Managing Phosphorus on Alberta Farms

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Alberta Soil Phosphorus Limits Project

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SUMMARY

Alberta's agriculture industry is having an adverse impact on surface and shallow ground water systems throughout the province. Most of agriculture's impacts on surface water are related to small streams and tributaries that feed the major rivers. Intensive livestock production has been identified as a primary agricultural source of excess phosphorus in surface water. Research has shown that current nitrogen-based manure application rates supported by the Agricultural Operation Practices Act (AOPA) result in phosphorus accumulation in soils, which in turn increases the risk of surface water contamination from runoff.

Alberta's agriculture 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 the 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 because most BMPs recommended in manuals and extension publications have not been field-tested on a regional basis to determine if they are (1) effective in reducing nutrient losses to surface or groundwater, (2) technically feasible to implement, and (3) economically possible for a producer. Until a comprehensive field-testing program is completed, widespread BMP adoption may not take place.

This report discusses BMP alternatives that may be effective for managing phosphorus to reduce losses to surface water bodies. Many new and timely provincial, national, and international initiatives are dedicated to establishing BMP guidelines and support programs that will help producers make informed decisions regarding BMP implementation. The process of BMP implementation includes identifying concerns, assessing the risks, identifying and prioritizing management options, implementing recommended BMPs, and maintenance and monitoring of the BMPs. 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 management using off-stream watering systems 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 utililization and increased weight gain by cattle. The second BMP is related to over-wintering sites, which are a significant source of livestock phosphorus loss to rivers. This BMP should be designed to eliminate the flow of runoff water through over-wintering areas to surface water. This often necessitates moving the over-wintering site 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 phosphorus losses to surface water bodies. 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 AOPA. Two critical issues arise: (1) current technology available to producers does not allow application of solid or liquid manure at these relatively low rates, and (2) even if the technology was available, producers will

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.

- 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.
- 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.
- Manure application prior to rainfall or in critical source areas is not recommended.
- Fertilizer should always be banded or applied with the seed.
- Runoff from over-wintering sites must be prevented from entering surface water.
- Livestock should be 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 always be practiced to reduce soil erosion, which in turn will reduce 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 compost and biogas production, should continue to be explored.

While individual BMPs may reduce phosphorus runoff at a farm level, reducing phosphorus runoff into surface water on a watershed scale is most successful when several BMPs are applied together. Before widespread adoption of BMPs by producers 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.

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INTRODUCTION

Excess phosphorus in surface waters can result in undesirable toxic algal growth and eutrophication of water bodies that can restrict water use for drinking, fisheries, recreation, agriculture, and industry. Sources of excess agricultural phosphorus include soil erosion, surface runoff, and fertilizer and manure application.

Concerns regarding agricultural phosphorus are largely the result of modern agricultural infrastructure that has partially separated crop and animal producing areas, resulting in excess nutrients in localized areas (Mallin and Cahoon 2003). As well, economical growth has not always occurred without consideration of long-term environmental sustainability (Sharpley et al. 2005).

Agriculture, particularly intensive livestock production, has been identified as a primary source of excess phosphorus in Alberta’s surface water (Canada-Alberta Environmentally Sustainable Agriculture 1998). Alberta has the largest cattle population in Canada, comprising about 40% of the national total in 2004 (AAFRD 2005a). Alberta is also home to significant numbers of hogs and poultry. It is not surprising that manure application from livestock, including cattle, hogs, and poultry, is a major concern in relation to phosphorus contamination of surface waters in Alberta.

In Alberta, the Agricultural Operation Practices Act (AOPA) was introduced in 2001 to ensure that intensive livestock operations become more environmentally sustainable. The AOPA regulates manure application in Alberta on the basis of nitrate nitrogen limits in the top 60 cm of soil (Province of Alberta 2004). However, it is recognized that manure applied at or above these nitrogen-based rates will result in phosphorus accumulation in the upper soil profile because of the ratio of nitrogen to phosphorus in the manure, and the significantly different crop requirements for nitrogen and phosphorus. While crops need about 4 to 10 times more nitrogen than phosphorus (Canadian Fertilizer Institute 2001), beef cattle manure contains similar amounts of available nitrogen and total phosphorus (Province of Alberta 2001). Applying manure to meet crop nitrogen requirements will significantly increase phosphorus levels in the soil.

Based on an 8-year field study, Olson et al. (2003) recommended that cattle manure rates of 15 to 25 tonnes/ha are sufficient to meet crop requirements and prevent the build-up of excess nitrogen. However, they cautioned that phosphorus build-up in surface soil would occur and pose a potential risk to surface water quality, even at these relatively low rates of application. In a 16-year field experiment, Whalen and Chang (2001) found that the amount of phosphorus removed in barley grain and straw was only about 5 to 18% of the total manure phosphorus applied. They suggested that manure application rates should more closely match manure phosphorus for crop production.

Switching from nitrogen-based to phosphorus-based manure application rates poses significant challenges, particularly for confined feeding operations. Phosphorus-based manure application will almost always result in lower manure application rates, which requires a larger land base to accommodate the manure (Olson 2004). This will result in additional transportation costs to producers.

