Nutrient Beneficial Management Practices Evaluation Project

Volume 2
Field Study

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EXECUTIVE SUMMARY

1 Introduction

In Alberta, crop and livestock producers face challenges with increasing input costs, market competition, and continued pressure to improve environmental stewardship. In recent years, the impact of agriculture on the environment has focused on livestock production, and in particular the intensive livestock industry and manure management, with concerns regarding the effects of nutrients on water quality. Producers seek proven and practical beneficial management practices (BMPs) that will maintain efficient and viable farm operations while protecting the environment.

Numerous BMPs have been developed and promoted to minimize the effects of agriculture on the environment and increase the sustainability of the agricultural industry. Beneficial management practices are defined as conservation practices, management techniques, or social actions that minimize potential negative effects on the environment while being practical for producers to meet or exceed regulatory requirements and meet production targets.

Beneficial management practices are often developed to protect water quality by managing nutrient inputs at the source to minimize or prevent nutrient losses. Nutrient management fulfills crop nutrient requirements and minimizes the potential for loss to the environment.

The effectiveness of BMPs under Alberta conditions is not well known. Producers are requesting science- and risk-based, site-specific analytical tools to assist them in deciding which management practices would yield the greatest benefit for their financial investment. Producers and policy makers require information on the least-cost alternatives for reducing environmental impacts, and this requires an economic analysis of costs and benefits.

It is largely assumed that BMPs elicit a positive effect on the environment. However, BMPs are often not assessed or evaluated at larger scales (i.e., watersheds) because fewer factors can be controlled, replication is less feasible, and larger studies are expensive. There is also limited research showing the cumulative effects of BMPs on the environment. Within Alberta, additional BMP study sites are especially needed because of the diverse agro-climatic regions in the province.

Under the leadership of Alberta Agriculture and Rural Development, and in partnership with the Alberta Crop Industry Development Fund, Alberta Environment, Municipality of Pincher Creek, County of Lacombe, and the University of Alberta, a 6-yr research project was carried out to evaluate BMPs at field and watershed scales in Alberta.

2 Objectives

In this study, suites of BMPs, rather than individual BMPs, were evaluated at each field site. The BMPs were assessed to determine if they improved surface water-quality, and other indicators, such as riparian and rangeland quality, were assessed at some sites. Nutrient BMPs were examined in this study, with a focus on livestock production systems. Three main BMP types were evaluated: manure nutrient management, livestock management, and surface-water management. The specific project objectives were to:

- Evaluate the effectiveness of nutrient BMPs in reducing agricultural impacts on the environment at the farm scale.
- Assess the effects of BMPs on water quality in specific reaches of a watershed stream.
- Predict the cumulative effects of BMPs on the overall quality of a watershed stream using models (refer to Volume 3).
- Evaluate nutrient BMPs for effective use of manure in crop production.
- Assess economic costs and benefits associated with BMPs implemented in this study.

3 Methods

The primary focus of this project was in two agricultural watersheds in Alberta: Indianfarm Creek (IFC) Watershed (14,145 ha) located east and southeast from Pincher Creek and Whelp Creek (WHC) Sub-watershed (4595 ha) located west from Lacombe. Investigations included watershed-wide assessments of water quality and land-use practices, as well as BMP assessment sites on the property of cooperating producers. Outside of these two watersheds, two additional field sites were selected: one (65 ha) in the Battersea Drain Watershed and the other (130 ha) in the Lower Little Bow River Watershed. Both of these field sites were irrigated and had a history of heavy manure application.

A total of 22 field sites were established in the study: 12 sites in the IFC Watershed, eight sites in WHC Sub-watershed, plus the Battersea Drain Field (BDF) and Lower Little Bow Field (LLB) sites. Beneficial management practices plans were developed for 20 sites, of which BMPs were implemented at 16 sites. Water quality data were used to assess the effectiveness of the BMPs at 11 sites. Water quality was the main indictor to evaluate the effectiveness of the BMPs implemented at the study sites. In addition, riparian quality, rangeland quality, and soil nutrient status were also used as indicators at certain sites. The total costs and labour for the BMPs were also recorded.

The number of water quality monitoring stations ranged from one to six stations among the BMP sites. In addition, watershed-wide stations, were established in the IFC and WHC watersheds, including the watershed outlets. The monitoring stations included edge-of-field and instream stations. The edge-of-field stations were equipped with automatic water samplers and the instream sites were either sampled with automatic samplers or grab sampled. Water flow was determined for all monitored sites using various instantaneous and continuous measuring techniques, including staff gauges, dataloggers, and flow metering.

