optimally distribute nutrients and meet target application rates.
- Maintain comprehensive records to track soil test P levels, actual yields etc. in order to adjust nutrient management practices accordingly.

Maximize P exports in meat, milk, eggs and crops - Phosphorus export from the farm can be maximized by improving overall crop and animal production efficiency. Optimizing the production potential will maximize the amount of P that leaves the farm in meat, milk, eggs and crops. For example:

- Improve animal management practices to improve overall animal production efficiency. For example, maintain a high health status in pig production. Healthy animals are more efficient and therefore utilize more of their ingested nutrients for growth and reproduction rather than for fighting disease.
- Improve crop management practices to improve overall crop production and maximize the economic yield:
 - Select more productive lands to maximize P removal. Assess the agricultural capability of the land to ensure that the land has the productive capacity to support the targeted yield and manure nutrient application.
 - Select crops that maximize P removal.
 - Ensure adequate supply of N and other nutrients besides P to optimize crop yields and increase the export of P in harvested product. In other words, be prepared to apply commercial fertilizer to fields that are periodically manured.
 - Remove as much crop material as possible to maximize removal of P from the field (e.g., harvesting seed and residue, harvesting forage as hay rather than pasture)
- Where the land base on the livestock farm is insufficient, purchase, lease or rent additional crop land to increase P exported from the farm in crop yield.

Export P from the farm in manure where necessary - Where manure P quantities exceed the landbase available for sustainable application, and additional land cannot be rented or purchased, manure P may have to be exported from the farm. This can be a very expensive option, particularly for liquid manures that require hauling of large volumes of water. Options could be to:

- Export raw manure from the livestock farm to other nearby farms. Manure application agreements with neighbouring crop producers might work well for this purpose, especially if commercial fertilizer prices remain high. Neighbouring lands which have not historically received regular manure applications or that are deficient in P may benefit the most from the manure addition. However, arriving at a mutually agreeable estimate for the agronomic value of manure nutrients may be a challenge (emphasizing the interdependence of specialized farming operations and the need for collaboration among agricultural commodity groups and good rural community relations, in general).
- Treat the manure on-farm and export treated manure. Solid-liquid separation is one example of treatment. Concentrating and transporting the P in the separated solids makes long distance transport more economical. Unfortunately, as mentioned earlier, the technical and economic efficiency of this practice has not been well documented under Manitoba conditions.

2. Reducing Phosphorus Mobilization

Based on knowledge of P loss elsewhere, there are several BMPs that may show promise for reducing mobilization. However, relatively little is known about the relative importance of the mobilization processes that account for P loss from agricultural land in Manitoba, and the most appropriate methods to control those processes.

- Solubilization appears to be the most important contributor to P mobilization in this province; therefore, soil test P thresholds are targeted in Manitoba's proposed regulations (Table 1).
- Although the detachment process has not yet received any regulatory attention, the importance of this P mobilization process and the other detrimental consequences of erosion should not be ignored. However, the challenge with promoting erosion control processes for controlling P loss is twofold. First, erosion does not appear to contribute much of the P loading into Manitoba's watersheds (Salvano and Flaten 2006); therefore, relying on erosion control measures to reduce P loading will not succeed. Second, some of the traditional practices that minimize the mobilization of particulate P, such as no-till crop production and cover crops, are not effective at controlling soluble P and may increase the risk of soluble P mobilization, especially during snowmelt (Bechmann et al. 2005, Flaten et al. 2005).
- The potential for losses of P directly from application of manure or fertilizer into waterways is also obvious; therefore, the Province has also proposed setbacks and buffers to reduce the risk of "incidental transfer" of manure and fertilizer P (Table 2).

Reduce the mobilization of dissolved P (solubilization) - Soils do not possess an infinite capacity to retain P. Therefore, as soil test P increases, the soil's capacity to retain P becomes saturated and the release of dissolved P (soluble P) also increases. Once P is solubilized, it moves with water and is very difficult to control. Therefore, the most promising way to reduce the risk of P loss as soluble P is by controlling the build-up of soil test P through reduced loading, especially in areas where runoff and ponding occur. In other regions, especially in the U.S., the combination of source and transport risk factors is often rated with a "P Index." However, there is currently no P Index for Manitoba and existing P indexes do not accurately indicate the risk of P loading into Manitoba watersheds (Salvano and Flaten 2006). Some of the BMPs that reduce P solubilization include:

- Reducing overall P loading (see previous section).
- Minimize tillage erosion that loads nutrient-rich topsoil into drains and depressional areas.
- Identify critical management areas where the risk of P solubilization is relatively high and be especially careful to avoid a buildup of soil test P in those areas, e.g. areas with:
 - high soil test P
 - soils that have low P retention capacity (e.g., sandy, coarse-textured soils). The P retention capacity of Manitoba's sandy soils is much less than in clay soils. Therefore, for a given rate of P application, the risk of solubilization is greatest in sandy soils. Even though the short term risk of losing the soluble P from the sandy soils is low, because of their low risk of ponding and surface runoff, the long term risk of loading shallow groundwater with excessive P is high and, in many cases, this groundwater eventually flows into surface water bodies.
 - soils and landscapes with poor internal and/or external drainage, high risk of inundation during spring snowmelt or heavy rainfall periods
- In hydrologically active areas where the risk of water, wind and tillage erosion is low, consider removing high P plant material with harvesting and burying high P surface soils with periodic tillage. These practices are intended to reduce the exposure of soluble P at the soil surface to runoff, but have not been evaluated under Manitoba conditions.

Therefore, both of these practices must be considered carefully within the context of other soil and crop management factors.

Reduce the mobilization of particulate P (detachment) - When soil is transported within a field or from a field, the soil particles carry a significant amount of P. Therefore, controlling soil movement due to wind, water and tillage erosion will control the movement of particulate P. Options include:

- Identify critical management areas at high risk of wind and water erosion of particulate P and reduce P loading and erosion risk in those areas, e.g. areas with:
 - high soil test P
 - soils that have high P retention capacity (e.g., loam or clay, fine-textured soils). For the same concentration of soil test P, a clay soil will contain more total P than a sandy soil. Therefore, if a given weight of clay soil is mobilized, it has the potential to carry more P to a surface water body than the equivalent weight of sandy soil.
 - higher natural risk of soil erosion due to water can be identified using soil and landscape properties, the Revised Universal Soil Loss Equation (RUSLE), agricultural capability (E subclass), etc.
- Minimize the mobilization of particulate P by controlling soil erosion, particularly in high risk areas, e.g., by:
 - planting cover crops
 - retaining annual crop residues on the surface, avoiding straw burning, reducing tillage operations
 - establishing and/or maintaining perennial forages and other forms of permanent cover
- Eliminate tillage in areas directly adjacent to surface water or within field drains. Reducing tillage erosion in these areas will minimize the risk of depositing nutrient-rich topsoil into depressional areas where surface water accumulates or flows.

Reduce the direct addition of fertilizer or manure P to water (incidental transfer) - Incidental transfer of P is the addition of manure or fertilizer directly into a water flow path. For example, incidental transfer occurs when fertilizer or manure is surface applied and then is "washed off" of the soil soon afterwards by a rainfall event that exceeds the infiltration capacity of the soil. Incidental transfer also occurs when "fresh frozen" manure or fertilizer that is applied in late fall or winter is "washed off" during spring snowmelt.

- Inject or incorporate manure to reduce the incidental transfer of manure to surface water from inundation due to rainfall and spring snowmelt (Table 2).
- Eliminate contaminated runoff from winter application (Table 2). Eliminating the incidental transfer of manure due to winter application may mean eliminating winter application altogether and, perhaps, minimizing late fall surface applications. This has significant economic consequences for small livestock operations that use liquid manure systems as it would mean increasing the manure storage capacity.

3. Reducing Phosphorus Delivery

Beneficial management practices that minimize delivery are practices which can filter or intercept P after the P has been mobilized, but before it enters surface water. Most of the BMPs designed for this purpose utilize vegetative growth or wetlands to reduce the delivery of particulate P after detachment. Unfortunately, none of these BMPs have been demonstrated as being very effective under Manitoba conditions where dissolved P in snowmelt runoff is the dominant cause of P loading into surface water and where the release of dissolved P from thawed vegetation may pose a greater risk for P loss than the soil which it is intended to protect. These issues, along with the overall issue of how to develop water management BMPs that will complement nutrient management BMPs for reducing P loading deserve more investigation before scientifically sound, economically affordable recommendations can be developed. However, keeping these challenges in mind, several options to consider for reducing P delivery include:

- Improve internal drainage within soils to improve water infiltration and reduce runoff, using crop rotations that increase soil organic matter and water utilization (e.g., perennial forages).
- Retain and utilize runoff water and the nutrients in the water through dams, reservoirs, retention basins (currently under investigation along South Tobacco Creek)
- For erosion-prone areas:
 - Consider using “Vegetated Buffer Strips” and riparian zones to filter runoff before it enters surface water. This is a standard BMP for areas where erosion of particulate P is responsible for most of the P loading to surface water. However, in a recent study in Eastern Manitoba, the effectiveness of vegetated buffer strips was much less than in other studies in other parts of the world (Sheppard et al. 2005). Part of the reason for this ineffectiveness may be due to the narrow widths of the strips, but part may also be due to the release of P from frozen and thawed vegetative residues (Bergmann et al. 2005, Flaten et al. 2005) and the overall challenge of trying to intercept P in situations like ours where the P is dissolved, the soil is frozen, and vegetation is dead and/or inactive during the predominant runoff event of snowmelt.
 - Preserve and/or construct wetlands to treat runoff from agricultural lands (value not fully documented under Manitoba conditions).
 - Vegetate and manage ditches to filter sediment (value not fully documented under Manitoba conditions).

Summary and Conclusions

Due to public concern about water quality, Manitoba Conservation and Manitoba Water Stewardship are expected to introduce nutrient management regulations that will limit the quantity of P applied onto agricultural land and the manner in which that P can be applied. The combination of these regulations will probably apply to all forms of nutrients, including commercial fertilizers, livestock manure, and municipal biosolids.

In order to comply with the proposed regulations for manure phosphorus, it is important for farmers and the people who work with farmers to understand the processes by which agricultural P moves from land to surface water, including phosphorus loading, mobilization, delivery and impact. By understanding those processes, the beneficial management practices (BMPs) can be designed that will be appropriate to the situation on a particular farm or in a particular field. Although all the processes of P loss to surface water are not fully understood for Manitoba's watersheds, many of the basic processes of P loss and some of the BMPs that reduce that loss still apply here.

Some of the key BMPs for reducing P transfer to surface water include:

- 1. Reduce P loading** by working towards P balance, where P application to land does not exceed crop removal. Long term planning to acquire an adequate land base for P-based manure application, minimizing P imports onto the farm through careful feeding practices (e.g., use of phytase and lowering mineral P supplements), soil testing, rotating land where manure is spread on an N-basis, and maximizing P exports from farms and fields offer the best prospects for this approach in the short term. Manure treatment may be a possibility or necessity for some farms, but the technical and economic effectiveness of this technique is not well documented for Manitoba conditions.
- 2. Reduce P mobilization** by preventing excessive accumulations of soil test P, reducing tillage erosion deposition of nutrient rich topsoil into drains and depressional areas, injecting or incorporating manure and eliminating winter application. Beyond these "universal" BMPs, some of the BMPs that may be effective for reducing detachment of P (e.g., zero tillage, cover crops) may increase the risk of solubilization and vice versa. Therefore, knowledge of the predominant processes of mobilization for a given situation is critical for selecting a BMP that will help solve the problem and not aggravate it further.
- 3. Reduce P delivery** is a substantial challenge in a situation such as Manitoba's where erosion of particulate P is not as important as runoff of dissolved P. However, in erosion-prone areas, some of the traditional practices of vegetated buffer strips or waterways; preserved, reconstructed or constructed wetlands may reduce delivery of particulate P. Retention and utilization of runoff water, using dams, reservoirs and retention basins may also offer some benefit, but these practices are still under investigation. Overall, the issue of how water management BMPs can complement nutrient management BMPs requires much more work for Prairie conditions.
- 4. Reducing P impact** using on-farm BMPs is very difficult. At this stage, the consequences of agricultural management practices are difficult to mitigate, reinforcing the importance of implementing BMPs as early as possible in the overall process.

Although many of these BMPs show promise, in most cases their environmental effectiveness and economic affordability has not been evaluated under Manitoba conditions, especially for reducing P mobilization and delivery. Therefore, the most obvious and fundamental of BMPs, reducing net loading or surpluses of P by balancing P application with P removal should be our immediate priority. Beyond that, more research and evaluation is required to develop a full complement of BMP tools for Manitoba's farmers to work with.

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