In conjunction with reduced manure application rates, reduction of manure phosphorus content through feed ration modification or manure processing (composting, bio-gas production) should be considered. Alternative uses of manure, other than land application, also need to be considered, particularly for regions where available land is limited.

During development of AOPA, it was recognized that more scientific data on phosphorus were required. As a result, the Alberta Soil Phosphorus Limits Project was initiated in 1999. One of the objectives of the Soil Phosphorus Limits Project was to identify potential management options that producers could implement to manage phosphorus within set limits (Paterson et al. 2004). Time and resource constraints prevented the project team from implementing and evaluating specific phosphorus management BMPs in the field. However, this report will identify research initiatives that focus on the environmental sustainability of agricultural practices and will identify BMPs that are applicable for managing phosphorus on Alberta farms.

BMP TOOLS, GUIDES, AND EVALUATION PROGRAMS

Within the last few years, extensive initiatives and programs have been initiated throughout the United States and Canada to promote implementation of agricultural BMPs. Suggested BMPs to limit the loss of phosphorus from land to surface water have included environmental farm planning; crop management, soil conservation; manure management, livestock diet modification, controlled livestock grazing and over-wintering, water management, and nutrient management planning (Sharpley et al. 2000; Soil Phosphorus Limits Committee and LandWise Inc. 2006). Some of the recent initiatives that promote or evaluate agricultural nutrient management, including but not limited to phosphorus management, are discussed below.

Initiatives in the United States

Phosphorus index and SERA-17. The phosphorus index is a tool that is used to assess the relative risk of phosphorus loss from agricultural land (Sharpley et al. 2003). Based on index values, recommendations are made regarding the areas that should be targeted for BMP implementation. Lemunyon and Gilbert (1993) published the first phosphorus index. This tool assigns a phosphorus index based on the theory of critical source areas, which are areas that tend to transport high concentrations of phosphorus, especially during storm events (Pionke et al. 1997). While the phosphorus index indicates whether or not source or transport management actions are required to prevent contamination of surface water, it does not specifically identify the management practice, or combination of practices, that will be most effective. While 47 states in the United States have implemented a version of the phosphorus index in nutrient management policies or regulations, research to validate and calibrate the phosphorus index continues (Sharpley et al. 2003). Several challenges that have arisen during implementation of the phosphorus index include the added complexity for nutrient management planning, additional cost (economic and labour) to gather the data required for the index and implementation of phosphorus-based plans, and the continued need for research to clarify phosphorus transport scaling effects and BMP effectiveness (Beegle et al. 2005). These challenges are continually being addressed as they arise, as the phosphorus index is the accepted approach to maintain water quality goals while promoting sustainable agriculture in the United States (Beegle et al. 2005).

The Southern Extension Research Activity 17 (SERA-17) is a United States Department of Agriculture Information Exchange Group that consists of more than 50 scientists from the United States and other countries. The objectives of the group are to study and try to reduce the impact of agricultural phosphorus on surface water quality. A BMP manual, specific to phosphorus, was published by SERA-17. Thirty-two BMPs that address phosphorus sources, transport mechanisms, or both concerns were categorized (Southern Extension Research Activity 17 2005). For each BMP, general information is provided on its purpose, the way it works, limitations, effectiveness, cost of establishment, operation and maintenance, and information contacts.

Conservation Effects Assessment Project. In 2003, the Conservation Effects Assessment Project (CEAP) was established to evaluate conservation programs targeted at improving the environment, including phosphorus management. The CEAP will provide a scientific accounting of environmental benefits achieved through select conservation initiatives introduced in the 2002 Farm Bill programs (United States Department of Agriculture 2004). Cooperators include the United States Department of Agriculture - Natural Resources Conservation Service, the Agricultural Research Service, the National Agricultural Statistics Service, and the Farm Service Agency.

The CEAP is composed of two basic parts: a nationwide assessment of conservation benefits, and more in-depth studies of these benefits in 20 selected watersheds. The CEAP will use validated data and model simulations to assess the impact of conservation practices on water quality, soil quality, air quality, and wildlife habitat. Annual reporting began in 2005, and some data are available online (http://www.nrcs.usda.gov/technical/nri/ceap/about.html). Mausbach and Dedrick (2004) also described the purpose and goals of the CEAP in more detail.

Initiatives in Canada

Agricultural Policy Framework. In 2003, the government of Canada invested $5.2 billion to establish the Agricultural Policy Framework (APF), a policy that will develop the architecture for agricultural policy in the 21st century (Agriculture and Agri-Food Canada 2004a). All provincial and territorial governments have pledged support for this agreement and are working with the agriculture and agri-food industry sectors to promote food safety, innovation, and environmentally responsible production. The APF action plan is composed of five elements: business risk management, food safety and quality, science and innovation, environment, and renewal.

Environmental concerns regarding phosphorus may be addressed under the APF's environment action plan. Funding for environmental initiatives includes support to the Environmental Farm Plan Program, Green Cover Program, Water Supply Expansion Program, and the National Water, Land and Information System. More than $100 million will support the

Environmental Farm Plan Program (1) to establish recognizable principles of environmental action in agriculture, (2) to achieve measurable progress on the landscape, and (3) to assess and identify environmental risks and benefits from agricultural practices.