The before-and-after approach was used to evaluate the BMPs. The sites were selected and water quality was monitored for 2 to 4 yr with existing management practices. In cooperation with the produces, the BMP plans were implemented. Then, water quality monitoring continued for another 2 to 4 years, depending on the site.

A summary of project study sites, sites for which BMP plans were developed, sites that were successfully implemented with BMPs, and sites where BMPs were able to be evaluated using environmental indicators.

	Site[z]	BMP type[y]	BMP plan developed	BMP plan successfully implemented	BMP evaluation carried out: Water quality	Water quantity	Soil nutrients	Riparian	Range-land	Photo points
Indianfarm Creek Watershed	IMP	C	✓	✓	✓			✓		
	NMF	C	✓	✓	✓					
	PST	C	✓	✓	✓			✓	✓[x]	
	WIN	C	✓	✓	✓			✓		
	SMF[w]	N	✓							
	DMF[v]	N	✓							
	REF[u]	C	✓							
	FLT[t]	C,S	✓	✓					✓[s]	✓
	DUG	C	✓	✓				✓		✓
	OSW	C	✓	✓				✓		✓
	FEN[r]	C	✓	✓						
	CAT	S	✓	✓						
Whelp Creek Sub-watershed	WFD	N	✓	✓	✓					
	NFD	N	✓	✓	✓					
	EFD[q]		✓							
	SFD	N	✓	✓	✓					
	NPS	C	✓	✓	✓				✓[p]	
	SPS	C	✓	✓	✓				✓[p]	
	REF1[o]									
	REF2[o]									
Irrigated field sites	BDF	N,S	✓	✓	✓	✓	✓			
	LLB	N,S	✓	✓	✓	✓	✓			
Number of sites	22		20	16	11	2	2	5	4	3

[z] IMP = Impoundment, NMF = North Manure Field, PST = Pasture, WIN = Wintering, SMF = South Manure Field, DMF = Dairy Manure Field, REF = Reference, FLT = Feedlot, DUG = Dugout, OSW = Off -stream Watering, FEN = Fencing, CAT = Catch Basin; WFD = West Field, NFD = North Field, EFD = East Field, SFD = South Field, NPS = North Pasture, SPS = South Pasture, REF1 = Reference 1, REF2 = Reference 2, BDF = Battersea Drain Field, and LLB = Lower Little Bow Field.

[y] C = cattle management BMPs involved infrastructure alterations, off-stream watering, windbreaks, fencing, and/or improved grazing plans; N = manure nutrient management BMPs on cropland involved nutrient management plans, application setbacks, and/or buffer zones; and S = Surface-water management involved berming and redirecting the flow of surface water (FLT, CAT) or irrigation management to reduce runoff (BDF, LLB).

[x] Rangeland survey and rangeland production.

[w] The BMP plan was not implemented due to the lack of a custom manure applicator and a late season.

[v] The BMP plan was only implemented for 1 yr due to wet weather and field access issues.

[u] The REF site was not supposed to require a BMP. However, cattle were introduced for fall grazing and a BMP plan was developed. The plan was only implemented 1 yr and then the BMP could not be maintained because of a crop failure, a change in crop management, and flooding of the drainage channel.

[t] Because of a lack of time, an adequate number of post-BMP water samples were not obtained in order to evaluate based on water quality.

[s] Rangeland survey.

[r] The BMP could not be evaluated because of cold weather, equipment failure, and failure of the erosion control.

[q] The BMP plan was not implemented as the crop was switched from annual cereal to perennial forage after the planning phase. However, this site was used to assess the risk of liquid manure application on a forage crop to runoff water quality.

[p] Rangeland production.

[o] The REF1 and REF2 sites were not supposed to require a BMP.