The Green Cover Program will receive more than $110 million to promote sustainable land use, and expand forage and tree land cover. One of the goals of the environmental action plan is to ensure healthy soil and water. The Environmental Farm Plan and Green Cover Programs will achieve these goals through implementation of BMPs.

Watershed Evaluation of Beneficial Management Practices. In 2004, Agriculture and Agri-Food Canada implemented a national initiative called Watershed Evaluation of Beneficial Management Practices (WEBs), which is supported by the Green Cover Program and Ducks Unlimited Canada (Agriculture and Agri-Food Canada 2004b). The objectives of this initiative are (1) to evaluate surface water quality following individual BMP implementation within small watersheds, and (2) to evaluate surface water quality from a suite of BMPs within the same watersheds. Evaluations will include economic and environmental cost-benefit assessments. Seven watersheds across Canada were chosen for evaluation. These watersheds include the Salmon River in British Columbia, Lower Little Bow River in Alberta, South Tobacco Creek in Manitoba, South Nation in Ontario, Bras d'Henri in Quebec, Black Brook in New Brunswick, and Thomas Brook in Nova Scotia (Figure 1). Through WEBs, data will be extrapolated from the plot or small-field scale, to the micro-watershed scale, and perhaps to even larger watersheds using appropriate modelling techniques.

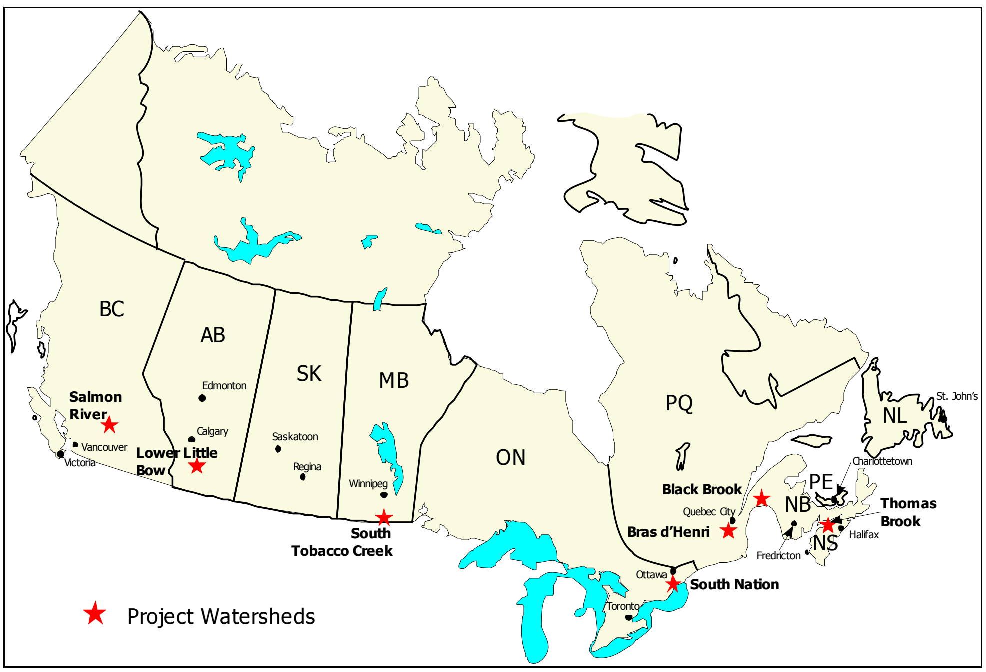


Figure 1. Location of the seven WEBs watersheds.

The Lower Little Bow River in Alberta (Figure 2) was an ideal WEBs watershed because it met the selection criterion of having a good water quality database. The Oldman Watershed

Council (formerly known as the Oldman River Basin Water Quality Initiative) has collected water quality information from the Lower Little Bow River since 1998. Through WEBs, many BMPs are being implemented and tested within a sub-watershed of the Lower Little Bow River. The BMPs include buffer strips, cropland conversion from annual crops to permanent cover, off-stream cattle watering with and without fencing, and manure management using phosphorus and nitrogen-based application rates. Concentrations of in-stream nutrients, including phosphorus, are being monitored up and down stream of the BMP sites. In addition, rainfall simulators are being used to assess agriculture impacts on water quality at the plot scale.

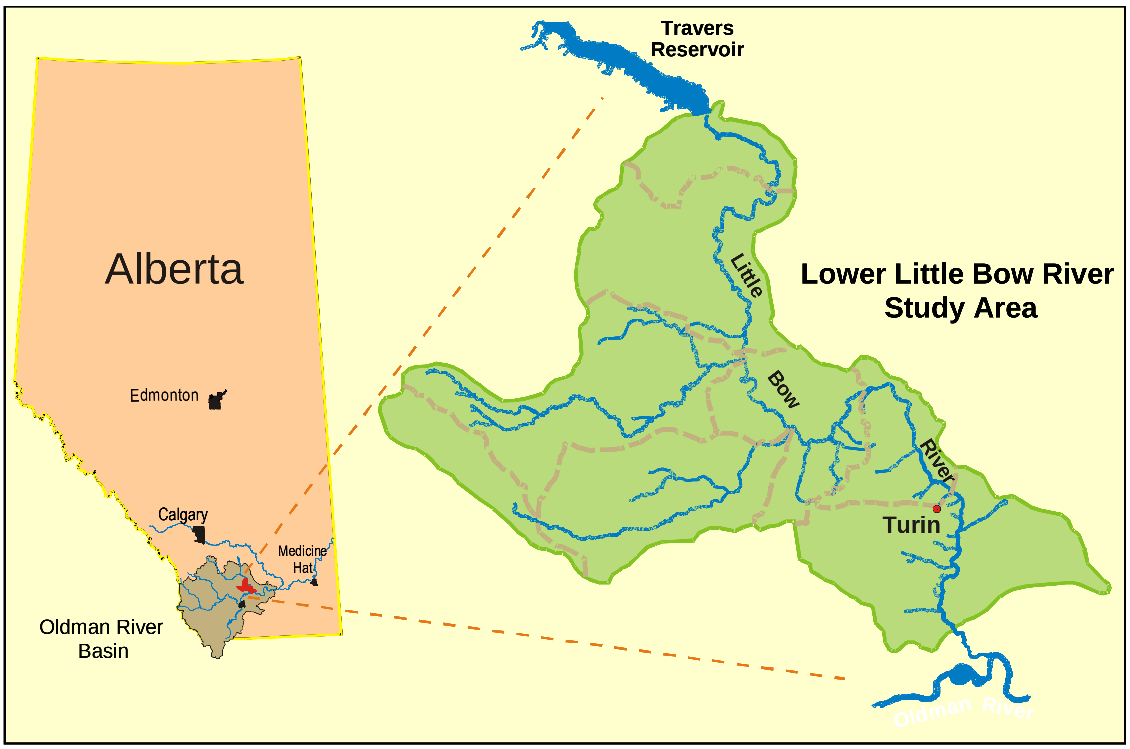


Figure 2. Lower Little Bow River watershed.

National Agri-Environmental Health Analysis and Reporting Program (NAHARP). The objective of NAHARP is to develop and improve agri-environmental indicators to assess and report on important national environmental issues related to the agriculture sector (Agriculture and Agri-Food Canada 2004c). Issues will be examined within five themes: soil quality, water quality, agro-ecosystem atmospheric emissions, agricultural biodiversity, and eco-efficiency. The risk of water contamination by phosphorus will be addressed under the water quality theme. Risks are known to be greater in areas where plant available soil phosphorus levels are high and the ability of soils to retain phosphorus are low, and within areas that are susceptible to runoff and erosion. The risk indicator of water contamination by phosphorus (IROWC-P) will estimate the risk of phosphorus contamination by agriculture and will show how this risk is changing with time. Originally developed for use in Quebec, the NAHARP will develop the IROWC-P for use across Canada. The NAHARP will also improve the indicator methodology by creating a soil phosphorus sorption capacity database, adding BMP factors into the phosphorus balance component, and adding hydrologic and climate components to refine the phosphorus transport component.

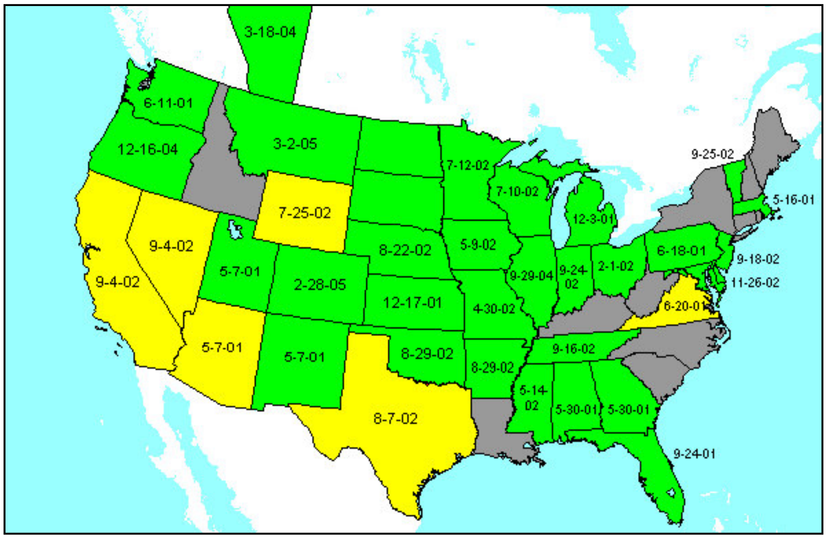
Initiatives in Alberta

Alberta Manure Management Planner (MMP). The MMP is a Windows®-based computer program that was customized from the Manure Management Planner developed at Purdue University, West Lafayette, Indiana (Purdue Research Foundation 2004). The MMP can be used to assist in the development of nutrient management plans for crop and animal feeding operations. The user enters information about the operation's fields, crop varieties, manure storage, animal types and numbers, and manure application equipment. The MMP helps the user allocate manure (where, when, and how much) on a monthly basis for the length of the plan (1 to 10 years). This allocation process helps determine if the current operation has sufficient crop area, seasonal land availability, manure storage capacity, and application equipment to manage manure in an environmentally responsible manner. The MMP is also useful for identifying changes that may be needed for a non-sustainable operation to become sustainable, and to determine the changes that may be needed to keep an operation sustainable if the operation expands. One of the strengths of the software is its use as a reporting system to keep track of each field.