Site[z]	BMP type[y]	Successfully implemented BMP plan
IMP	C	Cattle exclusion and distribution control using fencing; Off-stream watering; Portable windbreak
NMF	C	Cattle distribution control during fall grazing; Excluded cattle from drainage channel with temporary electric fence
PST	C	Rotational grazing and off-stream watering to protect riparian area during sensitive periods; Corral removal
WIN	C	Rotational grazing and off-stream watering to protect riparian area during sensitive periods; Wintering site relocated
FLT	C,S	Relocation of bedding and feeding site; Re-direct tributary flow, grass waterway; Improve berms around dugout and catch basin
DUG	C	Control access of cattle to dugouts with fencing; Off-stream watering; Improved cattle crossing with a bridge
OSW	C	Excluded cattle from dugout; Off-stream watering
FEN	C	Prevent access to creek with fencing; Off-stream watering
CAT	S	Drainage ditch was constructed to divert run-on away from the feedlot
WFD	N	Apply manure based on P crop removal; Manure application setbacks; Change to injected manure application; Relocated manure storage; Erosion control on a drainage channel
NFD	N	Apply manure based on P crop removal; Manure application setbacks; Change to spring manure application
SFD	N	Apply manure based on P crop removal; Manure application setbacks; Buffer zone at drainage outlet
NPS	C	Exclude cattle from degraded riparian area; Increase pasture size; Pasture rest with no grazing; weed control
SPS	C	Rotational grazing among paddocks created with new fencing and water system
BDF	N,S	Stop manure application and nutrient management plan; Pivot modification and irrigation management to control runoff from irrigation
LLB	N,S	Stop manure application and nutrient management plan; Pivot modification and irrigation management to control runoff from irrigation; Grass cover in drainage channel

[z] IMP = Impoundment, NMF = North Manure Field, PST = Pasture, WIN = Wintering, SMF = South Manure Field, DMF = Dairy Manure Field, REF = Reference, FLT = Feedlot, DUG = Dugout, OSW = Off -stream Watering, FEN = Fencing, CAT = Catch Basin; WFD = West Field, NFD = North Field, EFD = East Field, SFD = South Field, NPS = North Pasture, SPS = South Pasture, REF1 = Reference 1, REF2 = Reference 2, BDF = Battersea Drain Field, and LLB = Lower Little Bow Field.

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Water samples were collected using an event-based protocol. Soil samples were collected each year from the crop and pasture sites. Riparian assessment was carried out at five sites, and rangeland assessment was carried out at four sites. Water samples were analyzed for a variety of parameters including total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and *Escherichia coli* (*E. coli*). Soil samples were analyzed for extractable N and soil-test phosphorus (STP).

4 Key Points

4.1 General

With the addition of manure, from either grazing or manure application, TN and TP concentrations in edge-of-field runoff water were significantly higher compared to non-manured or pasture sites.

- For the pasture and non-manured (inorganic fertilizer) sites, the average TN concentration ranged from about 2 to 6 mg L^{-1} and TP concentration ranged from about 0.8 to 1.0 mg L^{-1}.
- Sites with moderate or heavy manure application (pre-BMP) had average TN concentrations that ranged from about 12 to 14 mg L^{-1} and TP concentrations that ranged from about 2 to 5 mg L^{-1}.

The location or scale at which water quality was measured had important implications on the expected nutrient concentration. Generally, the smaller the scale, the higher the concentration of nutrients (edge-of-field > tributary > mainstem of a stream).

- Measuring water quality at a smaller scale like at the edge-of-field rather than instream improved the likelihood of measuring a successful environmental response caused by BMPs.

4.2 Implementation of Beneficial Management Practices

There were challenges in implementing the BMPs. When issues arose, BMP plans were modified, partially implemented, or not implemented.

- Challenges included poor weather and difficult field access, untimely access to manure-spreading equipment, producers not willing to implement or maintain a portion of the BMP plans, and technical difficulties with irrigation equipment.
- There were also challenges trying to anticipate management changes, which could vary from year-to-year.

4.3 Cost of Beneficial Management Practices

The cost of the BMPs ranged from $466 to $87,770 and labour ranged from 13 to 202 h. The median cost was about $12,000 per site. The majority of cost was generally a one-time, up-front cost to implement the BMPs. The most costly BMPs involved surface-water management and manure hauling.

- The two surface-water management BMPs in IFC cost $87,770 and $13,200. The BMPs were at feedlots, and surface water was diverted away from the pens.
- Riparian bioengineering was implemented at two sites in IFC at an average cost of about $18,000. Bioengineering was particularly labour intensive.

4.4 Effectiveness of Beneficial Management Practices

Almost all of the BMP suites implemented at the sites were found to be effective (eight sites) at significantly improving water quality in terms of TN, TP, TSS, and/or *E. coli* concentrations. For those sites where water quality did not improve (three sites), the BMP plans were often not implemented as designed.