The MMP is currently supported by 31 states in the United States (Figure 3) by utilizing fertilizer recommendations and estimating manure nitrogen availability based on the extension and/or Natural Resources Conservation Service (NRCS) guidelines of each state. Alberta is the only province in Canada that has adopted the MMP. The Alberta MMP is not a tool specifically for phosphorus management, but rather, it is a general nutrient management calculator. The Soil Phosphorus Limits Project Technical Working Group took the initiative to have MMP customized for Alberta, so producers could have a computer calculator to prepare nutrient management plans, which may include phosphorus-based nutrient application, including manure. Following the introduction of the Alberta MMP in the spring of 2004, the Technical Service Division of Alberta Agriculture, Food and Rural Development assumed the responsibilities of implementing, field-testing, and training related to the Alberta MMP.

The first version of the Alberta MMP was delivered by Purdue University in January 2004. The second version of Alberta MMP, which included metric and imperial unit options, was tested and then an updated version was delivered in April 2004. The latest version of the MMP, released in early 2005, added updated input columns, cropping selections, operation selections, printouts, and worksheets. Approximately 500 electronic copies of the Alberta MMP program have been distributed to rural extension staff and producers and the current version is available on-line (AAFRD 2005b).

The next phase of development for the Alberta MMP will include a geographical information system (GIS) interface. The GIS software can determine total field size, setback area, and area where manure can be spread within the operator’s fields. The next phase may also include the integration of the MMP program and the Alberta Farm Fertilization Information and Recommendation Manager (AFFIRM) software (AAFRD 2005c). This can help producers make



Supported:
Illinois, Indiana, Iowa, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Jersey, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Utah, Vermont, Washington, and Wisconsin.

Under development: Arizona, California, Nevada, Texas, Virginia, and Wyoming.

Figure 3. Status of Manure Management Planner (MMP) development, as of March 2005.

fertilizer decisions based on production economics and predicted yield response to nutrients and moisture.

Beneficial management practices manuals. Alberta's agricultural industry and Alberta Agriculture, Food and Rural Development have been proactive towards supporting the implementation of BMPs. To date, six agricultural BMP manuals are available: crops (AAFC and AAFRD 2004), cow/calf (Alberta Beef Producers and AAFRD 2004), feedlot-beef (Alberta Cattle Feeders' Association and AAFRD 2002), dairy (Alberta Milk and AAFRD 2003), poultry (Alberta Egg Producers et al. 2003), and hog production (Alberta Pork and AAFRD 2002). These manuals provide a range of management options for producers and incorporate new technologies and information on environmental practices. While specific BMPs for reducing phosphorus accumulation in the soil and water are not the direct focus of the manuals, the BMPs promote environmental stewardship for maintaining and enhancing soil, water, and air quality, as well as biodiversity.

Tri-provincial manure application and use guidelines. Agencies from the three Prairie Provinces collaborated to develop and recommend manure management BMPs for producers. Scientists and professionals within industry, academic institutions, and provincial governments produced the tri-provincial manure application and use guidelines (The Prairie Province's Committee on Livestock Development and Manure Management). Information contained in the guidelines is based on research in Alberta, Saskatchewan, and Manitoba, plus experience from other jurisdictions.

PROCESS FOR PHOSPHORUS BMP IMPLEMENTATION

Processes that affect phosphorus runoff are not bound by regional or political boundaries, and the environmental impacts of phosphorus are usually downstream from the source area. While overall phosphorus management is more effectively addressed at a larger scale (Sims and Kleinman 2005), implementation of BMPs is usually carried out on a farm scale.

Step 1 – Identify Concern

The primary concerns related to phosphorus losses must first be identified. It is necessary to determine if phosphorus is the primary concern or if there are additional concerns, such as nitrogen or coliform bacteria. Determining the source(s) of excess phosphorus is important. For example, phosphorus may be a concern in surface runoff from a single farm field or from several fields on many farms. This may establish if water quality issues are related to a specific farm, a small number of farms, or an entire watershed. Sometimes regulatory processes need to be part of the solution. If so, there may be requirements such as prescriptive management options or time restrictions. The approach that is taken for managing phosphorus will be determined by the concerns and associated information.

Step 2 – Complete an Inventory and Risk Assessment

This requires an objective assessment and characterization of the entire farming operation, including nutrient inputs and outputs (animal, crop, and fertilizer), soil types, landscapes (flat or rolling topography), and water resources. In addition, the farm management strategies, nutrient budget, current regulations (e.g., AOPA), and the field risk to phosphorus loss should be identified (Sharpley et al. 2005; Sims and Kleinman 2005). For cow-calf operations, over-wintering sites located close to surface water are a significant risk. For intensive livestock operations, the most significant concern is related to manure spreading at high rates and/or close to surface water.

It is also recognized that low topographical areas that are prone to surface runoff are a high risk for phosphorus loss, but in some cases leaching or other pathways may also be of concern. There are many tools to assist in phosphorus loss assessments that range from soil testing to watershed basin models (Heathwaite et al. 2005). The Alberta Soil Phosphorus Limits Project identifies potential phosphorus losses from fields if the plant available phosphorus in the soil profile is known (Little et al. 2006). The Alberta Environmental Farm Plan provides a self-help guide that allows Alberta producers to assess the environmental sustainability of their operation.

Step 3 – Identify and Prioritize Management Options

It has been suggested that producers prefer to be given a range of BMPs to choose from and have the ability to decide what best fits with their practice rather than be instructed by individuals or groups that may not be familiar with their operation or limitations (Walker et al. 1996; Withers et al. 2003). However, producers also want assurance that the recommended BMPs are effective, practical, and financially possible for their site-specific problems. There are many guides and resources available to support the implementation of BMPs. Table 1 provides a partial list of BMP subject areas that may be considered for phosphorus management. This table shows the scale at which the BMPs are applied, and the mechanism of phosphorus loss that is addressed. These considerations are important to prioritize management options.

When prioritizing management options, practicality must be a consideration as, in some cases, implementation of desirable BMPs may not be possible in the short term. For example, a BMP that requires livestock relocation or manure application on a larger land base will only be possible if the producer has access to funds and an additional land base.

Table 1. Examples of BMPs for phosphorus management.

	Scale of application			Phosphorus loss mechanism	
BMP category[z]	**Field**	**Farm**	**Watershed**	**Source**	**Transport**
Nutrient application based on crop requirements	x			x	
Manure alternatives other than land application (e.g., compost, biogas)			x	x	
Physical or chemical treatment of manure		x		x	
Calibration of nutrient application equipment		x		x	
Mine phosphorus from soils using certain crops or grasses	x			x	
Minimize erosion and runoff through soil conservation and runoff management, including irrigation	x				x
Riparian management (e.g., buffers, grassed waterways)		x	x		x
Relocation of livestock		x		x	x
Grazing management		x			x

[z] Financial support for all the BMPs in this table is available through the Canada-Alberta Farm Stewardship Program for producers with a completed Alberta Environmental Farm Plan.

Step 4 – Financial Support

Under the Agricultural Policy Framework (APF), the Canada-Alberta Farm Stewardship Program (CAFSP) assists producers implement environmental enhancements on their farms. Producers in Alberta who successfully complete an Alberta Environmental Farm Plan (EFP) may qualify for up to $30,000 in funding assistance. There are currently many crop and livestock production and management BMP categories that are eligible for funding, including manure treatment, land application of manure, improved manure storage and handling, wintering site management, riparian area management, nutrient management planning, farmyard runoff control, and product and waste management (www.albertaEFP.com).

Step 5 – Implementation of BMPs

Research has shown that it is more effective to manage phosphorus by implementing a suite of several BMPs rather than a single BMP (Gilliam et al. 1997). Unfortunately, funding circumstances often mean that producers are unable to implement more than one BMP at a time.

Similar to individual BMPs, BMP systems need to be very site specific and cannot be generally prescribed. A BMP system will be most effective if the BMPs are located in critical source areas (Osmond et al. 1995). Systems of BMPs must involve at least 75 to 100% of the critical source areas to achieve water quality improvements. The latter percentage is required if problems are derived from livestock grazing (Meals 1993; Line and Spooner 1995).

Step 6 – Maintenance and Monitoring of BMPs

Continued maintenance of established BMPs is required to ensure that the systems will effectively operate for the long term. Ongoing soil and water quality monitoring is recommended to determine if anticipated changes occur as a result of the BMP implementation. Adjustments to the original BMPs may be required with time if the soil and water quality objectives are not being reached in a timely fashion.

BMP RECOMMENDATIONS SPECIFIC TO ALBERTA

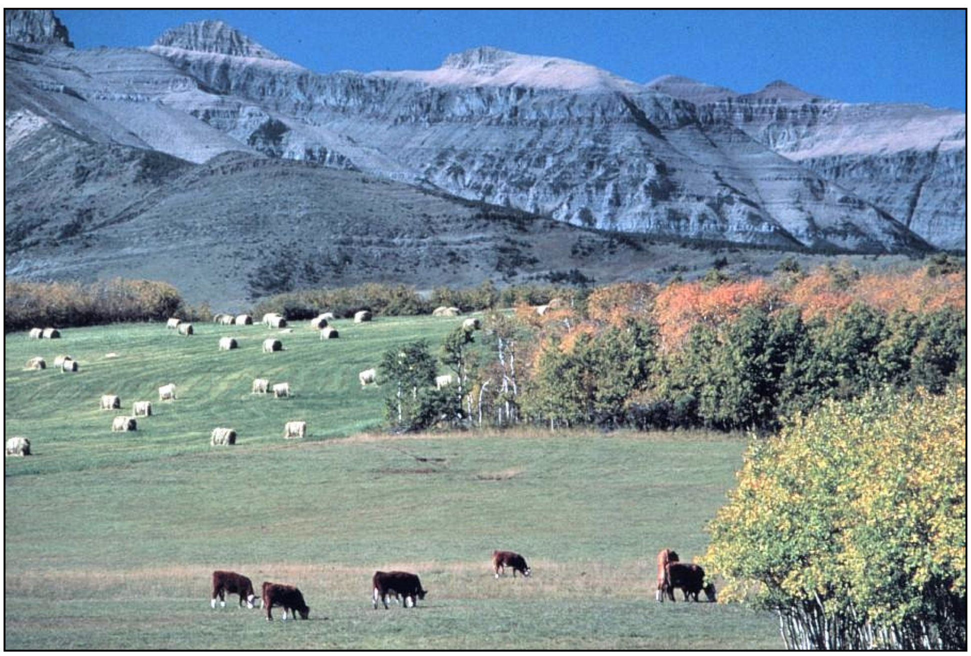
Alberta's surface water bodies, including streams, rivers, and lakes, tend to be naturally highly productive, or eutrophic (Howard et al. 2006). Consequently, surface water in Alberta is very sensitive to phosphorus loading. These concerns have been exacerbated by changes to our natural hydrologic systems, including the cultivation of natural wetlands, and intensive cropping of the landscape. While intact natural aquatic systems may serve as sources of phosphorus, they may also retain phosphorus (Riemersma et al. 2006).