- Cattle management BMPs were likely to show short-term immediate water quality improvement; whereas, nutrient management was a long-term and continuous improvement scenario. A monitoring time frame of a few years may be sufficient to capture environmental benefits for some BMPs like cattle management changes, although it depends on the variability of the weather, management practices, and expected response times.
- Of the six BMP sites that involved cattle management, four were effective at improving water quality. For the two sites that did not have significant improvements, one site was trending towards improvement and any possible positive results at the other site were likely masked due to the size of the contributing area.
- Of the five BMP sites that involved field-nutrient management, four were effective at improving water quality. For the one site that did not have significant improvement, the BMP was poorly implemented due to unavailability of manure injection equipment and inappropriate field conditions for establishing a vegetative buffer.
- For the BMPs that were effective at improving water quality, concentration reductions ranged from 2 to 85% during runoff events.
- In addition to water quality, the BMPs had a positive effect on riparian and/or rangeland quality, particularly when cattle were completely excluded (IMP, OSW, DUG) or access was denied at certain times of the year through rotational grazing (PST, WIN, PST, and FLT). The change to grazing practices also improved rangeland production at the PST site.
- At the two irrigated field sites, automatically turning off sprinkler nozzles reduced irrigation runoff from contributing drainage areas of the irrigated fields. However, in practicality, there were implementation challenges with the variable rate technology used at these two field sites.
- The Alberta Irrigation Management Model (AIMM) was able to reasonably predict soil moisture, except under wet conditions, particularly when there was contribution from subsurface water. Also, rainfall shortly after a major irrigation event increased the risk of runoff, and this could not be avoided by using AIMM.

4.5 Soil Nutrients and Water Quality

Fields with high soil P will likely take decades to be reduced P concentration. Field-nutrient management BMPs were costly when there was a requirement to haul manure further distances due to high soil nutrients.

- At the LLB site, the cost to haul manure 7.5 km was $30,000. If the BMP of manure cessation continued at LLB, the cost of manure transport would be borne on an annual basis.

- For the BDF and LLB sites, the focus should be on reducing the soil P levels to or below agronomic requirements, recognizing that it will take at least a decade to be able to measure changes in the soil profile. Realistically, however, the cost of manure transportation will continue to be an impediment if it must be borne by producers for the long term. Currently, BMP funding support programs do not have this type of long-term funding.

A key proactive action to protect water quality will be to avoid the build-up of soil nutrients. Fields with a slight accumulation of soil nutrients can be reduced within a few years with BMPs. Particular attention should be given to hotspots that can develop within fields if manure or livestock are confined to a small area.

- At the DMF site, dairy manure was applied at very high rates, but to only a few hectares in a given year. With time, this practice resulted in STP accumulation to more than 120 mg kg^{-1} on average. Similarly, the corral area (PST-corral) had a relatively high STP concentration, at slightly more than 100 mg kg^{-1} and was particularly affected by congregating of cattle, which resulted in high densities of fecal pats in this area compared to the rest of the pasture.
- Although it has high agricultural intensity with several confined feeding operations, the WHC Sub-watershed generally had soil nutrients that were only slightly above or below agronomic levels. Continued application of manure at or below crop uptake may be sufficient for environmental risk mitigation.

4.6 Water Quality from Agricultural Fields and Watersheds

Recommendations for BMPs within watersheds can be provided on the basis of natural regions, given that runoff, water quality, and land-use patterns are generally consistent in the regions.

- For the Grassland Natural Region watersheds, BMPs should target particulate concentrations during the spring rains. Many of the BMPs in the Grassland watersheds may involve extensive livestock (i.e., grazing) and field erosion.
- For the Parkland Natural Region watersheds, BMPs should target dissolved inorganic nutrient concentrations in snowmelt.
- This study confirmed that flow was the primary driver for the observed load and export differences at the watershed outlets. Hence, if load and export reductions are needed, flow reduction may need to be targeted.

Because only a few BMPs were implemented in relatively large watersheds, there is still a gap in understanding the cumulative benefit of implementing BMPs in effort to improve water quality at a watershed scale. Further, desired end states or water quality objectives for the edge-of-field and the outlets of agricultural watersheds need to be defined.

- Even though modelling component (Volume 3) of the BMP Project investigated the cumulative effects of BMPs, further work is required for on-the-ground validation of cumulative BMPs in improving water quality.
- It will be important to develop site-specific nutrient objectives with consideration of scale.

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