The climate and weather in Alberta greatly influence water quality. Periods of drought and freeze-thaw cycles may increase phosphorus release from sediments and vegetation (Klotz and Linn 2001). Nutrient concentrations, including phosphorus, tend to be highest in streams and rivers in the spring when snowmelt occurs. The majority of surface runoff in Alberta tends to be generated by snowmelt, and snowmelt runoff is hydrologically and chemically different than other runoff (Elliot and Maule 2005; Ontkean et al. 2005; Little et al. 2006). Spring snowmelt and intense, high-volume rains are a concern as these events can transport nutrients that may have accumulated on the land for some time. However, rainfall events that cause surface runoff can also contribute large amounts of contaminants to streams (Oldman Watershed Council 2005). The BMPs considered for Alberta must address spring snowmelt as well as rainfall.

The livestock industry is considered a significant cause of the agricultural loss of phosphorus to surface water in Alberta. Alberta is a major producer of livestock within Canada and 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 the hog production. Alberta ranks fourth in fed cattle production in North America. Studies have shown that livestock manure management is the most important area where Alberta needs to focus the development and implementation of BMPs (Canada-Alberta Environmentally Sustainable Agriculture 1998). Two specific areas where BMPs are being discussed include cow-calf operations, and intensive livestock operations.

Cow-Calf Operations

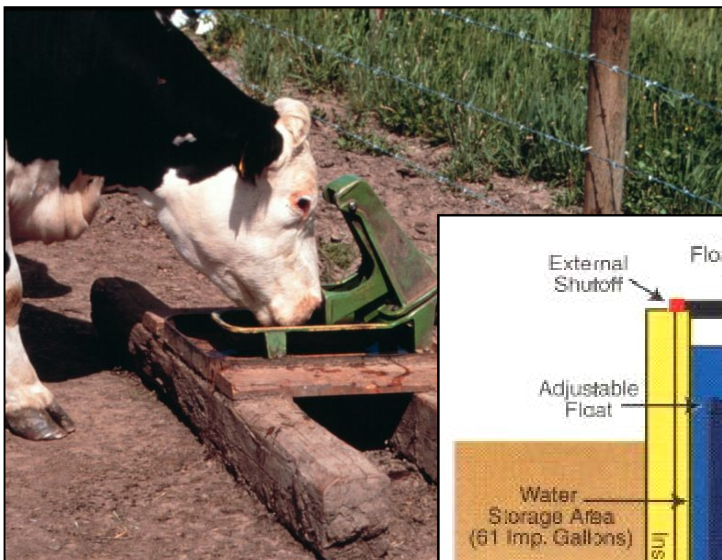
Management of critical source areas, such as riparian areas, may be the most effective way to reduce phosphorus transport to surface waters (Riemersma et al. 2006). Research has shown that these areas may contribute up to 90% of surface runoff (McDowell et al. 2001). The majority of riparian areas in Alberta are mixed grasslands, and much of this area is used for grazing or wintering livestock. Livestock use of riparian areas directly contributes to increased nutrients in streams, including phosphorus concentrations.



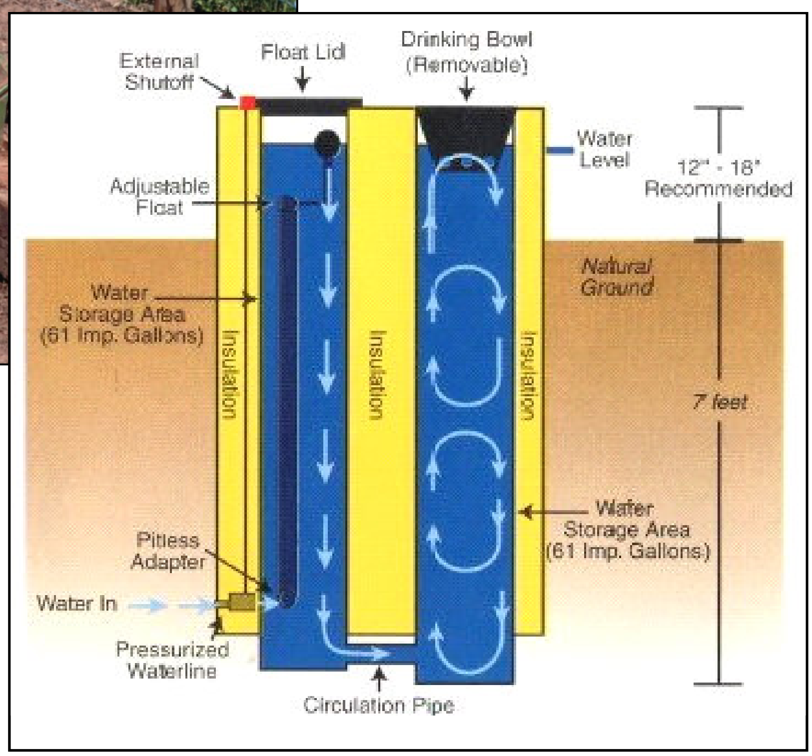
Cow-calf operation

Information on BMPs for managing livestock in Alberta's riparian areas is widely available (Fitch et al. 2003; Alberta Beef Producers and AAFRD 2004; West). The most effective BMPs include removal of wintering sites from riparian areas and beneficial grazing management of livestock in riparian areas with the use of fences or off-stream watering systems. In addition to livestock management, vegetation management of riparian buffers should be considered.

Off-stream watering systems. The development of off-stream watering systems is one of the most highly recommended BMPs for grazing cattle. These may include solar and wind powered systems that pump water from natural water bodies or dugouts, thermosinks, or nose pumps that allow the cattle to pump the water themselves. Either way, if good quality water is provided, cattle will prefer to drink from off-stream systems rather than wade into a surface water body (Willms et al. 2002). As a result, cattle will not travel to a river or lake as often, thereby having less impact on the riparian zone and the banks of the river or lake.



Nose pump for cattle



Thermosink off-site watering system

The quality of water from the off-stream systems is generally of better quality than the water in a creek, lake or dugout, particularly in the areas that have been trampled by cattle. Off-stream watering is not only beneficial to the environment, but research has shown that cattle supplied with clean, off-stream water tend to graze longer and gain more weight than cattle that drink from pond water (Willms et al. 2002). In addition, cattle that have access to strategically placed off-stream watering systems are more likely to utilize existing pasture resources more effectively than cattle that drink from a river or lake.

Over-wintering cattle. Over-wintering of cattle is a common practice among cow-calf operators throughout Alberta. Many of these sites are close to a river or stream, will generally have some protective trees and shrubs that offer protection to the livestock from wind and snow, and are on sloping land that offers good drainage. Unfortunately, what is often considered ideal from an over-wintering perspective is the worst-case scenario for nutrient and bacteria losses to rivers or streams. This is particularly evident during the spring snowmelt period, if surface runoff water flows through the over-wintering site to the river or stream. Manure built up in the over-wintering site throughout the winter is completely exposed to spring runoff water, which may transport significant amounts of nutrients and bacteria directly to a river or stream. Eliminating the flow of runoff water through the over-wintering site is critical to sustain the quality of water in Alberta's rivers or streams. A couple of alternatives are available to control these runoff losses: (1) move livestock away from the river and provide off-stream watering to the herd; or (2) construct a berm that will capture or divert the runoff water away from the river. Either of these alternatives need careful assessment to determine the costs and benefits.

Over-wintering site for cattle

Confined Feeding Operations

Confined feeding operations, whether they are cattle, hogs, or poultry, generate a significant amount of manure in a relatively small area. There are two key water quality issues related to intensive livestock operations: the feeding area (feedlot or housing facility) and manure application to the land.

The AOPA contains clear and rigorous standards related to the siting, construction, and management of intensive livestock feeding operations throughout Alberta. Comprehensive regulations are available to all producers, and the Natural Resources Conservation Board is responsible for administering the confined feeding operation application and approval process and monitoring compliance with the province-wide standards. If these regulations are followed, little if any negative impacts on water quality are expected to occur from the actual feeding operations themselves. The real issue where BMPs need to be implemented relates to the management and spreading of the manure generated by confined feeding operations.

Beef feedlot

Nutrient management. Field evaluations of BMPs have shown that the single, most effective BMP to reduce phosphorus export from a watershed is nutrient management (Sharpley and Rekolainen 1997). Effective nutrient management ensures that nutrient cycles achieve a balance between inputs and outputs. This requires the application of appropriate fertilizer and/or manure at rates that will maximize crop production, but do not increase environmental risks. Inorganic fertilizer applications are less frequently applied at levels in excess of crop requirements than are manure application rates. One reason for this is that producers have a better understanding of the nutrient content of fertilizers, and appreciate the cost of purchasing fertilizer nutrients. Conversely, some producers may not understand the value or amount of nutrients contained in manure, and are also faced with the necessity of disposing of a given volume of manure on a limited land base. This often results in excess manure being spread on agricultural fields and results in nutrient application that exceeds crop requirements.

Olson (2005) showed that some of the AOPA nitrogen limits for manure application are already higher than crop nitrogen requirements, and application of manure based on AOPA nitrogen limits may result in the continual over-application of nitrogen and phosphorus relative